QUEEN'S BEACH GOLF COURSE

Final
Environmental Impact Statement

Queen's Beach, O`ahu, Hawai`i

Volume 2
Appendices

September 1997

QUEEN'S BEACH GOLF COURSE

Final
Environmental Impact Statement

Queen's Beach, O`ahu, Hawai`i

September 1997

Prepared for: Kaiser Aluminum & Chemical Corporation

Prepared by: Helber Hastert & Fee, Planners

Queen's Beach Golf Course

Appendices

QUEEN'S BEACH GOLF COURSE

Appendix

A

Potential Impacts to Groundwater

(Tom Nance Water Resources Engineering)

Potential Impact on Groundwater of the Proposed Golf Course at Queen's Beach, Oahu, Hawaii

Prepared for

Helber Hastert & Fee, Planners
Grosvenor Center - Makai Tower
733 Bishop Street - Suite 2590
Honolulu, Hawaii 96813

Prepared by

Tom Nance Water Resource Engineering
680 Ala Moana Boulevard - Suite 406
Honolulu, Hawaii 96813

May 1995

Table of Contents

List of Figures

List of Tables

Introduction

Development of an 18-hole golf course, driving range, clubhouse, and related support facilities have been proposed for the 166-acre parcel identified as TMK 3-9-11:03 and :02 (portion) and known locally as Queen's Beach. Figure 1 illustrates the project area and a conceptual development scheme for the golf course. This report presents a description of the groundwater beneath the project site and an assessment of the golf course's potential impact on this resource.

Since the configuration of the golf course is at a conceptual stage, the actual turf acres to be irrigated are not known exactly. For the purposes of this assessment, it is assumed that 120 acres will be in turfgrass. Based on data presented subsequently, the irrigation rate is expected to average 0.6 to 0.65 million gallons per day (MGD) and reach a peak of 0.9 to 0.95 MGD during the most severe summer months. The source of irrigation supply will be treated effluent from the Hawaii Kai Wastewater Treatment Plant (WWTP). The quality of its effluent meets the State Department of Health's R-2 standards. This classification does impose some restrictions on the manner of effluent's reuse, particularly the hours of irrigation and proximity of habitable structures. The brackish groundwater beneath the site is not a satisfactory alternative or even supplementary source of irrigation supply. It occurs in very limited quantities which are not exploitable by wells and it is also too salty for irrigation use.

Hydro-Geologic Overview

Geologic Formations in the Project Area. There are three geologic formations of significance on the surface of the project site: the original island-building Koolau volcanics; alluvium washed down from the eroded Koolau volcanic slopes; and later-stage Honolulu series volcanics which flowed across the makai portion of the site from a vent in Kalama Valley. The inland edge of this later-stage flow, as mapped in Stearns, et al. (1935) and Takasaki and Mink, 1982, is depicted on Figure 2. This boundary is obscured on the ground today by extensive fill material which was brought onto the site over a number of years from the 1970s through the 1980s.

As is typical elsewhere, the Koolau volcanics are thin bedded and very permeable. At elevations below sea level at the site, they are separated from the later-stage volcanics by a layer of coral, sand, and other calcareous materials which accumulated on the submerged shelf of the ancient shoreline. The pre-existing sea level shoreline shown on Figure 2 was adapted from that shown in Takasaki and Mink, 1982. Described later in this report are the results of four boreholes drilled onsite

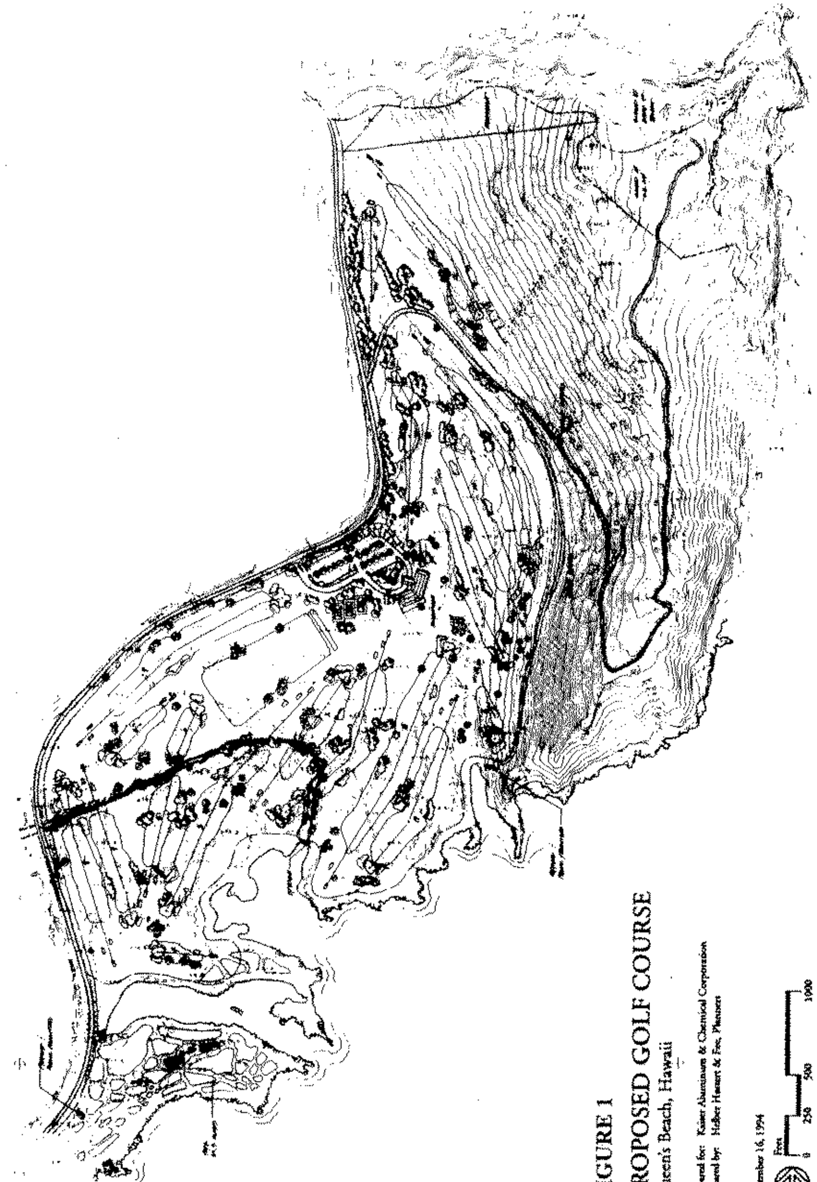


FIGURE 1
PROPOSED GOLF COURSE
Queen's Beach, Hawaii

Prepared for: Kaiser Aluminum & Chemical Corporation
Prepared by: Helber Hastert & Fee, Planners

September 16, 1994

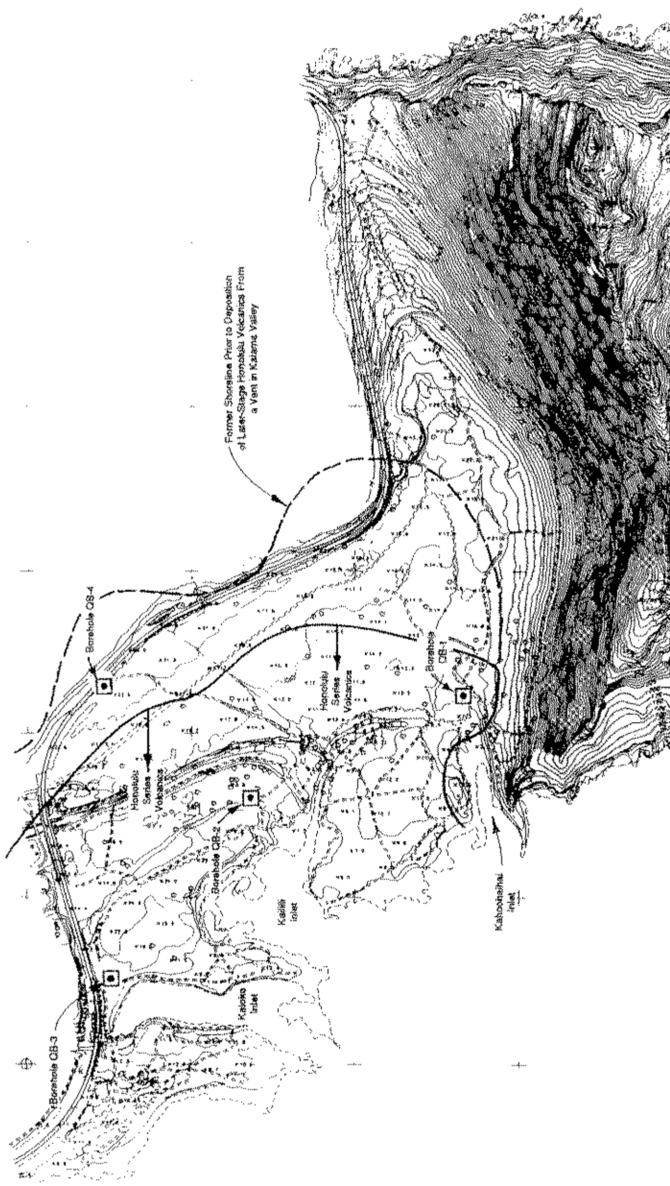


Figure 2
Surficial Geology and
Borehole Locations

Feet 0 250 500 1000

for this study. They show that the ancient shoreline drawn speculatively in Takasaki and Mink (1982) is surprisingly accurate, particularly since it was drawn without benefit of any borehole in formation.

The later-stage Honolulu series volcanics, which issued from a vent in Kalama Valley, form the present shoreline of the project site. Based on boreholes drilled for this study, it is comprised of two or more flows with a total thickness of more than 50 feet near the shoreline and about 35 to 45 feet thick at distances of 300 to 500 feet back from the shoreline. The lavas are dark gray and very dense. Since its permeability is primarily derived from shrinkage cracks and clinker layers, it is locally quite variable. At Borehole Nos. 1 and 3 (denoted QB-1 and QB-3 on Figure 2), the permeability is moderate to very permeable. At Borehole No. 2 (QB-2), it is quite low.

Rainfall and Pan Evaporation. The project site is a dry, hot, and windy area. Although there are no meteorological gages on the site, those at the Makapuu Lighthouse and along the shoreline at Waimanalo provide reasonably representative data (see Table 1). Rainfall is typically 25 to 30 inches annually with only 4 to 5 inches of this occurring during the five months from May through September.

The monthly pan evaporation amounts shown in Table 1 are from a gaging station in Waimanalo. Evaporation rates at the Waimanalo gage are undoubtedly significantly less than at Queen's Beach. Even using the lower values measured at the Waimanalo Station, a comparison of the monthly rainfall and evaporation rates indicates that irrigation of the golf course will be necessary year-round and that peak rates of irrigation are likely to occur in June and July.

Surface Water. Figure 3 indicates the areal extent of the watershed tributary to the Queen's Beach site. Most of this area is not naturally tributary. Runoff from Kalama Valley is intercepted by a concrete-lined ditch and conveyed along the edge of the Hawaii Kai Golf Course to a Kalanianaole Highway bridge which leads into the project site. Within the project area, the drainage ditch is unlined all the way to the shoreline. The tributary areas of surface runoff, including those which drain naturally to the site and those which are tributary via the drainage ditch, are as follows:

	Acres
Project Site Itself	166
Naturally Tributary Mauka Land	224
Tributary by the Drainage Ditch	950
Total	1,340

Table 1

Monthly Rainfall and Pan Evaporation at the Queen's Beach Site

Month	Rainfall at Makapuu Point (Inches)	Pan Evaporation at the Waimanalo Experimental Station (Inches)
January	4.41	4.13
February	3.03	4.13
March	3.74	5.41
April	2.09	5.97
May	1.02	7.15
June	0.59	8.75
July	0.79	8.45
August	0.87	7.47
September	0.83	7.30
October	2.60	6.45
November	2.83	4.33
December	3.86	4.05
Annual	26.93	66.84

Notes:

1. Rainfall is the adjusted mean values for Station No. 724 as reported in Giambelluca, Nullet, and Schroeder (1986).

2. Pan evaporation are the mean monthly values for Station 795.1 in Ekern and Chang (1985).

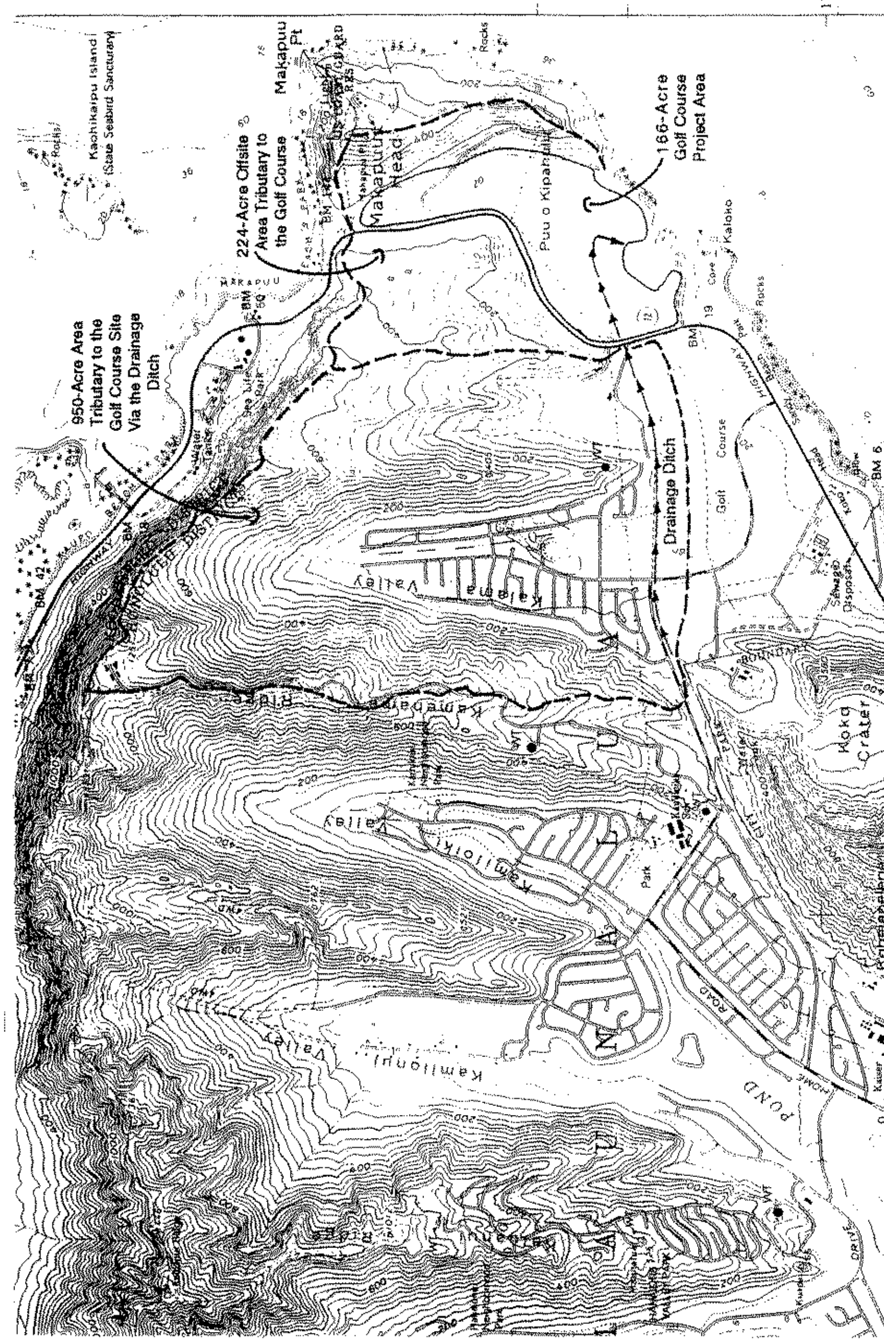


Figure 3
Areas Which Contribute Surface Runoff to the Project Site
Scale 1" = 2000'

Substantial stormwater runoff events in this dry area are infrequent. However, the curbs and gutters in the Kalama Valley residential area and the concrete-lined trapezoidal channel do deliver small amounts of water into the site at Kalanianaole Highway bridge on an almost continuous basis. Past runoff events have eroded a sump area immediately downstream of the concrete apron of the lined ditch. The small but almost continuous inflow from Kalama Valley creates a pond of standing water in this sump.

Groundwater. Based on data derived from the four onsite boreholes, groundwater beneath the site occurs as a thin, brackish basal lens in hydraulic contact with saline groundwater at depth and seawater at the shoreline. Groundwater levels move up and down in response to the ocean tide. Their mean levels are less than one foot above sea level everywhere throughout the site. Salinities at the top of this lens in the four boreholes varied from 3 to 13 parts per thousand (PPT), equivalent to 9 to 37 percent seawater. This water is too salty for irrigation use. Even worse, the salinity levels in the boreholes increase rapidly in response to pumping at moderate rates.

Eyre, Ewart and Shade (1986) includes a hydrologic budget of all the aquifers of southeast Oahu, including the project site. Based on monthly average values of rainfall, potential evapotranspiration, and surface runoff, this study computed the annual recharge to groundwater within the project site to be 0.044 million gallons per day (MGD). Since this computation does not include the benefit of recharge by surface water diverted onto the site, it undoubtedly underestimates the actual recharge. However, the computation does suggest that the natural rate of groundwater flow through the area is extremely limited. As shown subsequently, data from the boreholes fully supports this.

At present, there is no use of groundwater anywhere in the region, including the now abandoned wells that were drilled in Kalama Valley and on the northeastern side of Koko Head. Prior to residential development in the Valley, these wells were used on a limited basis for agricultural irrigation (see Table 2). None were used very extensively and all produced brackish water. As far as is known, no wells had ever been drilled on the project site prior to the four small diameter boreholes done for this study. These provide the first actual data of groundwater conditions.

Field Data From the Four Small Diameter Boreholes

The four 50-foot deep boreholes shown on Figure 2 were drilled by the HQ wire line core method to determine the underlying geologic strata and groundwater conditions. Three of these (QB-1, -2, and -3) were located near to the shoreline and directly inland of the site's three natural inlets. The

Table 2

Summary of Wells Drilled in the Kalama Valley Region

State Well No.	Ground Elevation (Feet msl)	Well Depth (Feet)	Casing Diameter (inches)	Year Drilled	Water Level (Feet msl)	Chloride Concentration (MG/L)
1740-01	40	125	6	1943	- -	1500
1740-02	100	120	6	1945	0.6	1050
1740-03	96	105	6	1947	0.8	875 to 1580
1740-04	139	- -	8	1950	3.3	604
1740-05	100	200	6	1951	- -	- -
1840-01	94	116	6	1945	1.3	667 to 1040
1840-02	106	116	6	1945	2.6	785
1840-03	78	99	6	1946	3.0	922
1840-04	88	110	7	1947	2.2	834 to 1080
1840-05	67	83	6	1949	0.6	1100 to 1300
1840-06	78	101	8	1949	0.8	1390
1840-07	75	89	6	1950	0.8	1740

Note: Information adapted from Table 6 of Takasaki and Mink (1982).

fourth was located further inland where it was anticipated that the groundwater level would be somewhat higher and the basal lens would be correspondingly thicker. Information derived from the boreholes is summarized on Table 3 and discussed below.

Geologic Strata Encountered. The strata encountered in holes QB-1 and QB-2 were quite similar. Both holes were started in a thin (4- to 5-foot) tuffaceous layer of the Honolulu volcanics which was underlain by relatively dense pahoehoe of the same volcanic series. At depth in each hole, there was an abrupt transition from these volcanics to coralline, sand, silt, and gravel. This calcareous material comprised the lower 13 and 5 feet of the 50-foot borings of QB-1 and QB-2, respectively.

QB-3 is located closest to the vent in Kalama Valley which produced the site's present shoreline. These later-stage volcanics, all dark gray and entirely unweathered, comprised the entire 50 feet of the boring. The lavas are relatively dense but contain significant fracturing which creates moderate to high permeability.

The location of QB-4 is inland of the Honolulu series volcanics. The upper 43 feet of this boring went through soft, silt and sand-sized, dark brown alluvium. The bottom of this alluvial layer contained numerous basalt boulders. Beneath the alluvium and comprising the bottom 7 feet of the boring was calcareous sand, silt and gravel. Based on data from these borings, the sea level shoreline which existed prior to the Kalama Valley eruption was inland of QB-4 (refer back to Figure 2).

Salinity and Temperature Profiles. Salinity and temperature profiles through the water columns of each borehole are shown on Figures 4 through 7. These were taken after each borehole had been air-lift pumped to get rid of all drilling water and then a sufficient time had elapsed for groundwater conditions to stabilize (successive salinity profiling done prior to those shown on Figures 4 to 7 was undertaken to ensure that stable conditions had been achieved). The profile for borehole QB-1 (Figure 4) exhibits a poorly developed basal lens with near seawater salinity at the bottom of the hole (seawater's salinity is 34 to 35 PPT). In QB-2, the unvarying salinity for the first 25 feet into groundwater (Figure 5) correlates almost exactly with the dense and virtually unfractured pahoehoe recovered in cores to that depth. The rapid salinity increase at the bottom of the borehole occurs right at the interface of the later-stage volcanics and underlying coralline material.

Borehole QB-3 has the most robust basal lens of the four borings, despite the fact that it is the closest to the shoreline (Figure 6). Salinity of 3 PPT, about 9 percent seawater, occurs at the top of the lens; 50 percent seawater occurs about 27 feet into the groundwater. QB-4 also shows reasonable

Table 3

Summary of Data From the Four Onsite Boreholes

Parameter	Borehole QB-1	QB-2	QB-3	QB-4
Ground Elevation (Feet msl)	10.5	6.0	14.7	23.5
Borehole Depth (Feet)	50	50	50	50
Elevation at Bottom of Borehole (Feet msl)	-39.5	-44.0	-35.3	-26.5
Mean Groundwater Level (Feet msl)[1]	0.46	0.52	0.49	0.68
Distance From Shoreline (Feet)	400	330	135	1410
Fraction of Ocean Tidal Amplitude[2]	0.22	0.13	0.47	0.34
Lag Time of Tidal Signal (Ave. Hours)	2.12	3.16	1.57	2.16
Thickness of Honolulu Series Volcanics (Feet)	37	45	>50	Not Present
Elevation of Underlying Calcareous Gravel, Sand, Silt (Feet msl)	-26.5	-39.0	Not Encountered	-20

[1] Mean groundwater levels are based on the recorded groundwater levels of October 31 to November 4, 1994 in comparison to the ocean tide recorded in a temporary gaging station over the same period.

[2] Recorded water level fluctuations in each well as compared to the measured ocean tide, October 31 to November 4, 1994.

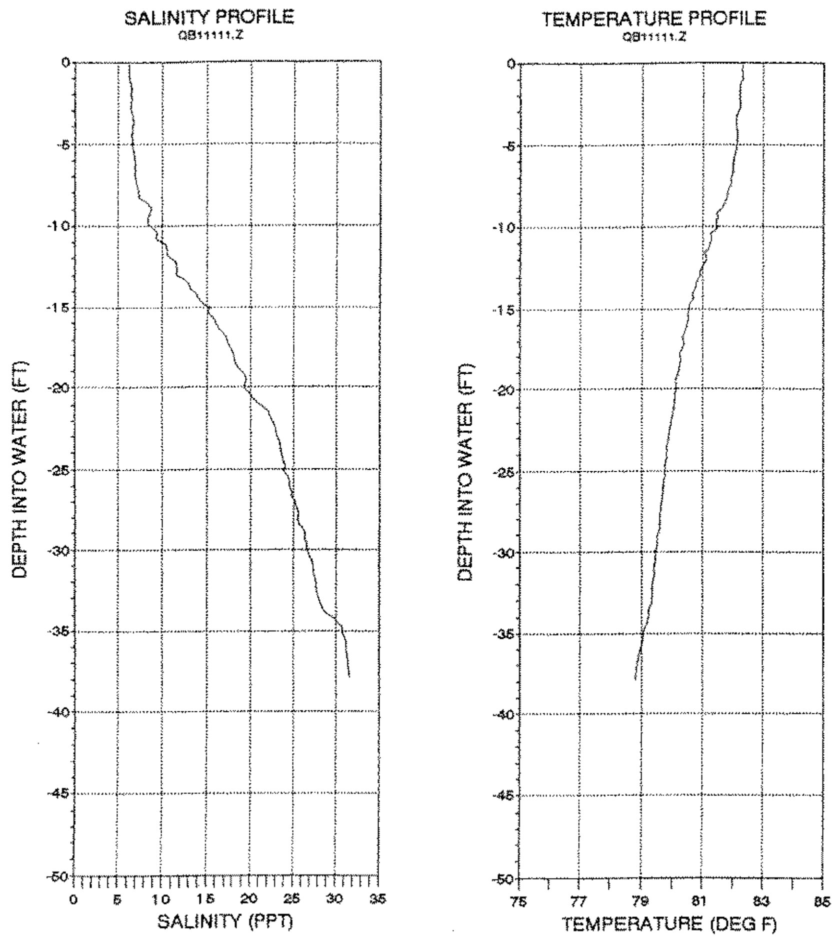


Figure 4

Borehole QB-1

November 11, 1994

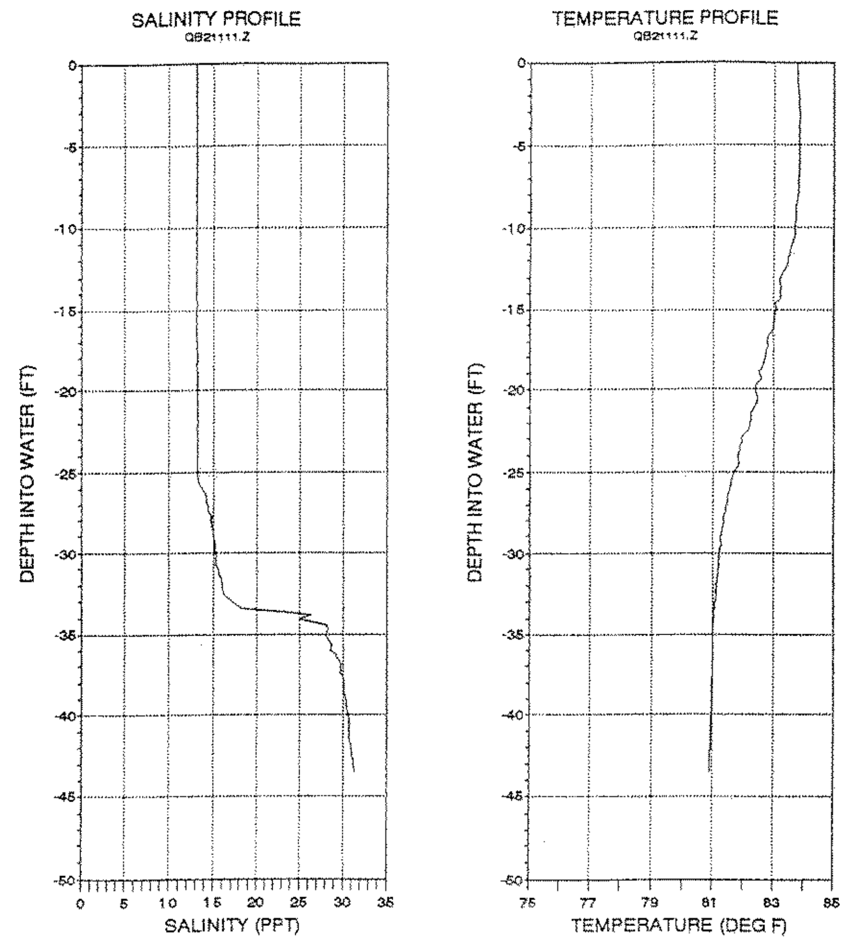


Figure 5

Borehole QB-2

November 11, 1994

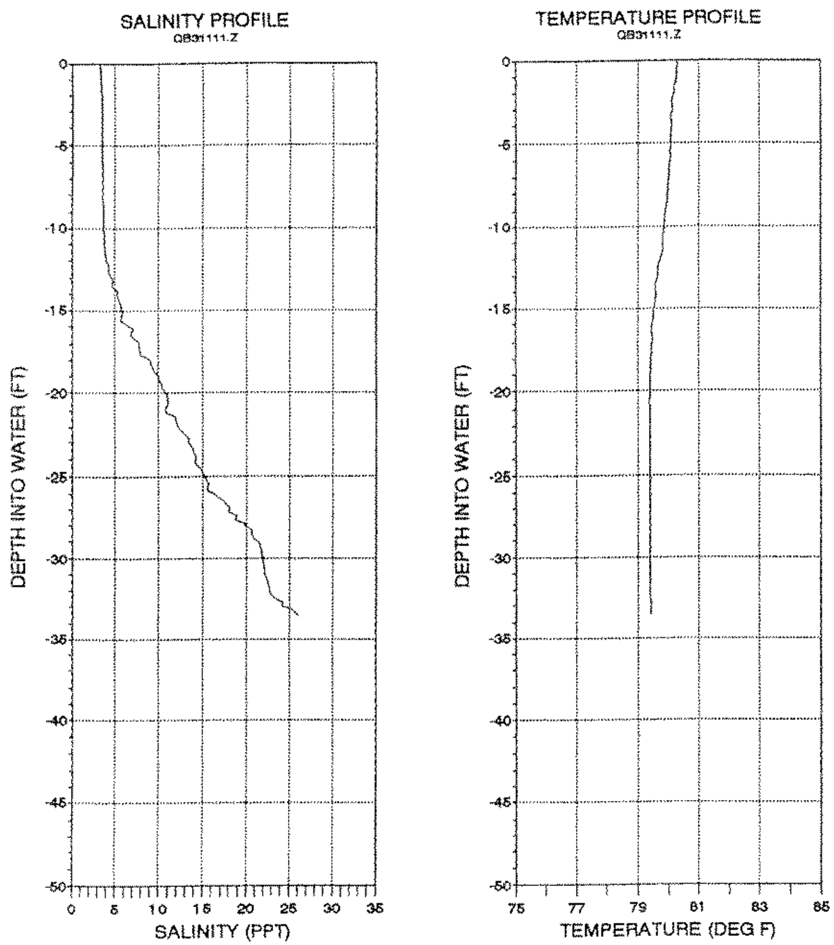


Figure 6

Borehole QB-3
November 11, 1994

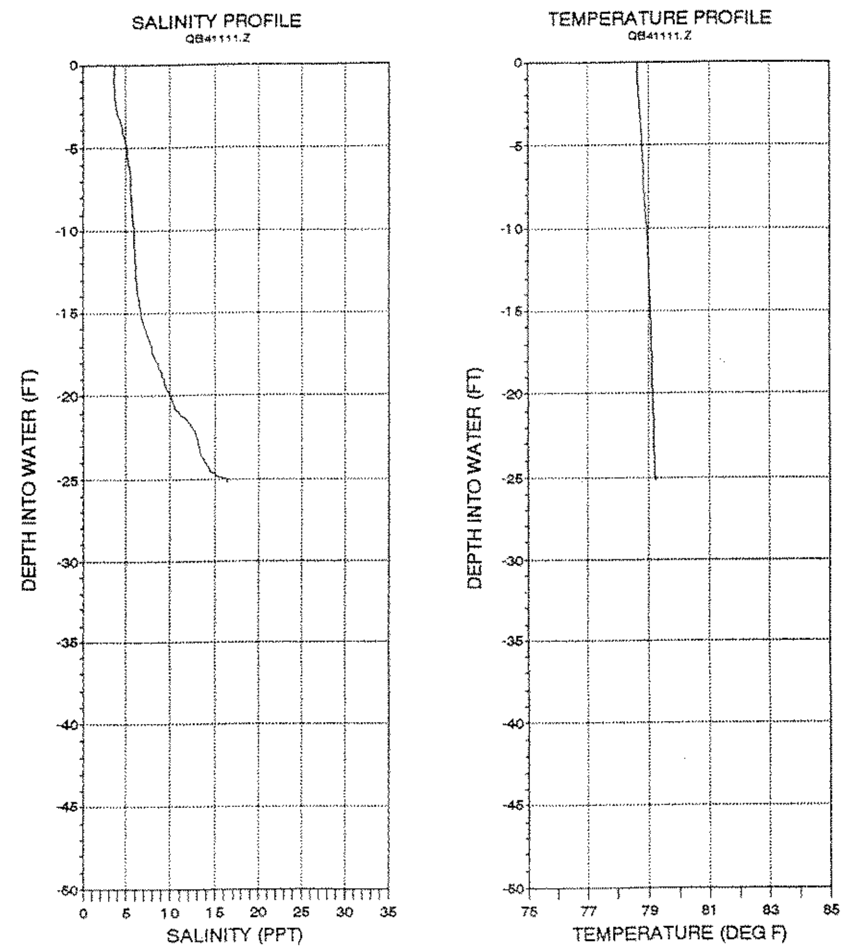


Figure 7

Borehole QB-4
November 11, 1994

development of a basal lens, perhaps surprisingly since much of this borehole is comprised of poorly permeable alluvium. Also curiously, it does not show a sharp change in salinity or temperature at the contact of alluvium and boulders with the more permeable calcareous materials near the bottom of the borehole. Figure 8 compares all four salinity profiles.

Groundwater Levels and Tidal Variations. A temporary tide gage was installed in Kaloko Inlet so that groundwater levels relative to mean sea level could be determined and to provide a recording of actual ocean tides to compare to the tidal variations in the boreholes. Groundwater levels and the ocean tide were recorded for five days from October 30 to November 4, 1994. The mean water level recorded in Kaloko Inlet was assigned an elevation of 0.00 and the mean levels in the four boreholes were established relative to this datum. The 5-day recordings are depicted on Figure 9. Mean groundwater levels, which varied from 0.46 feet in QB-1 to 0.68 feet in QB-4, are shown on the figure and listed in Table 3. These modest levels above the prevailing ocean level match the salinity profiles. The profiles depict lens thickness on the order of 17 to 27 feet; by the Ghyben Herzberg principle, this translates water levels of a fraction of a foot above mean sea level.

Tidal amplitudes and lag times in the boreholes are listed in Table 3. These suggest low to moderate permeability in QB-2, moderate permeability at QB-1, and unexpectedly high permeabilities at QB-3 and QB-4. The QB-3 borehole is entirely in the later-stage volcanics. The coral gravel at the bottom of QB-4 provides most of the permeability of the strata penetrated.

Groundwater Chemistry. Table 4 is a compilation of the water quality analyses done on samples collected from the top, middle, and bottom of each of the four boreholes. The wide variations of salinity with depth and from borehole-to-borehole are expected from the salinity profiles presented previously. However, there are also wide variations in nutrient levels, particularly the various forms of nitrogen. In QB-3, the high nitrate levels suggest enrichment, possibly by fertilizer leaching from the nearby Hawaii Kai Golf Course. The almost total depletion of nitrate in QB-2, coupled with its high ammonia and organic nitrogen, are probably the result of the low permeability and extremely limited groundwater movement in this vicinity. The source of nitrogen here may actually be the coralline sediments at the bottom of the hole. The same may also be true to QB-1 and -4 which have relatively low nitrate (i.e. lower than expectable background levels of 60 to 100 micro-molar).

Table 5 is a compilation of analyses of major anions and cations of samples taken from the four boreholes. The water samples for these analyses were splits of the samples from the tops of the boreholes listed in Table 4. Using chloride as a conservative tracer, the equivalent concentration of

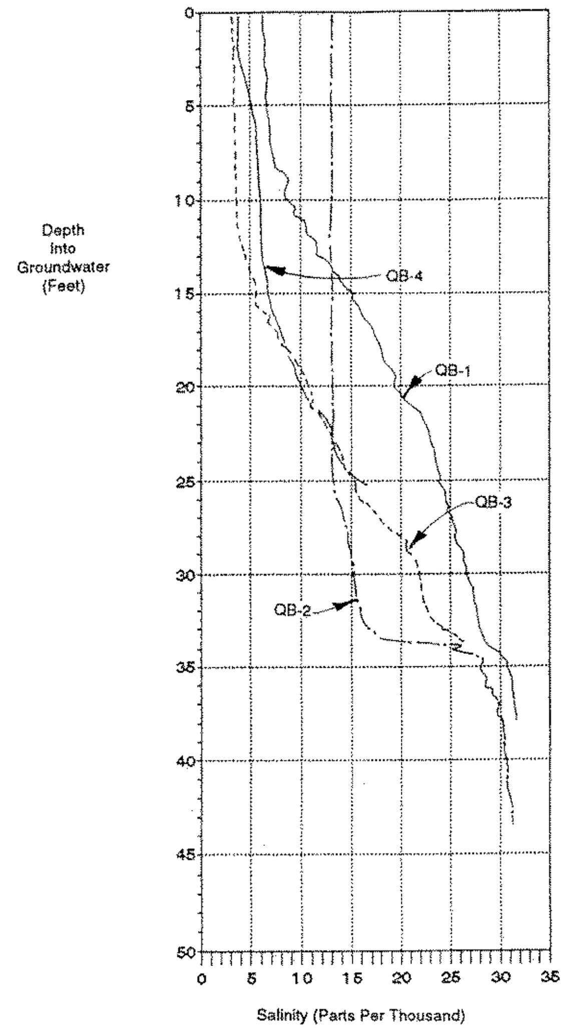


Figure 8
Salinity Profile Comparisons

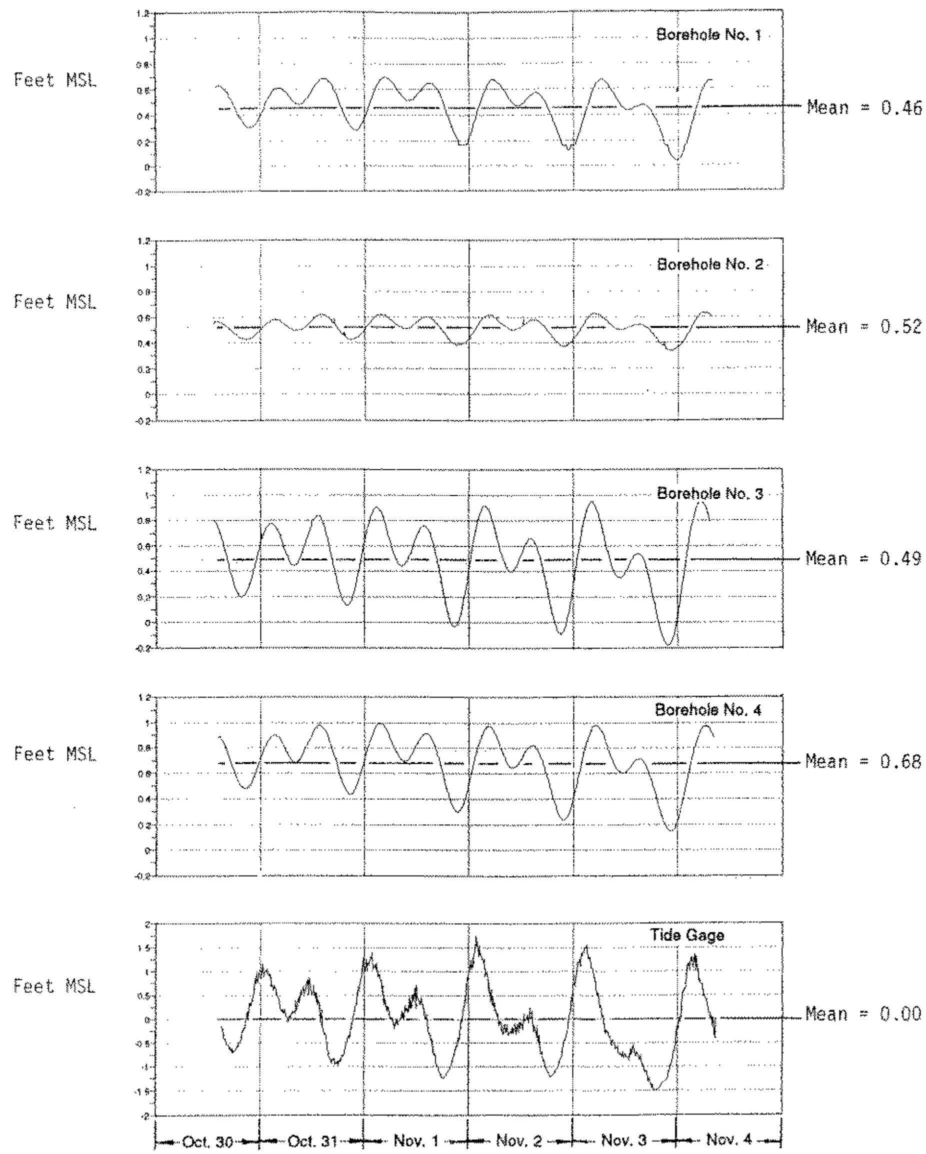


Figure 9

Recorded Groundwater Level Fluctuations and the Ocean Tide, October 30 to November 4, 1994

Table 4

Chemistry of Borehole Water Samples Taken on November 19, 1994

Borehole	Depth of Sample	Nitrogen NO_3 (µM)	Nitrogen NH_4 (µM)	Nitrogen Dissolved Organic (µM)	Nitrogen Total (µM)	Phosphorus PO_4 µM	Phosphorus Dissolved Organic µM	Phosphorus Total µM	Silica µM	Turbidity (NTU)	Salinity (PPT)
QB-1	Top	37.19	0.01	11.56	48.76	3.93	0.14	4.07	600.84	0.24	6.112
	Middle	10.36	0.90	9.87	21.13	3.54	0.24	3.78	413.26	3.60	15.067
	Deep	17.26	0.69	9.25	27.20	3.24	0.21	3.45	442.95	6.10	15.149
QB-2	Top	0.79	2.82	14.50	18.11	4.16	0.17	4.33	339.22	1.67	12.703
	Middle	0.31	5.64	13.39	19.34	3.39	0.15	3.54	311.97	11.20	14.623
	Deep	0.28	9.59	12.09	21.96	3.28	0.01	3.29	315.69	19.50	16.356
QB-3	Top	240.19	0.03	0.60	240.82	4.63	0.06	4.69	694.88	0.34	3.686
	Middle	141.32	0.01	10.32	151.65	3.26	0.07	3.33	671.70	0.16	10.251
	Deep	107.40	0.31	9.32	117.03	2.58	0.01	2.59	661.00	0.12	18.666
QB-4	Top	6.68	1.45	9.74	17.87	4.49	0.13	4.62	468.28	1.76	4.473
	Middle	2.65	4.40	7.16	14.21	3.22	0.06	3.28	393.29	3.80	7.443
	Deep	6.82	8.20	6.18	21.20	2.36	0.50	2.86	362.59	4.30	13.918

Notes: Samples were collected on November 19, 1994 by TNWRE. Water quality analyses were done on November 29, 1994 by Marine Analytical Specialists.

Table 5

Major Cations and Anions of Borehole Samples
Taken on November 19, 1994

Constituent	Units	QB - 1		QB - 2		QB - 3		QB - 4	
		Value	Equivalent for Dilute Seawater	Value	Equivalent for Dilute Seawater	Value	Equivalent for Dilute Seawater	Value	Equivalent for Dilute Seawater
Chloride (Cl)	MG/L	3156	3156	7482	7482	1982	1982	2355	2355
Sulfate (as So_4)	MG/L	548	440	1633	1044	434	277	374	329
Sodium (Na)	MG/L	2253	1755	4529	4159	1299	1102	1598	1309
Potassium (k)	MG/L	78	63	123	150	47	40	54	47
Calcium (Ca)	MG/L	375	66	581	158	184	42	302	50
Magnesium (Mg)	MG/L	355	211	620	501	195	133	184	158
pH	pH Units	7.4	- -	7.5	- -	7.4	- -	7.7	- -

Note: All analyses by Environmental Chemistry of Sacramento, California and are reported in Walker (1995). Samples were collected by TNWRE on November 19, 1994.

diluted seawater for these constituents is included in the table for comparison. Obviously, ocean water is the primary source of salts in these samples. Only the concentration of calcium deviates significantly from seawater.

Rate of Groundwater Flow Estimated From the Borehole Data. As indicated earlier, the hydrologic budget in Eyre, Ewart, and Shade (1986) estimates the groundwater flowrate in this area at 44,000 GPD, an amount which does not include recharge contributed by intercepted surface water. A more direct estimate of the groundwater flowrate can be made from the borehole data. Mean groundwater levels, particularly over the 1100-foot flow path from QB-4 toward QB-2 and the shoreline, indicate a gradient of about 0.00015 or 0.77 feet per mile. The width of the groundwater flow across the site is about 2700 feet and the lens thickness is about 25 feet over the area where the gradient is defined. For permeabilities in the range of 1,000 to 2,000 feet per day, a reasonable approximation for the formations penetrated, this translates to a flowrate of 70,000 to 150,000 gallons per day (GPD). An average of these, 110,000 GPD, is used for calculations made subsequently in this report. This very small flowrate is one to two orders of magnitude lower than typical groundwater flowrates found elsewhere throughout the State.

Proposed Source of Irrigation Supply

Secondarily treated effluent from the Hawaii Kai Sewage Treatment Plant is to be the primary source of irrigation supply. Samples of the treated effluent were collected on successive days in January 1995 and analyzed for nutrient content, salinity, and composition of major cations and anions (Table 6). The most significant aspect to note is the effluent's high salinity, easily an order of magnitude greater than the salinity of drinking water in the BWS system which serves the Hawaii Kai area. Saline water infiltrates those gravity collection lines of the Hawaii Kai system which are below sea level.

Due to this high salinity, zoysia is the grass of choice for the golf course's fairways. However, it is not a desirable grass for the greens. Bermuda will be used for this purpose. Its irrigation will require a blend of equal amounts of effluent and drinking water to achieve an acceptable salinity. This will require a separate delivery system for the individual greens. Based on these choices of grass and irrigation supply, the monthly average irrigation rates in Table 7 were calculated in Walker (1995). The assumed 115 acres of fairways would average 0.619 MGD year-round. The anticipated five acres of greens would average 0.030 MGD, half of which would be provided by the drinking water system.

Table 6

Analyses of the Chemical Constituents of Effluent From the Hawaii Kai Sewage Treatment Plant

Constituent	Units	Sample of January 5, 1995	Sample of January 6, 1995
Forms of Nitrogen (as N)			
• Nitrate	µM	400	349
• Ammonium	µM	254	168
• Dissolved Organic Nitrogen	µM	76	92
• Total Nitrogen	µM	729	608
Forms of Phosphorus (as P)			
• Phosphate	µM	20.5	32.8
• Dissolved Organic Phosphorus	µM	0.25	2.25
• Total Phosphorus	µM	20.8	35.0
Silica (SiO_2)	µM	723	746
Salinity	PPT	3.491	3.110
Chloride	MG/L	1,857	1,550
Sulfate (SO_4)	MG/L	Not Detected	Not Detected
Sodium	MG/L	1,106	983
Potassium	MG/L	70	62
Magnesium	MG/L	282	257
Calcium	MG/L	774	766
pH	pH Units	7.1	6.9

Notes:
1. Analyses of the nutrients and salinity were done by Marine Analytical Specialists.
2. Analyses of the major cations and anions were done by Environmental Chemistry of Sacramento, California and are reported in Walker (1995).

Table 7

Projected Average Irrigation Applications
(All Figures in MGD)

Month	Fairways (115 Acres)	Greens (5 Acres)	Total (120 Acres)
January	0.306	0.014	0.320
February	0.505	0.023	0.528
March	0.395	0.018	0.413
April	0.605	0.027	0.632
May	0.717	0.041	0.758
June	0.909	0.045	0.954
July	0.847	0.043	0.890
August	0.827	0.040	0.867
September	0.847	0.036	0.883
October	0.593	0.026	0.619
November	0.508	0.023	0.531
December	0.370	0.017	0.387
Annual Average	0.619	0.030	0.649

Note: Calculated application rates from Walker (1995).

Impact of the Golf Course's Operation on Groundwater

Walker (1995) calculates that percolation from the golf course due to rainfall and irrigation application will average 16 inches per year. Over the 120-acre area of the course, this would amount to 140,000 GPD. Since the present groundwater flow is estimated to be only 110,000 GPD, percolation from the golf course would ultimately more than double the amount of groundwater discharging along the project's shoreline. Walker (1995) also computes the expected quality of water percolating from the golf course. On Table 8, these expected concentrations are compared to the quality of the receiving groundwater. With the exception of those chemicals which were not analyzed for the borehole water samples, constituent concentrations in the percolate are lower than in the groundwater. In effect, the percolate will create lower salinities and otherwise dilute the receiving groundwater.

As indicated earlier, the saline groundwater which occurs in only small quantities beneath the site is not a conceivable source of drinking water or irrigation supply. As such, the forecast changes due to the golf course -- an increase in flow from 110,000 to 250,000 GPD and a dilution of constituents -- are of little consequence to the groundwater resource. However, since the rate of discharge at the shoreline would be more than doubled, potential impacts to the nearshore environment should be assessed with the estimated quantities of discharged nutrients tallied below. The increased nutrient loading is obviously very minor.

	Conditions at Present	Conditions at Full Maturity of the Golf Course
• Groundwater Discharge Into the Marine Environment (GPD)	110,000	250,000
• Total Nitrate-Nitrogen Discharged Into the Marine Environment (lbs/day)	1.24	1.37
• Total Phosphate-Phosphorus Discharged Into the Marine Environment (lbs/day)	0.12	0.12

The possible impact of pesticides on groundwater and the nearshore environment must be considered differently. The nutrient loading tallied above represents the average concentrations contributed continuously, day after day, as long as the golf course is being fertilized and irrigated. On this basis, the concentrations of pesticides in the percolate would be undetectable and have no impact on the marine environment. To produce some pesticide leaching, Walker (1995) created a "worst" case scenario in which all of the annual pesticide application is followed immediately by a 100-year storm event. Of the pesticides that would be used, only three -- 2, 4, D, Dicambra, and MSMA -- would actually leach under this circumstance. Their concentrations, which are extremely low in the percolate (refer to Table 8), would be further diluted in groundwater and then again at the shoreline.

Table 8

Predicted Chemistry of Irrigation Water Which Will Ultimately Reach Groundwater

Constituent	Units	Percolate Quality	Representative Receiving Groundwater Quality
Sodium	MG/L	1,104	1,720
Potassium	MG/L	10	60
Calcium	MG/L	756	290
Magnesium	MG/L	102	245
Chloride	MG/L	1,850	2,500
Nitrate (as NO_3)	MG/L	< 0.5	6.0
Phosphate (as PO_4)	MG/L	< 0.001	0.4
Sulfate (as SO_4)	MG/L	None	430
pH	pH Units	7.0±	7.5
Metals (Ni, Cu, Cd, Zn, & Pb)	MG/L	< .01	Not Analyzed
Pesticides : 2, 4-D	MG/L	3.7×10^{-3}	Not Analyzed
: Dicambra	MG/L	0.43	Not Analyzed
: MSMA	MG/L	8.5×10^{-8}	Not Analyzed

Notes:

1. Prediction of percolate water quality from Walker (1995).
2. Representative receiving water quality values are the averages of QB-1, QB-3, and QB-4 from Tables 4 and 5.
3. Computations of pesticides (from Walker, 1995) are based on a "worst case" of putting the entire year's pesticide application on at one time followed immediately by a 100-year storm event. Other pesticides than those listed will be used on the golf course. However, they will not leach.

References

Department of Water and Land Development. 1973. Climatological Stations in Hawaii. Report R42, Department of Water and Land Development, Department of Land and Natural Resources, State of Hawaii.

Ekern, P.C. and Jen-Hu Chang. 1985. Pan Evaporation: Station of Hawaii, 1894-1983. Report R74, Department of Water and Land Development, Department of Land and Natural Resources, State of Hawaii.

Eyre, Paul, Charles Ewart, and Patricia Shade. 1986. Hydrology of the Leeward Aquifers, Southeastern Oahu, Hawaii. Water Resources Investigations Report 85-4270, U.S. Geological Survey, Honolulu, Hawaii.

Giambelluca, T.W., M.A. Nullet, and T.A. Schroeder. 1986. Rainfall Atlas of Hawaii. Report R76, Department of Water and Land Development, Department of Land and Natural Resources, State of Hawaii.

Stearns, Harold T. and Knute N. Vaksvik. 1935. Geology and Ground-Water Resources of the Island of Oahu, Hawaii. Bulletin 1, Division of Hydrography, Territory of Hawaii.

Takasaki, K.J. and J.F. Mink. 1982. Water Resources of Southeastern Oahu, Hawaii. Water Resources Investigations Report 82-628, U.S. Geological Survey, Honolulu, Hawaii.

Visher, F.H. and J.F. Mink. 1964. Geological Survey Water Supply Paper 1778, U.S. Government Printing Office, Washington, D.C.

Walker, William J. 1995. Geochemistry, Soil Chemistry and Potential Chemical Impacts From Construction and Maintenance of a Proposed Golf Course: Queen's Beach, Oahu, Hawaii. Consultant Report prepared for Helber Hastert & Fee.

Queen's Beach Golf Course

Appendix

B

Baseline Survey of Water Quality and Marine Community Structure and Baseline Pesticide Sampling

(Marine Research Consultants)

BASELINE SURVEY OF WATER QUALITY AND MARINE COMMUNITY STRUCTURE IN THE VICINITY OF THE PROPOSED QUEEN'S BEACH GOLF COURSE, OAHU, HAWAII

Prepared for:

Helber Hastert & Fee, Planners
Grosvenor Center - PRI Tower
733 Bishop St., Suite 2590
Honolulu, HI 96813

By:

Marine Research Consultants
4467 Sierra Dr.
Honolulu, HI 96816

Revised
April 8, 1996

I. EXECUTIVE SUMMARY

Development of an 18-hole golf course, driving range, clubhouse, and related support facilities have been proposed for the ±166-acre site on the eastern coast of Oahu, Hawaii, known locally as Queen's Beach. A baseline survey of the marine environment, including water chemistry and biotic community structure was conducted in order to evaluate the potential effects of the proposed golf course. The evaluation of water chemistry was conducted in January 1995. Forty-one water samples from three sites were analyzed for 14 constituents, including those specified by DOH water quality standards. Sampling sites extended from the most landward points of Kaloko Inlet (Site 1), Ka'ili'ili Bay (Site 2), and Kaho'ohaihai Inlet (Site 3) across the shoreline to the open ocean, and from the surface and bottom of the water column. In addition, 12 samples were collected from 4 groundwater monitoring wells upslope of the project area.

Patterns of water chemistry indicate somewhat different processes occurring at the three survey Sites. At Site 1, it appears that low salinity groundwater is mixing with saline oceanic water in Kaloko Inlet. Low salinity groundwater, which contains high concentrations of Si, NO_3^-, and PO_4^{3-}, percolates to the inland areas of the inlet resulting in an area of mixing. At Site 1 the region of mixing is greatest between 800 and 1250 m inland from the primary shoreline. Within this area, a rock sill restricts circulation of inflowing seawater to the landward portions of the inlet. At Sites 2 and 3, the gradients of NO_3^-, Si and salinity from the back inlet areas across the primary shoreline to the open ocean are much less pronounced than at Site 1. Horizontal salinity profiles at Sites 2 and 3 reveal gradients of decreasing salinity moving seaward, exactly the opposite pattern from Site 1. The pattern of hypersaline water in the inlets at Sites 2 and 3 suggests that there is little groundwater input to these regions, and restricted mixing results in evaporative distillation of the oceanic water trapped in the inlets. As a result of the low groundwater input, low flushing rates, and evaporative distillation, both salinity and dissolved nutrients are somewhat higher at the inland portions of transect sites 2 and 3 relative to the outer oceanic portions of the sampling transects. Conservative mixing analyses suggests that groundwater entering Kaloko Inlet is enriched in NO_3^- from leaching of the irrigation water from the Hawaii Kai Golf Course. However, the subsidy of NO_3^- is reduced to background oceanic levels at the mouth of Kaloko Inlet. No State of Hawaii Department of Health water quality standards for open coastal ocean conditions were exceeded in samples collected seaward of the shoreline.

Assessment of benthic and reef fish community structure off the proposed Queen's Beach Golf Course was conducted in January 1995. Six quantitative transects were evaluated at three sites located offshore of the property. Physical structure of the nearshore region consists predominantly of rocky basaltic shorelines that form the land-sea interface. The reef area is divided into three major zones; a shallow nearshore zone characterized by basaltic boulders and substantial water motion from breaking waves, a mid-reef zone which comprises the major "reef-building area", and a deeper sand-rubble zone. In general, the coral communities off Queen's Beach are typical of the type that occurs off much of east Oahu. Ten coral species were encountered on transects, and total coral cover was approximately 18% of bottom cover. The dominant coral species at all sites was *Porites lobata* which comprised 50% of total coral cover, and 9% of total bottom cover. At all three study sites, coral cover increased with depth until the sand-rubble zone. It appeared that coral cover was highest in the deeper surveyed areas as these regions are less impacted by the forces of breaking waves. In the shallow inshore zones, coral cover was relatively low, probably as a result of limits to settlement and growth of many species as a result of normal water motion associated with wave action. Reef fish community structure was fairly typical of the assemblages found in exposed coastlines of Oahu. The relatively low abundance of food fishes indicates that the area has been subjected to substantial fishing pressure.

Based on the body of scientific information on existing projects constructed on Hawaiian shorelines, and the data collected at the Queen's Beach site, it does not appear that the construction or operation of the proposed golf course has the potential to cause adverse impacts to the marine environment. Stresses from natural forces that are presently the dominant factors in influencing community structure appear to be substantially greater than those that could result from the proposed shoreline development. The absence of plans to modify the shoreline or nearshore environment eliminates the potential for direct alteration of ecosystems. Typical oceanic conditions of rapid mixing in the nearshore environment will rapidly dilute any material entering the ocean to background levels. While it is projected that percolation of irrigation water will nearly double the amount of groundwater reaching the shoreline, the increases in nutrient concentrations of groundwater will be small for NO_3^- and none for PO_4^{3-}. Based on the present mixing and dilution of groundwater in Kaloko Inlet (the only site where groundwater input was detectable), there does not appear to be any potential to change the concentration of nutrients in the nearshore ocean.

Even if nutrients (NO_3^-) should increase slightly from groundwater flow, documented case histories from around Hawaii indicate that there is virtually no potential for impacts to the marine environment, including protected species. Similarly, even with a potentially worst case scenario of pesticide application, there is no potential for impact of the marine environment. Impacts associated with surface runoff of materials associated with the development also do not appear to present the potential for changes at Queen's Beach based on similar, existing projects, provided that proper management scenarios are employed. Continued monitoring during the course of development will allow determination of potential impacts to marine communities at levels where mitigative steps can be instituted prior to actual changes.

II. INTRODUCTION

Development of an 18-hole golf course, driving range, clubhouse, and related support facilities have been proposed for the ±166-acre site on the eastern coast of Oahu, Hawaii, identified as TMK 3-9-11:03 and :02 (portion), known locally as Queen's Beach. Figure 1 illustrates the project area and a conceptual development scheme for the golf course and related facilities.

While the project site encompasses approximately one-half mile of coastline, there are presently no plans for direct alteration of any portions of the marine environment. However, the estimated 120 acres of turfgrass will require an average irrigation rate of approximately 0.60 to 0.65 million gallons per day (MGD), and a peak irrigation of 0.90 to 0.95 MGD during the summer months. The source of irrigation supply water will be treated effluent from the East Honolulu Wastewater Treatment Plant (EHWWTP), a privately owned and operated facility that serves the communities of Hawaii Kai. The quality of the effluent presently meets the State Department of Health (DOH) R-2 standards.

A primary concern in the planning of the development is protection and preservation of the existing environmental quality of the area. Because of the use of sewage effluent (or any other source of fertilizer nutrients) for irrigation/fertilization of the golf course turf, it is possible that leaching of irrigant through the turf mantle may affect the characteristics of groundwater that presently flows into the coastal ocean. In turn, with altered groundwater input, it is possible that marine community structure in the coastal area could be altered. In order to assess the potential for such environmental changes, it has been deemed important to conduct a detailed study of the existing conditions of water chemistry and marine community structure adjacent to the proposed Queen's Beach Golf Course. The results of this study, along with estimates of alterations to groundwater flow provided by Tom Nance Water Resource Engineering, as well as documented information from similar existing golf courses in Hawaii will provide the background information to assess the potential changes that may, or may not, occur as a result of the proposed project. Presented below are the methods, results and conclusions of these investigations.

III. WATER CHEMISTRY

A. ANALYTICAL METHODS

Figure 1 is a map of the Queen's Beach area showing the locations of three sampling transects extending from the shoreline to the open coastal ocean. The Queen's Beach area is somewhat unique for the east Oahu coastline in that it contains several inlets that penetrate up to several hundred meters inland from the primary coastline. Because groundwater flow and reduced mixing into these inlets would potentially result in higher concentrations of golf course related materials in the inlets compared to open coastal areas, the three sampling transects bisected the three inlets. Transect site 1 originates in Kaloko Inlet, Site 2 originates in Ka'ili'ili Bay, and site 3 originates in Kaho'ohaihai Inlet (Figure 1). At all three transect sites, sampling was carried out from the most landward portion of the Inlet, to approximately 150 feet offshore. This sampling range covered the complete horizontal span from inland shallows to open coastal ocean condition.

In addition to ocean sampling, water was collected from four test wells drilled for monitoring. Each well was sampled at three depths. Water from these wells was analyzed for dissolved nutrients and salinity in a manner similar to ocean water samples. Test Well Q1 was located upslope of Site 3; Wells Q2 and Q4 were located upslope of Site 2 with Well Q2 located closest to the ocean; Well Q3 was located upslope of Site 1.

Water sampling was conducted on January 4, 1995. Sea conditions during the sampling consisted of light and variable winds and very little swell. Sampling was done by swimmers working from shore. Sample collection was carried out by filling 1-liter polyethylene bottles at the desired location following several rinses with sample water. At each sampling station where water depth exceeded 1 m, two water samples were collected; a surface sample from within 10 centimeters (cm) of the air-sea interface, and a deep sample within 50 cm of the sea floor. At stations where the depth of the water was less than 1 m, only a surface sample was taken.

Water quality constituents that were evaluated include the 10 specific criteria designated for open coastal waters in Chapter 11-54, Section 06 (Open Coastal waters) of the Water Quality Standards, Department of Health, State of Hawaii. These criteria include: total dissolved nitrogen (TDN), nitrate + nitrite nitrogen ($NO_3^- + NO_2^-$), ammonium (NH_4^+), total dissolved phosphorus (TDP), chlorophyll a (Chl a), turbidity, salinity, pH and temperature. In addition, orthophosphate phosphorus (PO_4^{-3}) and silica (Si) are also reported because these constituents can be indicators of biological activity and the degree of groundwater or streamwater mixing.

Subsamples for nutrient analyses were immediately passed through sub-micron filters (GF-F) into 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice until returned to Honolulu. Analyses for NH_4^+, PO_4^{3-}, NO_3^-, and Si were performed using a Technicon autoanalyzer according to standard methods for seawater analysis (Strickland and

Parsons 1968, Grasshoff 1983). TDN and TDP were analyzed in a similar fashion following oxidative digestion. Dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) were calculated as the difference between TDN and dissolved inorganic N, and TDP and dissolved inorganic P, respectively. The level of detection for the dissolved nutrients is 0.2 μM for TDN and Si, 0.02 μM for TDP, and 0.01 μM for PO_4^{3-}, NO_3^- and NH_4^+.

Water for other analyses was subsampled from 1-liter polyethylene bottles and kept chilled until analysis. Turbidity was determined on 60-ml subsamples fixed with $HgCl_2$ to terminate biological activity. Fixed samples were kept refrigerated until turbidity was measured on a Monitek Model 21 90-degree nephelometer, and reported in nephelometric turbidity units (ntu, level of detection 0.01 ntu). Chl a was measured by filtering 300 ml of water through glass fiber filters; pigments on filters were extracted in 90% acetone in the dark at -5° C for 12-24 hours, and the fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer (level of detection 0.01 μg/L). Salinity was determined using an AGE Model 2100 laboratory salinometer with a precision of 0.0003 ‰.

Water temperature was measured in the field with a hand-held mercury thermometer with a readability of 0.1°C. pH was determined using a field meter with a combination electrode with precision of 0.01 pH units.

Nutrient, turbidity and salinity analyses were conducted by Marine Analytical Specialists (Laboratory Certification NO: HI-0009) of Honolulu, HI.

B. RESULTS OF WATER CHEMISTRY ANALYSES

1. Horizontal and Vertical Stratification

Water chemistry sampling was conducted on January 4, 1995 under overcast skies, calm winds and minimal wave action. Sampling was conducted during a falling tide with a change in tidal stand of approximately 0.8 feet over the course of sampling.

Tables 1 and 2 show results of all marine water chemistry analyses for samples collected in January 1995. Table 1 shows concentrations of dissolved nutrients in micromolar (μM) units, while Table 2 shows dissolved nutrient concentrations in units of micrograms per liter (μg/L). Table 3 shows chemical composition (in units of μM and μg/L) of water collected from 3 depths in test wells located directly mauka of the marine monitoring sites.

Concentrations of eight dissolved nutrient constituents in surface and deep samples on the three sampling transects are plotted as functions of distance from the shoreline in Figure 2.

Concentrations of salinity, turbidity, Chl a and temperature as functions of distance from shore are shown in Figure 3. For purposes of plotting, negative distances from shore indicate sampling locations within the inlets landward of the primary coastline; positive distances from shore indicate sampling locations seaward of the primary shoreline.

It can be seen in Figure 2 that concentrations of Si, NO_3^-, PO_4^{3-}, TDN and TDP decreased moving seaward along the transects. These constituents occurred in relatively high concentrations in samples collected from Site 1 compared to Sites 2 and 3. At Site 1, salinity showed corresponding increases with distance seaward, while at Sites 2 and 3 salinity decreased moving seaward. These gradients differ substantially between the transect sites; NO_3^- varied by about 7 μM along the transect at Site 1, compared to 0.15 μM at Sites 2 and 3, while salinity increased by 1.3 ‰ moving seaward over the transect at Site 1, while salinity decreased by about 0.5‰ at Site 2 and 0.2‰ at Site 3.

These patterns indicate somewhat different processes occurring at the three survey Sites. At Site 1, it appears that low salinity groundwater is mixing with saline oceanic water in Kaloko Inlet. Low salinity groundwater, which contains high concentrations of Si, NO_3^-, and PO_4^{3-} (see values for well water in Table 3), percolates to the inshore areas of the inlet at the shoreline resulting in an area of mixing. At Transect Site 1 the region of mixing can be detected throughout the entire 1250 m of the sampling regime landward of the primary shoreline. However, the gradient is significantly steeper from the sampling stations between 800 and 1250 m from the shoreline. Within this area, a rock sill restricts circulation of inflowing seawater to the landward portions of the inlet. Calm sea conditions during the period of sampling, which minimize turbulent mixing resulted in maximal horizontal gradients of groundwater nutrients and salinity within the sampling regime.

At Transect Sites 2 and 3, the gradients of NO_3^-, Si and salinity from the back inlet areas across the primary shoreline to offshore are much less pronounced than at Site 1. The smaller magnitude of these gradients suggests substantially less input of groundwater into Ka'ili'ili Bay and Kaho'ohaihai Inlet than in Kaloko Inlet. In fact, the horizontal salinity profiles at Sites 2 and 3 reveal gradients of decreasing salinity with distance offshore, exactly the opposite pattern from Site 1. The pattern of hypersaline water in the inlets at Sites 2 and 3 suggests that there is little groundwater input to these regions, and restricted mixing results in evaporative distillation of the oceanic water trapped in the inlets. As a result, of the low groundwater input, low flushing rates, and evaporative distillation, both salinity and dissolved nutrients are somewhat higher at the inland portions of transect sites 2 and 3 relative to the outer oceanic portions of the sampling transects.

Concentrations of groundwater from the four monitoring wells show a corresponding pattern as the marine samples with respect to groundwater flux from land to the ocean. It can be seen in Table 3 that concentrations of nutrients found in groundwater (NO_3^-, PO_4^{3-} and Si) are substantially higher in Well 3 which is directly mauka of Kaloko Inlet (Site 1) than in the other wells which are mauka of Sites 2 and 3.

The patterns of distribution of NH_4^+ along the transects is somewhat random; at Transect Site 1 concentrations are uniformly low ($\leq$0.5 μM) except at one sampling site within Kaloko Inlet; at Transects 2 and 3 the concentrations are somewhat higher ($\leq$0.7 μM) with a trend of decreasing concentration with distance seaward (Figure 2). It can be seen in Table 3 that NH_4^+ does not occur in high concentrations in shallow well water relative to ocean water. Thus, the high concentrations within the inlets of the three transect sites are likely a result of biotic activity within the shallow lagoonal areas, rather than as a result of input from land sources.

Dissolved organic nutrient constituents that are not associated with groundwater input (DON, DOP) do not show any consistent pattern with respect to distance from the shoreline. The highest turbidity values were measured in the most landward areas of each of the sampling inlets, with generally decreasing values with distance from the shoreline. Turbidity in the ocean samples beyond the primary shoreline was substantially lower at all sites than turbidity within the inlets landward of the primary shoreline.

Concentrations of Chl a were substantially higher at Site 1 than Sites 2 and 3, and decreased with distance from the back of Kaloko Inlet. Chl a concentrations in Ka'ili'ili Bay (Site 2) and Kaho'ohaihai Inlet (Site 3) were in general higher within the inlets compared to the open ocean samples, but were approximately an order of magnitude lower than in Kaloko Inlet. Temperature decreased slightly with distance from shore on all transects, but was elevated by approximately 1°C within the inlets at Sites 2 and 3 compared to Site 1. This temperature elevation at Sites 2 and 3, presumably from solar warming corroborates the conclusions regarding low groundwater input and restricted circulation in these areas that were based on patterns of nutrients and salinity.

2. Vertical Stratification

Owing to the lower density of groundwater compared to seawater, the nearshore water column off many coastlines of Hawaii is often stratified, with a surface layer of lower salinity and higher dissolved nutrient content relative to subsurface water. Figures 2 and 3 show water chemistry composition of both surface and deep water. In few cases is there substantial difference in concentrations between surface and deep water. At Site 1, only the station approximately 300 m inland of the primary shoreline exhibits substantially higher nutrients and lower salinity at the surface relative to bottom water. While dissolved nutrients and salinity were essentially uniform throughout the water column at the remaining sampling stations at Site 1, Chl a and turbidity were consistently higher in the deep samples compared to the surface. At Sites 2 and 3, there is little indication of vertical stratification at any of the sampling stations.

3. Conservative Mixing Analyses

It is possible to evaluate the extent of nutrient input from sources other than groundwater efflux by plotting the concentration of the dissolved material as a function of salinity (Officer 1979, Dollar and Atkinson 1992, Smith and Atkinson 1993). Comparison of the curves produced by such plots with conservative mixing lines provides an indication of the origin and fate of the material in question. Figure 4 shows plots of concentrations of four chemical constituents (Si, NO_3^-, NH_4^+, PO_4^{3-}) as functions of salinity for the samples collected in January 1995 off of Queen's Beach.

Each graph also shows conservative mixing lines that are constructed by connecting the endmember concentrations of open ocean water and groundwater from test wells located upslope of the proposed Queen's Beach Golf Course. Three lines are shown in each plot corresponding to mixing lines constructed from well water upslope of each site.

If the parameter in question displays purely conservative behavior (no input or removal from any process other than physical mixing), data points should fall on, or near, the conservative mixing line. If, however, external material is added to the system through processes such as leaching of fertilizer nutrients to groundwater, data points will fall above the mixing line; removal of nonconservative materials will result in data points falling below conservative mixing lines. The shape of the mixing line can also indicate the fate of the dissolved material in the marine environment. If material is being taken up by biological processes that could result in alteration in water quality or community structure, data points will prescribe a concave upward curve. Conversely, downward concave curvature indicates an additional source of material in addition to that coming from land, such as biological production.

Dissolved Si represents a check on assumptions of the method, as this material is present in high concentration in groundwater, but is not a major component of fertilizer, and is not utilized rapidly within the nearshore environment by biological processes. It can be seen in Figure 4 that when Si concentrations are plotted as a function of salinity, samples from each transect form distinct lines that all converge on the marine endpoint. Samples from Transect

Site 1 prescribe a straight line close to the mixing lines (increasing concentration with decreasing salinity) for salinities below 34.5‰, and above the mixing lines at lower salinities. This deviation from the mixing line suggests that either the water in Kaloko Inlet is a mixture of groundwater that is higher in Si concentration than the well water, or that evaporation has raised the nutrient concentration relative to salinity in the more landward portions of the Inlet. In either case, the linearity of the data points from Transect 1, corroborates the results of the horizontal gradients (discussed above) which indicate groundwater input to Kaloko Inlet, which mixes with ocean water.

Plots of concentrations of Si versus salinity at Transect sites 2 and 3, reveal the opposite pattern as Site 1. Concentration of Si increases with increasing salinity above about 35‰. These salinities, which are above the oceanic value, are the result of evaporation of oceanic water with no input of groundwater. As a result, the mixing lines prescribed by Si versus salinity for the hypersaline waters within the Inlets at Sites 2 and 3 shows distinctly different characteristics as the line from Site 1.

The plot of NO_3^- versus salinity for the January 1995 survey (Figure 4) shows a different pattern than dissolved Si. Of particular interest is the large variation between the endpoints of the mixing lines prescribed by the three monitoring wells. It is apparent that the groundwater in the well upslope of Kaloko Inlet (Site 1) has substantially higher NO_3^- concentrations than wells upslope of Sites 2 and 3. Such a large variation suggests that the groundwater entering Kaloko Inlet is subsidized with NO_3^- from the Hawaii Kai Golf Course. At Site 1, the line prescribed by the data points falls well below the conservative mixing line; in addition the line has distinctly upward concave curvature. These characteristics suggest that NO_3^- is being removed from the water in Kaloko Inlet by biotic processes. It is apparent that the curvature (i.e. uptake) is much more pronounced at the more landward portions of the lagoon, where circulation is restricted compared to the more seaward portions of the transect. As with Si, data points at Sites 2 and 3 exhibit slight elevation in concentration with increased salinity above oceanic values as a result of evaporation of water within the inlets. There is also slight upward curvature in the data points from Sites 2 and 3 suggesting uptake of NO_3^- by biotic processes within the inlets.

The other form of dissolved inorganic nitrogen, NH_4^+, shows a different relationship. There is essentially no difference in NH_4^+ concentrations between open ocean water and groundwater, resulting in a "flat" conservative mixing line (Figure 4). Distribution of data points lies predominantly above all conservative mixing lines. There is no indication of increased concentrations of NH_4^+ with decreased salinity, and many of the highest concentrations of NH_4^+ occur at the highest salinities. The lack of such a relationship suggests that the source of most NH_4^+ is not input from land, but rather from biotic metabolic processes occurring in the nearshore zone.

PO_4^{3-} is also a component of fertilizer, but is usually not found to leach to groundwater to the extent of nitrate nitrogen, owing to a high absorptive affinity of phosphorus in soils. It can be seen in Figure 4 that the PO_4^{3-} concentrations at Site 1 fall in a relatively linear array along the conservative mixing line. Unlike NO_3^-, the endpoints for the mixing lines at all three sites are very similar, indicating that there does not appear to be a subsidy of PO_4^{3-} to groundwater from the Hawaii Kai Golf Course. Concentrations of PO_4^{3-} at Sites 2 and 3 are in general lower than at Site 1 and display a similar pattern as NO_3^- with slight upward curvature. As most of the data points fall above the conservative mixing lines, it appears that like Si, concentrations of PO_4^{3-} may be elevated above that expected solely from mixing of groundwater and ocean water as a result of evaporation. The lack of distinct concave upward curvature at Site 1, however, suggests that PO_4^{3-} is not taken up to the same degree as NO_3^- in Kaloko Inlet.

4. Compliance with DOH Criteria

Also shown in Tables 1 and 2 are samples from January 1995 that exceed State of Hawaii Department of Health (DOH) water quality standards for open coastal waters under "dry" conditions. The criteria for dry conditions are applied to the Queen's Beach Golf Course site as this area probably receives less than 3 million gallons of groundwater input per mile per day. DOH standards include specific criteria for three situations; criteria that are not to be exceeded during either 10% or 2% of the time, and criteria that are not to be exceeded by the geometric mean of samples. With only one set of samples, geometric means or percentage exceedances are not statistically applicable. However, the 10% and 2% criteria provide an indication of overall water quality. Comparing sample concentrations to these criteria provide an indication of whether water quality is near the stated specific criteria. Results from the January 1995 ocean water chemistry survey reveal that six measurements of NO_3^-, eleven measurements of NH_4^+, three measurements of TDN, seventeen measurements of turbidity and seven measurements of Chl a exceeded the 10% criteria set by the DOH. No measurements for TDP exceeded the specific DOH criteria during January 1995. All of the samples that exceeded these criteria were located landward of the primary shoreline. Thus, as discussed above, the higher concentrations appear to be primarily a response to groundwater input (Site 1), and biotic activity in the inlets with restricted circulation and high evaporative rates (Sites 2 and 3). No criteria were exceeded at true oceanic stations seaward of the primary shoreline.

IV. BIOLOGICAL COMMUNITY ASSESSMENT

A. METHODS

Marine community structure as represented in this report can be defined as the abundance, diversity, and distribution of benthos (bottom dwelling organisms), including stony and soft corals, marine plants (algae), motile benthos such as echinoderms, pelagic species such as reef fish, and federally protected endangered and threatened species. When considering environmental changes caused by changes in land use or changes in non-point input of water of altered composition, benthic communities are probably the most useful biological assemblages for direct evaluation of environmental impacts to the offshore marine environment. Because benthos are generally long-lived, immobile, and can be significantly affected by exogenous input of sediments and other potential pollutants, these organisms must either tolerate the surrounding conditions within the limits of adaptability or die.

All fieldwork was carried out on September 30, 1994, and was conducted from a 17-foot boat using SCUBA gear. Biotic structure of benthic (bottom dwelling) communities inhabiting the reef environment was evaluated by establishing a descriptive and quantitative baseline in the region between the shoreline and approximately the 15 m depth contour. Initial qualitative reconnaissance surveys were conducted that by divers towing behind a slowly moving boat. These reconnaissance surveys were useful in making relative comparisons between areas, identifying any unique or unusual biotic resources, and providing a general picture of the physiographic structure and benthic assemblages occurring throughout the region of study.

Following the preliminary survey, three quantitative transect sites were selected in the same approximate areas as the three water chemistry transect sites (fronting the three inlets). Site 1 was located off of Kaloko Inlet, Site 2 was located off Ka'ili'ili Bay, and Site 3 was located off of Kaho'ohaihai Inlet (see Figure 1). Transect locations were selected to bisect areas primarily of hard bottom. Within the hard bottom areas, care was taken to place transects in random locations that were not biased toward either peak or low coral cover.

Quantitative benthic surveys were conducted by stretching a 50-m long surveying tape in a straight line over the reef surface. An quadrat frame with dimensions of 1 m by 0.66 m, was sequentially placed over 10 random marks on the transect tape so that the tape bisected the long axis of the frame. At each quadrat location a color photograph recorded the segment of reef area enclosed by the quadrat frame. In addition, a diver knowledgeable in the taxonomy of resident species visually estimated the percent cover and occurrence of organisms and substratum type within the quadrat frame. No attempt was made to disturb substrata to observe organisms, and no attempt was made to identify and enumerate cryptic species dwelling within the reef framework. Only macrofaunal species greater than approximately 2 centimeters were noted.

In the laboratory, accurate estimates of benthic cover of biota and substrata were obtained by overlaying a grid on the quadrat photographs and summing cover of each species and substratum type. This information was combined with the *in-situ* cover estimates and the combined assessment provides the data base for the benthic community structure analysis. The photo-quadrat data was augmented by *in-situ* observations of small individuals or colonies that were not distinguishable in the photos. Thus, the resultant data set has the advantage of including small and rare organisms that occurred within the quadrats, as well as accurate estimates of area coverage of large organisms or colonies that comprised substantial area within the quadrats. Few, if any other quantitative transect survey technique has the advantage of including both of these parameters.

The photo-quadrat transect method is a modification of the technique described in Kinzie and Snider (1978), and has been employed in numerous field studies of Hawaiian reef communities (e.g. Dollar 1979, Dollar 1985, Grigg and Maragos 1974), and has proven to be particularly useful for quantifying coverage of attached benthos such as corals and large epifauna (e.g., sea urchins, sea cucumbers). While this methodology is quantitative for the larger exposed fauna, many coral reef invertebrates are cryptic or nocturnal. Coupled with the generally small size of cryptic invertebrates, quantitative assessment of these groups requires methodologies that are beyond the scope of the present baseline assessment program.

Quantitative assessment of reef fish community structure was conducted in conjunction with the benthic surveys. As the transect tape was being laid along the bottom, all fish observed within a band approximately 2 meters wide along the transect path were identified by species name and enumerated. Care was taken to conduct the fish surveys so that the minimum disturbance was created by divers, ensuring the least possible dispersal of fish. Only readily visible individuals were included in the census. No attempt was made to seek out cryptic species or individuals sheltered within coral. This transect method is an adaptation of techniques described in Hobson (1974).

B. RESULTS AND DISCUSSION

1. Physical Structure

The main structural feature of the approximately 1.5 mile of shoreline of the Queen's

Beach property is a basaltic ledge of pahoehoe lava interspersed with small pocket beaches. As described above, there area also a series of indentations, or shallow embayments bounded by outcrops of lava that extend seaward. The northern area of the property is bounded by high sea cliffs of Makapuu Point.

Other than the shallow embayments, the intertidal zone consists primarily of a wave-swept basaltic bench that is nearly barren of macrobiota. Seaward of the wave impact zone near the shoreline, the offshore region is comprised of a gently sloping limestone encrusted extension of the basaltic shoreline bench. Water depth in this mid-reef zone ranges from about 7 to 15 m. As wave stress in this region is substantially less than in the shallower areas, and suitable hard substrata abound, the area provides an ideal locale for colonization by attached benthos, particularly reef corals, and generally the widest assortment of species and growth forms are encountered in this region.

The mid-reef bench is cut by numerous sand-filled fissures which create ledges and undercuts. Off the southwestern end of the property (Transect Site III), bottom topography was characterized by a large number of irregularly-shaped basalt blocks, along with numerous small caves and ledges eroded into the basaltic structures. In comparison to the composition at Site III, bottom topography at Sites I and II was relatively flat.

Coral community structure at Site III differed substantially from the other two sites in that *Pocillopora meandrina* was the dominant species rather than *Porites lobata*. In addition, reef fish community structure, in terms of numbers of species and individuals, was markedly higher on the deep transect at Site III than any other survey location. The difference in both fish and coral community structure appears to be a response to the greater topographical relief created by the basaltic blocks that occur at Site III, but not at Sites I and II.

The seaward edge of the mid-reef platform (at a depth of about 15 m) is marked by a grading from solid basalt-limestone topography to an aggregate of generally unconsolidated sand and rubble. Little benthic biota occurred in the sand-rubble deep reef zone, with the predominant forms being small colonies of *Porites spp.* growing on rubble fragments. The sand-rubble bottom extends offshore to depths well beyond the bounds of the present study.

2. Coral Community Structure

Table 4 shows abundance estimates of invertebrates observed throughout the region of study. The predominant taxon of macrobenthos (bottom-dwellers) throughout the nearshore zones off the Queen's Beach property are Scleractinian (reef-building) corals. Other dominant benthos are echinoids (sea urchins) and holothurians (sea cucumbers). Results of quantitative line transects conducted at the three representative survey sites provide a data base characterizing coral community structure. Table 5 shows the quantitative summary of coral community structure from the six transects, while Appendix A is comprised of individual quadrat results.

In total, 13 species of "stony" corals, and two "soft corals" were observed throughout the region of study, while 10 species of coral were encountered on transects. The number of coral species on a single transect ranged from 4 to 7. Species of coral that were observed in the region but did not occur on transects included *Pocillopora eydouxi*, *Cyphastrea ocellina*, *Leptastrea purpurea*, *Fungia scutaria*, and *Anthelia edmondsoni* (see Tables 5 and 6). The dominant species on transects were *Porites lobata* and *Pocillopora meandrina*. *P. lobata* accounted for about 50% of total coral cover, and about 9% of all bottom cover. The second most abundant species, *Pocillopora meandrina*, accounted for about 27% of coral cover, and 5% of total bottom cover. Thus, these two species comprised about 77% of living coral cover, and 14% of all bottom cover. In total, living coral cover accounted for 18% of bottom cover. Such a percentage of total coral cover is typical of many open coastal regions off Oahu. However, coral cover does vary greatly within a fairly small geographical area dependent on physical conditions and habitat suitability. For instance, coral cover adjacent to the East Honolulu Wastewater Facility Ocean diffuser off Sandy Beach has been measured at about 30% for the last 10 years (Marine Research Consultants 1995). On the other hand, coral communities in Waimanalo Bay were determined to comprise less than 5% of bottom cover, primarily as a result of lack of hard bottom and constant sand scour (Marine Research Consultants 1994).

Table 5 shows coral cover, coral species diversity, and number of species on each transect. With respect to coral cover, it can be seen that at all sites, there is a higher cover, higher number of species, and lower diversity on the deep transects. Such a pattern is largely a reflection of the degree of wave stress that limits coral growth. On the shallow transects, coral cover is lower than in deeper water, presumably in response to the "normal" range of wave effects that limit settlement and growth of some species. The high percentage of living coral cover, and domination by one or two species on the deeper transects is a result of less wave force that is potentially detrimental to coral growth and settlement. As a result, there is lower cover in the shallower areas, as well as less domination by species that are adapted to grow in Hawaiian near shore environments (hence higher diversity).

3. Other Benthic Macroinvertebrates

The other dominant group of macroinvertebrates are the sea urchins (Class Echinoidea). Table 4 summarizes the occurrence of sea urchins at all of the survey stations. The most

common urchin was *Echinometra matheai*, which occurred at all transect sites. *E. matheai* are small urchins that are generally found within interstitial spaces bored into basaltic and limestone substrata. *Echinostrephus aciculatus* and *Echinometra oblonga* occupy similar habitats within spaces bored in the reef platform.

Tripneustes gratilla, and *Heterocentrotus mammillatus* were other species of urchins that occurred commonly on many transects. Both of these urchins occur as larger individuals (compared with *E. matheai*) that are generally found on the reef surface, rather than within interstitial spaces.

Sea cucumbers (Holothurians) observed during the survey consisted of three species, *Holothuria atra*, *H. nobilis*, and *Actinopyga obesa*. Individuals of these species were distributed sporadically across the mid-reef and deep reef zones. The predominant Asteroid (starfish) observed on the reef surface were *Linckia spp.* Several crown-of-thorns starfish (*Acanthaster planci*) were observed feeding on colonies of *Pocillopora meandrina* and *Montipora verrucosa*. Numerous sponges were also observed on the reef surface, often under ledges and in interstitial spaces.

Frondose benthic algal zonation was not apparent at the study area off of the Queen's Beach property. However, encrusting red calcareous algae (*Porolithon spp.*, *Peysonellia rubra*, *Hydrolithon spp.*) were common on the boulders and exposed rocks throughout the study area. These algae were also abundant on bared limestone surfaces, and on the non-living parts of coral colonies. Frondose algae observed on the reef included *Valonia sp.*, *Lyngbya majuscula*, *Halimeda spp.*, *Sargassum spp.* and *Asparagopsis sp.* All of these plants occurred sporadically, and did not constitute a major component of the benthic biota.

The design of the reef survey was such that no cryptic organisms or species living within interstitial spaces of the reef surface were enumerated. Since this is the habitat of the majority of mollusks and crustacea, detailed species counts were not included in the transecting scheme. No dominant communities of these classes of biota were observed during the reef surveys at any of the study stations.

4. Reef Fish Community Structure

The reef fish community off Queen's Beach is not particularly rich, and typical of that found along an exposed coastline of Oahu. Reef fish community structure was largely determined by the topography and composition of the benthos. However, the fish community also appears to be affected by a significant amount of fishing. A total of 47 species representing 15 families were observed on transects. Considering single transects, the number of species ranged from 8 to 27, while individual fish encountered on transects ranged from 43 to 338 (Table 6). The largest numbers of species and individuals were observed on transect III-2 at a depth of 12 m. The area where this transect was conducted was characterized by a large number of irregularly shaped basalt blocks, with many small caves and ledges eroded into the basaltic features. Transects I-1 and I-2 also had relatively high numbers of fish. These transect sites had several low ledges cut into the basalt bottom that provided shelter for fish. Several of the stones from the nearby old jetty had also been carried offshore by waves which provided additional shelter. Most of the bottom topography in the vicinity of transects II-1, II-2, and III-1 was characterized by a relatively flat and featureless bottom that afforded little shelter for reef fish. As a result, counts of both individuals and species were lowest on these transects (Table 6).

The most abundant group of fish were algal-feeding acanthurids such as the brown surgeonfish (ma'i'i'i, *Acanthurus nigrofuscus*), goldring surgeonfish (kole, *Ctenochaetus strigosus*), orangeband surgeonfish (na'ena'e, *Acanthurus olivaceus*), convict tang (manini, *A. triostegus*), yellow tang (lau'i papa, *Zebrasoma flavescens*, and the orangespine unicornfish (umaumalei, *Naso lituratus*). The saddleback wrasse (hinalea, *Thalassoma duperry*), was also common at all sites. Other common fish were the planktivorous blackfin chromis (*Chromis vanderbilti*), the manybar goatfish (moano, *Parupeneus multifasciatus*) and several triggerfish (family Balistidae). A large school of the planktivorous unicornfish (opelu kala, *Naso hexacanthus*) was observed at transect site III-2.

A few individuals of several "food fish" species were observed during the survey. These included jacks (ulua, *Caranx melamphygus*), parrotfishes (uhu, *Scarus spp.*), goatfishes (weke, *Parupaneus spp.* and *Mulloidichthys spp.*), emperorfish (mu, *Monotaxis grandoculis*), and the previously mentioned opelu kala. However, most individuals were small and actively avoided divers. The behavior, small size and limited number of food fish noted at the site indicates that fishing is exerting a significant influence on the fish community. The effect of fishing is superimposed on the effects of a physical habitat that, across most of the area, does not favor the development of a rich fish community.

5. Endangered and Protected Species

Four species of marine animals that occur in Hawaiian waters have been declared threatened or endangered by Federal jurisdiction. The threatened green sea turtle (*Chelonia mydas*) occurs commonly along the coastlines of Oahu, and is known to feed on selected species of macroalgae. The endangered hawksbill turtle (*Eretmochelys imbricata*) is known infrequently from waters off the Hawaiian Islands. Several green sea turtles were sighted on the surface and underwater during the baseline surveys off of Queen's Beach.

Populations of the endangered humpback whale (*Megaptera novaeangliae*) are known to winter in the Hawaiian Islands from December to April. The present survey was conducted in September, when whales are not present in Hawaiian waters. The Hawaiian monk seal (*Monachus schlauslandi*) occurs predominantly in the Northwest Hawaiian Islands, but is occasionally observed in the main Hawaiian Islands. In recent years, 21 mature male seals have been relocated throughout the main islands as a method to reduce "mobbing" attacks on females. As a result, sightings of seals off the main Islands, as well as hauled out seals on beaches of the main islands have increased. Mr. John Naughton of the National Marine Fisheries Service has indicated that there are presently reports of monk seal sightings in the main islands on a daily basis. However to his knowledge, Queen's Beach does not appear to be an area where sightings have occurred in the past. No monk seals were observed during the present study.

V. CONCLUSIONS

The purpose of this baseline survey is to provide the data for to make valid estimates of the potential for impact to the marine environment from shoreline development. Implementation of the proposed plan for Queen's Beach Golf Course would involve grading, vegetation removal, new construction, and irrigation and fertilization of the completed course. There are, however, no plans for any alteration of the shoreline or offshore areas. Therefore, potential impacts to the marine environment can only be considered from activities on land that may result in delivery of materials to the ocean through infiltration to groundwater, changes in surface runoff, and wind transport. Presented below are considerations of potential impacts from sedimentation, nutrient enrichment and biocides that may are considerations for the planned project.

A. SEDIMENTATION AND RUNOFF

A potential mechanism for negative impact to nearshore marine systems is increased sedimentation from wind and surface runoff as a consequence of grading and changes in land use. There appears to be little potential for alteration to the marine community offshore of Queen's Beach from increased sedimentation associated with the project for several reasons. The climate of the Queen's Beach area is one of the driest on Oahu. Nance (1995) reports that on an annual basis rainfall is likely to be far exceeded by evaporation at the proposed project site. Surface water runoff from storm events is infrequent. Presently the area receives runoff from the Kalama Valley residential area, which reaches the ocean through a ditch which empties into Kaloko Inlet. Therefore, the marine environment is presently subjected to the small surface water input from drainage of the area. Even in the event of heavy rainfall, the porous nature of the soil ground cover is such that sheet flow carrying suspended sediment toward the ocean would be expected to be relatively small. Rather, most rainwater that would enter the ocean as runoff would do so following percolation through the surface rock layers to the water table, followed by groundwater extrusion at the shoreline.

The project site is presently comprised of extensive areas of exposed soil, with relatively little vegetative groundcover. Cover of this area with a completed golf course will surely result in less potential for windbourn dust. During the construction phases, it is likely that permit regulations will limit the area of excavation at any one time, and require dust-control measures. In addition, the predominant direction of wind (tradewinds) is from the northeast, resulting in transport of dust inland, and not toward the ocean. In fact, none of the predominant directions of wind (tradewinds, kona winds, or north winds) produce significant offshore transport. As a result, it appears that there is little potential for significant input of sediment to the marine environment resulting from the proposed project.

Within the marine environment, the nearshore area contains locally high regions of cover of calcareous sands of marine origin. Corals and other reef organisms are capable of removing sediment suspended by natural phenomena, up to threshold levels of deposition where cleaning mechanisms are overwhelmed and organisms become buried. Because of the existence of natural sands, and the normally turbulent conditions which continually resuspend natural sediment, biotic community structure is presently adapted to extremes in sediment stress from natural conditions. Organisms that do occur in the region are therefore capable of withstanding the stress associated with large natural sediment loads. In comparison to the frequent natural sediment resuspension within the study area, any additional input from land resulting from construction activity would probably not have the potential to accumulate to the point were organisms could be buried.

Several other scenarios around the Hawaiian Islands can also be drawn upon to estimate the potential for impact from sedimentation at Queen's Beach. In particular, a study conducted at Princeville, Kauai (Grigg and Dollar, 1980) compared the reef environments off the completed phase of the resort with the environments off an area of pristine coastline. The hypothesis tested during this comparison was that increased sedimentation from exposure of soil during construction caused some modification of the coral reef environments offshore. Results of the survey showed that, if anything, the coral environments were better developed off of the existing Princeville development that was potentially subjected to increased runoff compared to the unperturbed parcel. Even though the resort construction might have temporarily increased suspended sediment loads, this increase was insignificant in comparison to the natural sediment loads to which the reef communities are already pre-adapted. A second follow-up study of the same study sites off Princeville conducted in 1995 has revealed

consistently higher coral cover at all sites 15 years after completion of the golf course (R. Grigg, personal communication). Therefore, the hypothesis was rejected that developmental alteration of land for the Princeville Golf Courses caused negative impacts to the marine environment. By inference, similar golf course developments located on the shoreline, such as at Queen's Beach, should result in no offshore impacts to the marine environment.

B. GOLF COURSE IRRIGATION, FERTILIZATION, AND PEST CONTROL

The potential for impacts to the aquatic ecosystems owing to possible increases in rates of nutrient loading due to golf course fertilization and irrigation is also an important consideration in planning of the Queen's Beach project. When subjected to substantial increases in nutrients, the response of some marine and freshwater systems is termed "eutrophication," and consists of increased growth of a portion of the community that is able to directly utilize the nutrients (phytoplankton or benthic marine plants), generally at the expense of normal community integrity. The overall result of this process is usually a degradation of environmental quality.

At the Queen's Beach site, it is anticipated that no such impacts will occur for several reasons. Most importantly, the unrestricted circulation of the offshore zone by tidal and wind-driven currents, and nearly constant wave action promotes rapid dilution and water exchange. Residence time of a parcel of water fronting the development is probably on the order of hours, so buildup of any nutrient is unlikely.

Based on the estimates of Nance (1995) and Walker (1995) it is possible to derive quantitative estimates of the changes that might occur to marine water quality as a result of the operation of the proposed golf course. Because of the dry climate of the Queen's Beach area, the golf course will require irrigation and fertilization. Saline groundwater beneath the site, which occurs only in relatively small quantities is not a conceivable source of drinking water or irrigation supply (Nance 1995). Rather, secondarily treated sewage effluent from the East Honolulu Sewage Treatment Plant is projected to be the primary source of irrigation supply. However, presently the treated effluent contains salinity of 3-4‰ from saline infiltration of leaky gravity collection lines. As a result of the high salinity, irrigation of the greens will require an equal blend of effluent and drinking water to achieve an acceptable salinity.

Based on predicted irrigation rates, Walker (1995) calculates that percolation from the golf course due to rainfall and irrigation application will average 16 inches per year. Over the 120-acre turf area of the course, this would amount to 140,000 gallons per day (GPD). Since the present groundwater flow is estimated to be only 110,000 GPD (Nance 1995), percolation from the golf course would ultimately more than double the amount of groundwater discharging along the project shoreline. Walker (1995) also computed the expected quality of water percolation from the golf course. For all of the chemical constituents analyzed, including the primary nutrients used in fertilizers (NO_3^- and PO_4^{3-}), concentrations in the percolate are lower than in existing groundwater. In effect, the percolate will dilute the receiving groundwater with respect to salinity and nutrient concentration.

Because of the diluting effect of the irrigation waters on present groundwater chemical composition, the change in NO_3^- discharged to the ocean is relatively small, from the present situation of 1.24 lbs/day to 1.37 lbs/day (Nance 1995). Thus, with the golf course developed to full maturity, discharge of NO_3^- is expected to increase by about 10% over the present situation. Discharge of PO_4^{3-} is not expected to change from the present rate of 0.12 lbs/day at full maturity of the golf course (Nance 1995).

In order to evaluate the potential effect of these changes in groundwater volume and chemistry to the marine environment, it is useful to examine Figures 2 and 3, which show the relationships of NO_3^- concentration (Figure 2) and salinity (Figure 3) as functions of distance from the shoreine. Because there is no predicted change in percolation of PO_4^{3-}, it can be assumed that there will be no effect to the marine ecosystem from golf course operation. As discussed above, it is apparent from Figures 2 and 3 that there is little groundwater input to Ka'ili'ili Bay (Site 2) and Kaho'ohaihai Inlet (Site 3). Thus, the only area where it appears that groundwater is reaching the ocean is through Kaloko Inlet. Considering NO_3^-, the highest concentration measured in Kaloko Inlet was approximately 8 μM. This peak concentration rapidly dropped to below 1 μM approximately 250 m inland from the primary shoreline, and was approximately 0.25 μM at the sampling stations located from about 75 m inland from the shorline to the seaward extent of the sampling scheme. These data indicate that within Kaloko Inlet, the gradient in the concentration of NO_3^- from the most inland part of the inlet to the open ocean shows a decrease of approximately 3200% It is obvious that a change of the input of 10% to the 8 μM measured in the inlet will have virtually no detectable effect on the chemical composition of the marine environment, or even of Kaloko Inlet.

Similar arguments are apparent for changes in salinity of groundwater following percolation of irrigant to groundwater from maintenance of the golf course. It is calculated that groundwater discharge into the marine environment will increase from 110,000 to 250,000 GPD along the property boundary. This is an increase of 127%. As the percolate will be slightly less salty than the receiving groundwater, it can be assumed that the percolate will represent the equivalent of dilution groundwater by about 150%. In Figure 3, it can be seen that the landward sampling site in Kaloko Inlet had a salinity of about 33.5‰. The gradient of salinity increases rapidly in the landward parts of Kaloko Inlet and reaches oceanic salinity of about 34.5‰ about 230 m inland from the open ocean shoreline. Increasing the percolation to

groundwater could result in a salinity depression in the landward part of Kaloko Inlet to about 31.5‰. Should the mixing of groundwater and ocean water take place at the same ratio as during baseline conditions measured in the study, Kaloko Inlet water should reach oceanic salinity at approximately 500 feet inland from the shoreline. By the time groundwater in Kaloko reaches the shoreline and enters the open ocean, it will be of oceanic salinity regardless of whether the golf course is in operation or not.

While it appears that the operation of the Queen's Beach Golf Course will not result in any detectable input of nutrients to the marine environment, it is important to understand the potential for negative effects even if substantial input of golf nutrients did reach the ocean. Dollar and Atkinson (1992) modeled the input of golf course nutrients to the ocean downslope from two golf courses in West Hawaii over a four-year period. Results of the studies showed that at a location where fertilizer nutrients entered an embayment with restricted circulation relative to open coastal shorelines, nitrates increased by about 100% and phosphate increased by about 20% over natural groundwater input. Because the nutrients were retained within a surface layer, however, there was no exposure to the benthos. Circulation within the embayment was also rapid enough to prevent phytoplankton blooms. These results indicated that even with long-term input of extremely high nutrient subsidies, there are situations where there are no negative effects to the receiving environment.

Another factor that accounts for the lack of potential for impact is the secondary level of sewage treatment commonly used by golf course for irrigants and fertilizers. An ongoing monitoring program at the site of ocean discharge of the effluent from the East Honolulu Wastewater Treatment Plant (the same effluent planned for use on the Queen's Beach Golf Course) reveals that there is virtually no effect to coral communities from discharge through a multiport diffuser at a depth of 12 m off Sandy Beach (Marine Research Consultants 1995). Studies done at several other ocean discharges on Oahu (e.g. Russo et al. 1981, Henderson 1992, Grigg and Dollar 1995) show that intentional discharges of greater volumes of secondary sewage into marine environments caused no detrimental effects whatsoever. In fact, the impacts that have been reported all can be considered beneficial since they result in increased fish populations, apparently in response to increased particulate food and shelter due to the outfall structure. Coral communities have also been documented to increase near the outfalls because diffuser structures provide settling sites that appear to be superior to natural sites.

Potential for negative alteration to marine ecosystems owing to pesticides and herbicides also seems to be nil. It has not been found necessary to utilize substantial quantities of pesticides on golf courses in Hawaii, and only very small applications of herbicides are periodically made to the greens. Such small quantities do not appear to be of a magnitude great enough to leach through the soil and lava, be carried to the ocean via groundwater extrusions, and then bioaccumulate to the point of producing a noticeable effect. To date, there have been no substantiated instances of even detection of golf course biocides in any marine biota in Hawaii.

As a hypothetical "worst case" scenario for the Queen's Beach Golf Course, Walker (1995) created a situation of some pesticide leaching by assuming that all pesticides applied in an entire year would by applied at one time, followed immediately by a 100-year storm. Of the pesticides projected for usage, only three, 2-4-D, Dicambra, and MSMA, would actually leach to groundwater under this extreme circumstance. Dilution by mixing of groundwater percolate containing these pesticides with ocean water, and turbulent mixing of groundwater in the nearshore ocean would rapidly reduce these concentrations to far beyond detectable limits.

C. POTENTIAL EFFECTS TO PROTECTED SPECIES

As mentioned in the Results (Section B.3), there are several protected marine species that may inhabit the offshore environment. Because there is no plan for any work in the nearshore region, there is no potential for blasting or excavation that might affect behavior of whales, monk seals and other marine mammals. Short term changes in water quality resulting from construction would also not be of a magnitude to affect the behavior of sea turtles that might inhabit the reefs off of Queen's Beach. It is not likely that the proposed golf course will result in increased access to the shoreline, once the project is constructed. Thus, there is little potential for any negative factors associated with the project that may affect turtles or other protected species.

D. SUMMARY

The potential for impacts to marine communities as a result of development of the Queen's Beach Golf Course project appear to be minimal. None of the developmental activities appear to have the potential to induce long-term changes in physio-chemical composition of marine waters of a magnitude sufficient to cause changes in biological community structure. Marine environments are routinely subjected to stresses that can be much more destructive than the small changes that might result from any development activity. Tolerance to such changes appears to already be part of the physiological range of the community.

It can be concluded that as long as normal precautionary measures are followed during construction to minimize potential runoff, and operational procedures for the golf course follow the predicted guidelines used for the projection described above, there should be no adverse impacts to the marine environment. However, regardless of how unlikely, there is always the potential for an unexpected event. It is recommended that the development plan

includes a time-course monitoring program. If any development practices cause changes in physical-chemical parameters which lead to changes in environmental integrity, these effects could be quantified through time-series monitoring surveys. Such changes in water quality would be indicative of potential changes to marine community structure. Thus, any changes in water quality owing to shoreline development would trigger mitigative action, hopefully at a level below that capable of inducing change in biotic structure.

REFERENCES CITED

Dollar, S. J. 1979. Ecological response to relaxation of sewage stress off Sand Island, Oahu, Hawaii. Water Resources Research Center Tech. Rpt. No. 124. Water Resources Research Center, University of Hawaii.

Dollar, S. J. 1985. Environmental assessment of Hilo Bay: Marine biological community structure in the vicinity of the proposed Hilo sewage outfall extension. Prepared for M & E Pacific, Inc.

Dollar, S. J. and M. J. Atkinson. 1992. Effects of nutrient subsidies from groundwater to nearshore marine ecosystems off the Island of Hawaii. Est. Coast. Shelf Sci. 35:409-424.

Grasshoff, K. 1983. Methods of seawater analysis. Verlag Chemie, Weinheim, 419 pp.

Grigg, R. W. and S. J. Dollar. 1980. Environmental impact assessment of nearshore marine life at Princeville, Kauai, Hawaii. Prepared for Princeville Development Corporation.

Grigg, R. W. and S. J. Dollar. 1995. Environmental protection misapplied: alleged versus documented impacts of a deep ocean sewage outfall in Hawaii. Ambio 24:125-128.

Grigg, R. W. and J. E. Maragos. 1974. Recolonization of hermatypic corals on submerged lava flows in Hawaii. Ecology 55:387-395.

Henderson, R. S. 1992. Environmental conditions and sewage effects (or non-effects?) around Mokapu Peninsula, Oahu, Hawaii. Proceedings of the 7th Int. Coral Reef Symposium. Vol 1.

Hobson, E. S. 1974. Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii. Fishery Bull. 72:915-1031.

Kinzie, R. A. III and R. H. Snider. 1978. A simulation study of coral reef survey methods. In:Coral reefs: research methods. UNESCO, eds: D. R. Stoddart and R. E. Johannes.

Marine Research Consultants. 1995. Marine environmental monitoring in the vicinity of the East Honolulu Wastewater Treatment Facility Outfall. Report No. 94.

Nance, T. 1995. Potential impact on groundwater of the proposed golf course at Queen's Beach, Oahu, Hawaii. Prepared for Helber, Hastert & Fee.

Officer, C. B. 1979. Discussion of the behavior of nonconservative dissolved constituents in estuaries. Est. Coast. Mar. Sci. 9:569-576.

Russo, A. R., S. J. Dollar, and E. A. Kay. 1981. Benthic ecosystems and fish populations off the Mokapu outfall: a third postinstallation study. Water Resources Research Center Tech. Memo. 65. University of Hawaii. Honolulu, HI.

Smith, S. V. and M. J. Atkinson 1993. Mass balance analysis of C, N, and P fluxes in coastal water bodies, including lagoons. Coastal Lagoon Processes. (ed) B. Kjerfve, Elsevier Oceanography Series, 60. pp. 123-145.

Strickland J. D. H. and T. R. Parsons. 1968. A practical handbook of sea-water analysis. Fisheries Research Bd. of Canada, Bull. 167. 311 p.

Walker, W. J. 1995. Geochemistry, soil chemistry and potential chemical impacts from construction and maintenance of a proposed golf course: Queen's Beach, Oahu, Hawaii. Consultant report prepared for Helber, Hastert & Fee.

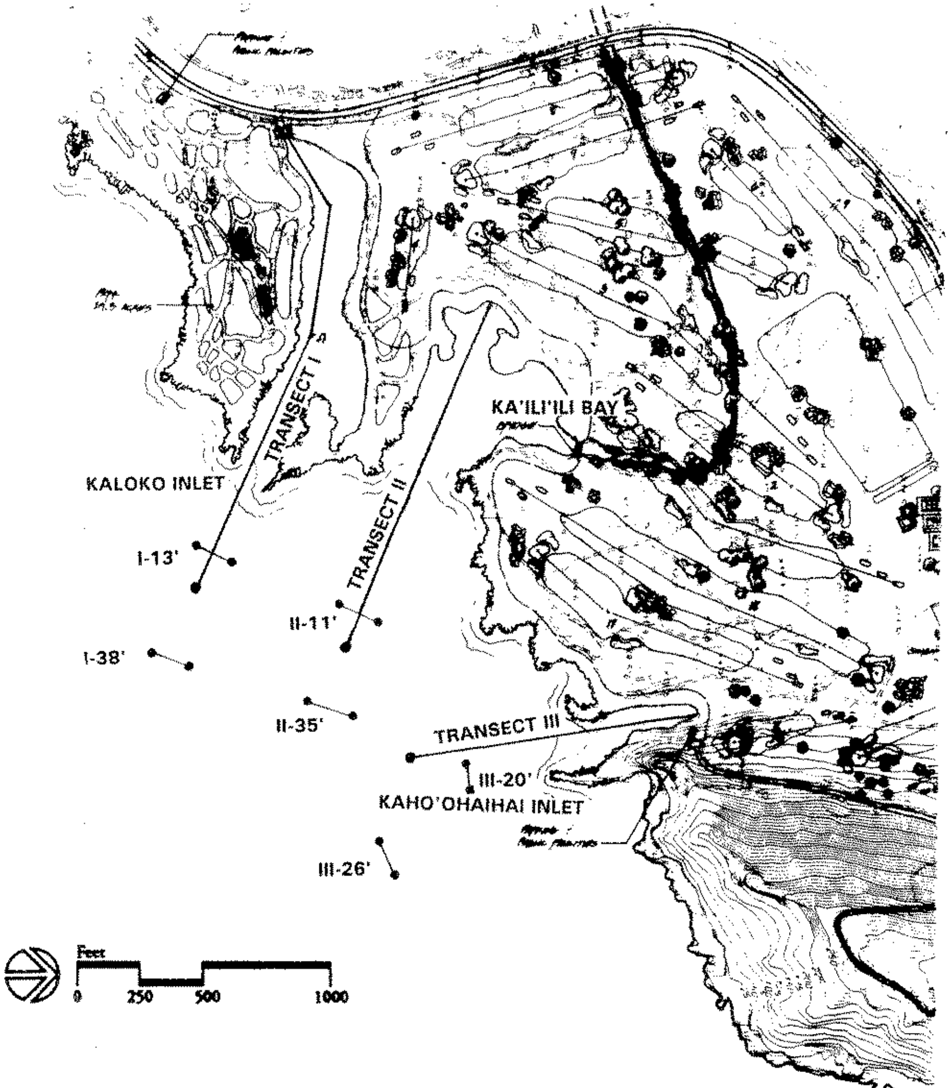


FIGURE 1. Map showing location of Queen's Beach area and location of three sampling transects that originate in the shoreline embayments and extend to the open ocean. Biological survey stations are indicated by transect number followed by depth (example: transect I at 26 feet = I-26').

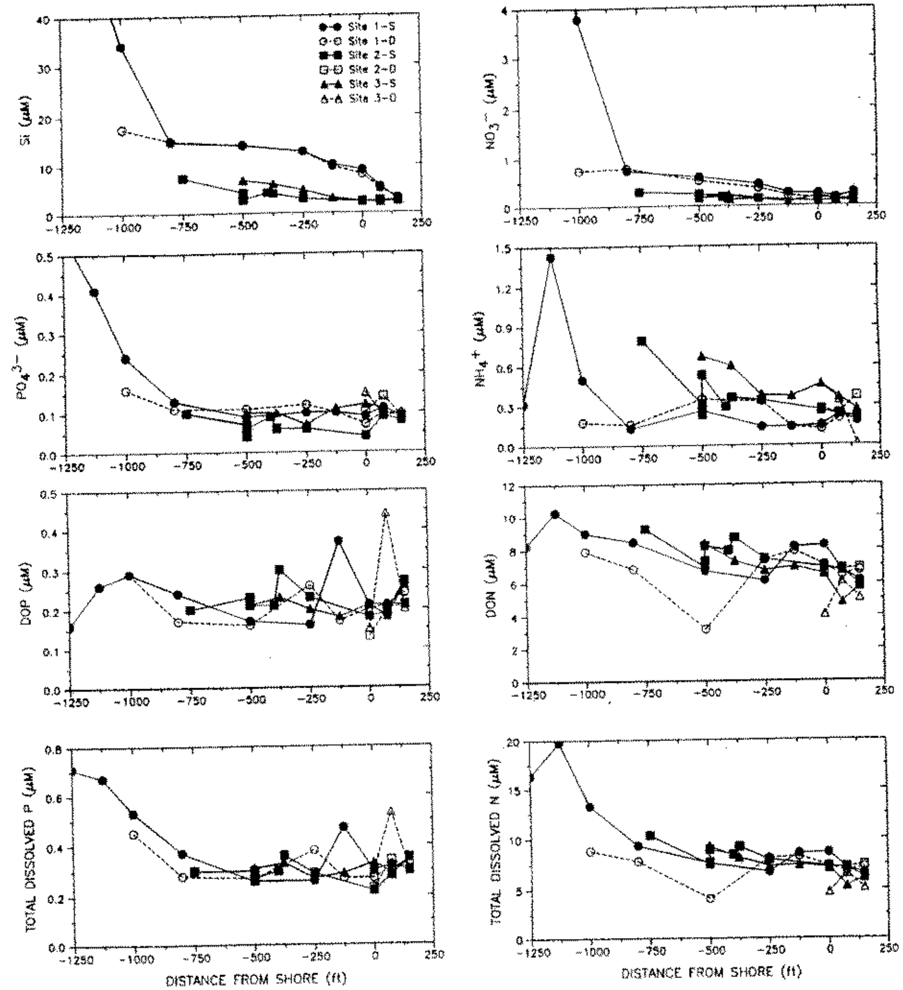


FIGURE 2. Plots of dissolved nutrient constituents from surface (S) and deep (D) samples at three sites in the vicinity of the Queen's Beach Golf Course project area collected in January 1995. Negative distances are distances landward from an imaginary shoreline drawn across the mouth of the inlets. For location of sites and stations, see Figure 1.

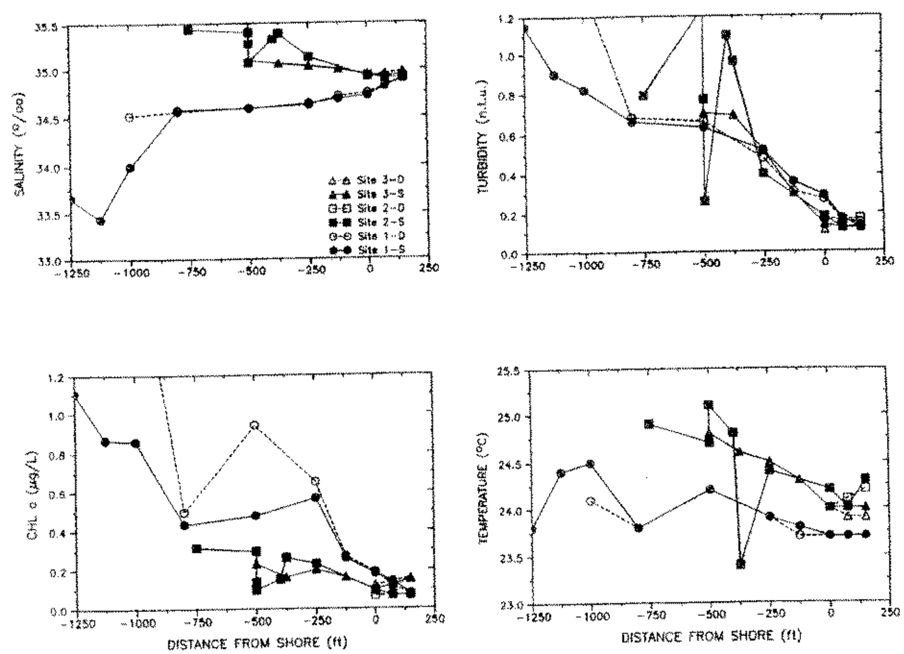


FIGURE 3. Plots of water chemistry constituents from surface (S) and deep (D) samples at three sites in the vicinity of the Queen's Beach Golf Course project area collected in January 1995. Negative distances are distances landward from an imaginary shoreline drawn across the mouth of the inlets. For location of sites and stations, see Figure 1.

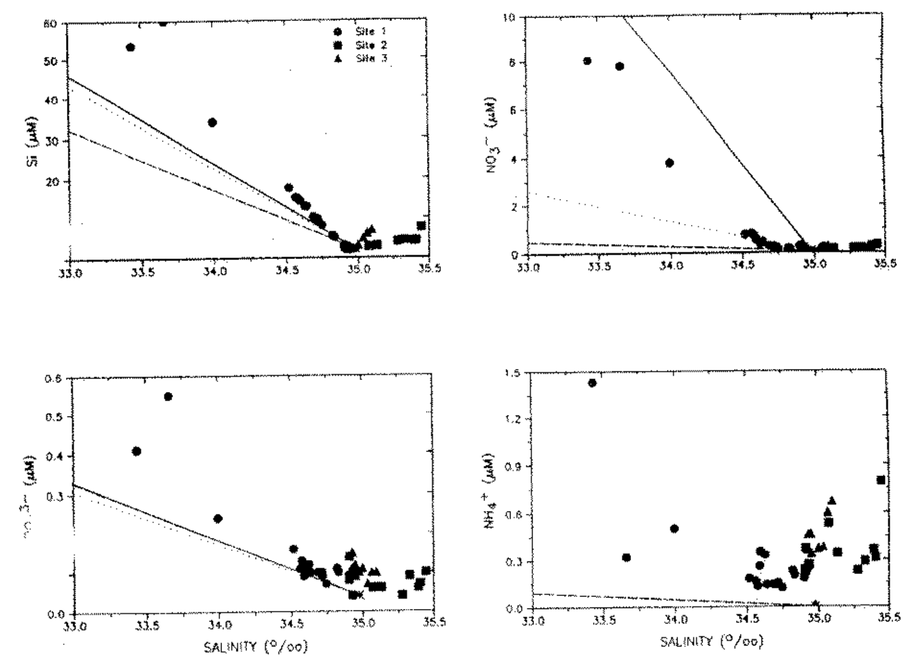


FIGURE 4. Plots of dissolved nutrients from all water samples collected in January 1995 at three sites in the vicinity of the Queen's Beach Golf Course project area as functions of salinity. Straight lines are conservative mixing lines constructed by connecting endpoint concentrations of open ocean water and well water from test wells located upslope of each sampling site (solid line = well upslope of Site 1; dashed line = well upslope of Site 2; dotted line = well upslope of Site 3). For site locations, see Figure 1.

TABLE 1. Water chemistry measurements from samples collected in the vicinity of the Queen's Beach Golf Course project area on January 4, 1995. Abbreviations as follows: DFS=distance from shore (negative values refer to distances landward from the mouth of inlets); S=surface; D=deep; BDL=below detection limit. Shaded values exceed DOH criteria for open coastal waters under "dry" conditions. For sampling site locations, see Figure 1.

SITE	NO.	DFS (ft)	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	DOP (µM)	DON (µM)	TDP (µM)	TDN (µM)	TURB (NTU)	SALINITY (o/oo)	CHL a (µg/L)	TEMP (deg.C)	pH
QB-1	1-S	-1250	0.55	7.78	0.32	59.98	0.16	8.25	0.71	16.35	1.15	33.660	1.11	23.8	7.93
	2-S	-1125	0.41	8.05	1.43	53.50	0.26	10.27	0.67	19.75	0.90	33.436	0.86	24.4	7.99
	3-S	-1000	0.24	3.78	0.50	34.02	0.29	9.00	0.53	13.28	0.82	33.994	0.86	24.5	8.06
	3-D	-1000	0.16	0.75	0.18	17.54	0.29	7.90	0.45	8.83	1.36	34.517	1.97	24.1	8.09
	4-S	-800	0.13	0.74	0.13	14.97	0.24	8.45	0.37	9.32	0.66	34.575	0.43	23.8	8.07
	4-D	-800	0.11	0.79	0.16	15.14	0.17	6.85	0.28	7.80	0.68	34.563	0.50	23.8	8.07
	5-S	-500	0.09	0.61	0.26	14.27	0.17	6.72	0.26	7.59	0.63	34.589	0.48	24.2	8.12
	5-D	-500	0.11	0.53	0.35	14.18	0.16	3.17	0.27	4.05	0.66	34.594	0.94	24.2	8.11
	6-S	-250	0.10	0.46	0.14	12.85	0.16	6.12	0.26	6.72	0.52	34.638	0.57	23.9	8.15
	6-D	-250	0.12	0.37	0.33	12.89	0.26	7.38	0.38	8.08	0.48	34.625	0.65	23.9	8.15
	7-S	-125	0.10	0.27	0.14	10.17	0.37	8.15	0.47	8.56	0.36	34.685	0.26	23.8	8.16
	7-D	-125	0.10	0.21	0.14	9.74	0.17	7.90	0.27	8.25	0.31	34.713	0.27	23.7	8.15
	8-S	0	0.09	0.25	0.15	9.04	0.21	8.24	0.30	8.64	0.29	34.718	0.18	23.7	8.16
	8-D	0	0.07	0.15	0.12	8.08	0.20	7.05	0.27	7.32	0.27	34.746	0.19	23.7	8.16
	9-S	75	0.11	0.17	0.23	5.48	0.21	6.75	0.32	7.15	0.17	34.818	0.14	23.7	8.15
	9-D	75	0.10	0.14	0.20	5.06	0.21	6.47	0.31	6.81	0.16	34.832	0.12	23.7	8.16
	10-S	150	0.09	0.25	0.18	2.78	0.21	6.12	0.30	6.55	0.12	34.899	0.08	23.7	8.17
	10-D	150	0.09	0.27	0.20	3.12	0.24	6.74	0.33	7.21	0.15	34.901	0.07	23.7	8.17
QB-2	1-S	-750	0.10	0.30	0.79	7.47	0.20	9.25	0.30	10.34	0.79	35.444	0.31	24.9	7.98
	2-S	-500	0.07	0.25	0.31	4.26	0.23	6.92	0.30	7.48	1.24	35.405	0.29	24.7	8.08
	3-S	-500	0.04	0.16	0.23	4.04	0.22	7.32	0.26	7.71	0.77	35.276	0.14	25.1	8.12
	4-S	-500	0.06	0.17	0.53	2.76	0.21	8.22	0.27	8.92	0.26	35.071	0.10	25.1	8.32
	5-S	-400	0.09	0.19	0.29	4.29	0.21	7.94	0.30	8.42	1.10	35.330	0.15	24.8	8.06
	6-S	-375	0.06	0.13	0.36	4.12	0.30	8.72	0.36	9.21	0.96	35.391	0.26	23.4	8.10
	7-S	-250	0.06	0.15	0.34	2.95	0.23	7.43	0.29	7.92	0.40	35.131	0.23	24.4	8.24
	8-S	0	0.04	0.08	0.26	2.33	0.18	6.92	0.22	7.26	0.18	34.928	0.09	24.2	8.27
	8-D	0	0.10	0.08	0.27	2.31	0.13	6.69	0.23	7.04	0.17	34.935	0.07	24.0	8.27
	9-S	75	0.09	0.10	0.23	2.41	0.19	6.76	0.28	7.09	0.12	34.915	0.07	24.0	8.24
	9-D	75	0.14	0.12	0.24	2.59	0.20	6.84	0.34	7.20	0.16	34.906	0.07	24.1	8.22
	10-S	150	0.08	0.14	0.21	2.53	0.27	5.89	0.35	6.24	0.13	34.905	0.07	24.3	8.20
	10-D	150	0.09	0.16	0.37	2.59	0.21	6.88	0.30	7.41	0.17	34.910	0.07	24.2	8.20
QB-3	1-S	-500	0.10	0.23	0.67	6.95	0.21	8.33	0.31	9.23	0.70	35.094	0.23	24.8	8.32
	2-S	-375	0.10	0.22	0.60	6.16	0.23	7.30	0.33	8.12	0.69	35.063	0.16	24.6	8.33
	3-S	-250	0.07	0.15	0.38	4.85	0.20	6.75	0.27	7.28	0.52	35.034	0.20	24.5	8.39
	4-S	-125	0.11	0.07	0.37	3.08	0.18	6.96	0.29	7.40	0.30	34.999	0.16	24.3	8.36
	5-S	0	0.12	0.20	0.46	2.43	0.21	6.52	0.33	7.18	0.14	34.946	0.10	24.0	8.17
	5-D	0	0.15	0.17	0.46	2.28	0.15	4.08	0.30	4.71	0.11	34.928	0.12	24.0	8.18
	6-S	75	0.11	0.13	0.36	2.17	0.18	4.82	0.29	5.31	0.12	34.923	0.12	24.0	8.16
	6-D	75	0.09	0.12	0.34	2.26	0.44	6.10	0.53	6.56	0.16	34.950	0.14	23.9	8.17
	7-S	150	0.09	0.09	0.27	2.46	0.26	5.75	0.35	6.11	0.12	34.940	0.15	24.0	8.17
	7-D	150	0.10	0.06	BDL	2.35	0.20	5.07	0.30	5.13	0.14	34.976	0.16	23.9	8.17
DOH WATER QUAL. STDS.															
NOT TO EXCEED 10%				0.71	0.36				0.96	12.86	0.50		0.50		
NOT TO EXCEED 2%				1.43	0.64				1.45	17.86	1.00		1.00		

TABLE 2. Water chemistry measurements (in µg/L) from samples collected in the vicinity of the Queen's Beach Golf Course project area on January 4, 1995. Abbreviations as follows: DFS=distance from shore (negative values refer to distances landward from the mouth of inlets); S=surface; D=deep; BDL=below detection limit. Shaded values exceed DOH criteria for open coastal waters under "dry" conditions. For sampling site locations, see Figure 1.

SITE	NO.	DFS (ft)	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	DOP (µg/L)	DON (µg/L)	TDP (µg/L)	TDN (µg/L)	TURB (NTU)	SALINITY (o/oo)	CHL a (µg/L)	TEMP (deg.C)	pH
QB-1	1-S	-1250	17.05	108.92	4.48	1685.4	4.96	115.50	22.01	228.90	1.15	33.660	1.11	23.80	7.93
	2-S	-1125	12.71	112.70	20.02	1503.4	8.06	143.78	20.77	276.50	0.90	33.436	0.86	24.40	7.99
	3-S	-1000	7.44	52.92	7.00	956.0	8.99	126.00	16.43	185.92	0.82	33.994	0.86	24.50	8.06
	3-D	-1000	4.96	10.50	2.52	492.9	8.99	110.60	13.95	123.62	1.36	34.517	1.97	24.10	8.09
	4-S	-800	4.03	10.36	1.82	420.7	7.44	118.30	11.47	130.48	0.66	34.575	0.43	23.80	8.07
	4-D	-800	3.41	11.06	2.24	425.4	5.27	95.90	8.68	109.20	0.68	34.563	0.50	23.80	8.07
	5-S	-500	2.79	8.54	3.64	401.0	5.27	94.08	8.06	106.26	0.63	34.589	0.48	24.20	8.12
	5-D	-500	3.41	7.42	4.90	398.5	4.96	44.38	8.37	56.70	0.66	34.594	0.94	24.20	8.11
	6-S	-250	3.10	6.44	1.96	361.1	4.96	85.68	8.06	94.08	0.52	34.638	0.57	23.90	8.15
	6-D	-250	3.72	5.18	4.62	362.2	8.06	103.32	11.78	113.12	0.48	34.625	0.65	23.90	8.15
	7-S	-125	3.10	3.78	1.96	285.8	11.47	114.10	14.57	119.84	0.36	34.685	0.26	23.80	8.16
	7-D	-125	3.10	2.94	1.96	273.7	5.27	110.60	8.37	115.50	0.31	34.713	0.27	23.70	8.15
	8-S	0	2.79	3.50	2.10	254.0	6.51	115.36	9.30	120.96	0.29	34.718	0.18	23.70	8.16
	8-D	0	2.17	2.10	1.68	227.0	6.20	98.70	8.37	102.48	0.27	34.746	0.19	23.70	8.16
	9-S	75	3.41	2.38	3.22	154.0	6.51	94.50	9.92	100.10	0.17	34.818	0.14	23.70	8.15
	9-D	75	3.10	1.96	2.80	142.2	6.51	90.58	9.61	95.34	0.16	34.832	0.12	23.70	8.16
	10-	150	2.79	3.50	2.52	78.1	6.51	85.68	9.30	91.70	0.12	34.899	0.08	23.70	8.17
	10-	150	2.79	3.78	2.80	87.7	7.44	94.36	10.23	100.94	0.15	34.901	0.07	23.70	8.17
QB-2	1-S	-750	3.10	4.20	11.06	209.9	6.20	129.50	9.30	144.76	0.79	35.444	0.31	24.90	7.98
	2-S	-500	2.17	3.50	4.34	119.7	7.13	96.88	9.30	104.72	1.24	35.405	0.29	24.70	8.08
	3-S	-500	1.24	2.24	3.22	113.5	6.82	102.48	8.06	107.94	0.77	35.276	0.14	25.10	8.12
	4-S	-500	1.86	2.38	7.42	77.6	6.51	115.08	8.37	124.88	0.26	35.071	0.10	25.10	8.32
	5-S	-400	2.79	2.66	4.06	120.5	6.51	111.16	9.30	117.88	1.10	35.330	0.15	24.80	8.06
	6-S	-375	1.86	1.82	5.04	115.8	9.30	122.08	11.16	128.94	0.96	35.391	0.26	23.40	8.10
	7-S	-250	1.86	2.10	4.76	82.9	7.13	104.02	8.99	110.88	0.40	35.131	0.23	24.40	8.24
	8-S	0	1.24	1.12	3.64	65.5	5.58	96.88	6.82	101.64	0.18	34.928	0.09	24.20	8.27
	8-D	0	3.10	1.12	3.78	64.9	4.03	93.66	7.13	98.56	0.17	34.935	0.07	24.00	8.27
	9-S	75	2.79	1.40	3.22	67.7	5.89	94.64	8.68	99.26	0.12	34.915	0.07	24.00	8.24
	9-D	75	4.34	1.68	3.36	72.8	6.20	95.76	10.54	100.80	0.16	34.906	0.07	24.10	8.22
	10-	150	2.48	1.96	2.94	71.1	8.37	82.46	10.85	87.36	0.13	34.905	0.07	24.30	8.20
	10-	150	2.79	2.24	5.18	72.8	6.51	96.32	9.30	103.74	0.17	34.910	0.07	24.20	8.20
QB-3	1-S	-500	3.10	3.22	9.38	195.3	6.51	116.62	9.61	129.22	0.70	35.094	0.23	24.80	8.32
	2-S	-375	3.10	3.08	8.40	173.1	7.13	102.20	10.23	113.68	0.69	35.063	0.16	24.60	8.33
	3-S	-250	2.17	2.10	5.32	136.3	6.20	94.50	8.37	101.92	0.52	35.034	0.20	24.50	8.39
	4-S	-125	3.41	0.98	5.18	86.5	5.58	97.44	8.99	103.60	0.30	34.999	0.16	24.30	8.36
	5-S	0	3.72	2.80	6.44	68.3	6.51	91.28	10.23	100.52	0.14	34.946	0.10	24.00	8.17
	5-D	0	4.65	2.38	6.44	64.1	4.65	57.12	9.30	65.94	0.11	34.928	0.12	24.00	8.18
	6-S	75	3.41	1.82	5.04	61.0	5.58	67.48	8.99	74.34	0.12	34.923	0.12	24.00	8.16
	6-D	75	2.79	1.68	4.76	63.5	13.64	85.40	16.43	91.84	0.16	34.950	0.14	23.90	8.17
	7-S	150	2.79	1.26	3.78	69.1	8.06	80.50	10.85	85.54	0.12	34.940	0.15	24.00	8.17
	7-D	150	3.10	0.84	BDL	66.0	6.20	70.98	9.30	71.82	0.14	34.976	0.16	23.90	8.17
DOH WATER QUAL. STDS.															
NOT TO EXCEED 10%				10.00	5.00				30.00	180.00	0.50		0.50		
NOT TO EXCEED 2%				20.00	9.00				45.00	250.00	1.00		1.00		

TABLE 7. Reef fish abundance on transects off the proposed Queens Beach Golf Course.

FAMILY / Species	TRANSECT I-13	I-38	II-11	II-35	III-20	III-26
MURAENIDAE						
Gymnothorax meleagris					1	
KYPHOSIDAE						
Kyphosus bigibbus		18				
CIRRHITIDAE						
Cirrhitus pinnulatus		1				
MULLIDAE						
Mulloides vanicolensis		18				
Parupeneus multifasciatus	3	12	2	3	3	6
P. bifasciatus		10				
P. cyclostomus					1	
CARANGIDAE						
Caranx melamphygus					1	
LUTJANIDAE						
Lutjanus kasmira		2				
LETHRINIDAE						
Monotaxis grandoculis		9				
CHAETODONTIDAE						
C. quadrimaculatus					2	
C. ornatissimus		2			2	
C. multicinctus				2		
Forcipiger flavissimus		2				
C. miliaris		8				
C. unimaculatus		2				
C. fremblii		2				
POMACANTHIDAE						
Abudefduf abdominalis	20					
Plectro. johnstonianus			2		2	2
P. imparipennis			3	1	1	
Stegastes fasciolatus			5		1	
Chromis vanderbilti			12		45	35
C. ovalis		20				3
LABRIDAE						
Bodianus bilunulatus					1	
Coris gaimard		2		2		1
C. flavovittata		2		2		
Thalassoma duperrey	5	17	9	11	17	8
T. ballieui		1				2
T. trilobatum	3		11			
Halichoeres ornatissimus					2	
SCARIDAE						
S. perspicillatus		2			1	
S. psittacus					2	2
S. rubroviolaceus		2				1
juvenile Scarus		8				12
ACANTHURIDAE						
Zebrasoma flavescens		17			8	8
Acanthurus triostegus	32				12	26
A. leucoparelus						16
A. olivaceus				12	30	15
A. blochii			2	6		12
A. nigrofuscus	19					15
Ctenochaetus strigosus		31				17
Naso lituratus		30				6
N. hexacanthus		100				
ZANCLIDAE						
Zanclus cornutus	2	3			1	1
BALISTIDAE						
Rhinecanthus rectangulus			1	3		
Sufflamen bursa		2		1	2	2
Melichthys vidula	2	15	3		3	6
BLENNIIDAE						
Plagiotremus goslinei					2	
NUMBER SPECIES	8	27	10	10	22	21
NUMBER INDIVIDUALS	86	338	60	43	140	194
SPECIES DIVERSITY	1.62	2.59	2.02	1.95	2.2	2.64

APPENDIX A. REEF CORAL TRANSECT DATA .

TRANSECT SITE: QUEENS GOLF COURSE
TRANSECT ID #: I-13'
DATE: 9/30/94

MEAN CORAL COVER 2.7
STD. DEV. 3.9
SPECIES COUNT 4
SPECIES DIVERSITY 0.97

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata		2					1	2			0.
Pocillopora meandrina	4	12		1		1					1.
Pavona duerdeni					2						0.
Montipora flabellata			2								0.
QUAD CORAL TOTAL	4	14	2	1	2	1	1	2	0	0	2.
Basalt	94	86	86	99	98	99	99	98	100	98	95.
Limestone	2		12							2	1
Sand											0.
Rubble											0.

TRANSECT SITE: QUEENS GOLF COURSE
TRANSECT ID #: I-38'
DATE: 9/30/94

MEAN CORAL COVER 22
STD. DEV. 4.4
SPECIES COUNT 5
SPECIES DIVERSITY 0.56

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata			3	2			1	4			1.
Pocillopora meandrina	15	15	14	24	26	24	21	18	17	16	19.
Montipora patula					2						0.
Pavona duerdeni	5		2			4			2		1.
Pavona tuberculosa		1		1		1			2		0.
QUAD CORAL TOTAL	20	16	19	27	28	29	22	22	21	16	22.
Basalt	68	73	54	36	53	47	65	33	75	46	55
Limestone	12	11	27	37	19	24	13	37	4	26	21
Sand								8		12	2
Rubble											0

TRANSECT SITE: QUEENS GOLF COURSE
TRANSECT ID #: II-11'
DATE: 9/30/94

MEAN CORAL COVER 11.8
STD. DEV. 6.6
SPECIES COUNT 5
SPECIES DIVERSITY 1.31

SPECIES	QUADRAT 1	2	3	4	5	6	7	8	9	10	SPECIES TOTAL
Porites lobata	1	10	6	5	2	2	6	1	2		3
Porites compressa										4	0
Pocillopora meandrina	2	8	4	15	10	8	5	1			5
Pavona duerdeni		4	4						1		0
Montipora flabellata		2	2			2	3	1	4	3	1
QUAD CORAL TOTAL	3	24	16	20	12	12	14	3	7	7	11
Basalt	95	55	60	77	86	85	73	96	90	90	82
Limestone	2		4	2	2	3	12	1	2	3	3
Sand											0
Rubble		21		1			1		1		2

TABLE 3. Water chemistry measurements (in µM and µg/L) from test wells in the vicinity of the Queen's Beach Golf Course project area sampled during January 1995. Each well was sampled at 3 depths. For well locations, see Figure 1.

WELL	DEPTH (ft)	PO4 (µM)	PO4 (µg/L)	NO3 (µM)	NO3 (µg/L)	NH4 (µM)	NH4 (µg/L)	Si (µM)	Si (µg/L)	DOP (µM)	DOP (µg/L)	DON (µM)	DON (µg/L)	TDP (µM)	TDP (µg/L)	TDN (µM)	TDN (µg/L)	TURB (NTU)	SALINITY (o/oo)
Q1	4	3.93	121.72	37.19	520.88	0.01	0.14	601	16878	0.14	4.34	11.56	161.91	4.07	126.06	48.76	682.93	0.24	6.112
	16	3.54	109.64	10.36	145.10	0.90	12.61	413	11608	0.24	7.43	9.87	138.24	3.78	117.08	21.13	295.95	3.60	15.067
	33	3.24	100.35	17.26	241.74	0.69	9.66	443	12442	0.21	6.50	9.25	129.56	3.45	106.86	27.20	380.96	6.10	15.149
Q2	10	4.16	128.85	0.79	11.06	2.82	39.50	339	9529	0.17	5.27	14.50	203.09	4.33	134.11	18.11	253.65	1.67	12.703
	33	3.39	105.00	0.31	4.34	5.64	78.99	312	8763	0.15	4.65	13.39	187.54	3.54	109.64	19.34	270.88	11.20	14.623
	40	3.28	101.59	0.28	3.92	9.59	134.32	316	8868	0.01	0.31	12.09	169.33	3.29	101.90	21.96	307.57	19.50	16.356
Q3	5	4.63	143.40	240.19	3364.10	0.03	0.42	695	19519	0.06	1.86	0.60	8.40	4.69	145.26	240.82	3372.92	0.34	3.686
	20	3.26	100.97	141.32	1979.33	0.01	0.14	672	18868	0.07	2.17	10.32	144.54	3.33	103.14	151.65	2124.01	0.16	10.251
	30	2.58	79.91	107.40	1504.24	0.31	4.34	661	18567	0.01	0.31	9.32	130.54	2.59	80.22	117.03	1639.12	0.12	18.666
Q4	3	4.49	139.07	6.68	93.56	1.45	20.31	468	13154	0.13	4.03	9.74	136.42	4.62	143.10	17.87	250.29	1.76	4.473
	15	3.22	99.73	2.65	37.12	4.40	61.63	393	11048	0.06	1.86	7.16	100.28	3.28	101.59	14.21	199.03	3.80	7.443
	22	2.36	73.10	6.82	95.52	8.20	114.85	363	10185	0.50	15.49	6.18	86.56	2.86	88.58	21.20	296.93	4.30	13.918

TABLE 4. Marine Invertebrate occurrence at transect stations off the proposed Queens Beach Golf Course.
For station locations, see Figure 1.
Abundance code: "R" = rare (0 - 5 individuals or colonies sited on station)
"O" = occasional (5 - 20 individuals or colonies sited on station)
"C" = common (more than 20 individuals or colonies sited on station)

	TRANSECT					
	I-13	I-38	II-11	II-35	III-20	III-26
SCLERACTINIA						
(Reef-Building Corals)						
Porites lobata	C	C	C	C	C	C
Porites compressa			R			
Porites brighami	R			R	R	
Pocillopora meandrina	C	C	C	C	C	C
Pocillopora eydouxi		R				
Montipora verrucosa	R	R	R	R	R	R
Montipora patula	O	R	O	C	C	C
Montipora flabellata	O	O	O	O	O	O
Leptastrea purpurea	R			R	R	
Cyphastra ocellina	R	R		R	R	
Pavona varians	R			R	O	O
Pavona duerdeni	C	C	C	C	C	C
Fungia scutaria					R	
ZOANTHINIARIA						
(Colonial "soft" corals)						
Palythoa tuberculosa	R	R	R	R	O	O
ALCYONACEA						
(Colonial "soft" corals)						
Anthelia edmondsoni	O	O	O	O	O	O
HOLOTHUROIDEA						
(Sea Cucumbers)						
Actinopyga obesa		R				
Holothuria atra	O	O	R	R	R	R
Holothuria nobilis	O	O	O		O	
ECHINOIDEA						
(Sea Urchins)						
Diadema paucispinum					R	
Echinothrix diadema	C	R	R	R	C	R
Echinothrix calamaris	R		R		R	
Tripneustes gratilla	C	C	O	O	O	C
Echinometra mathaei	C	C	C	C	C	C
Echinometra oblonga				O	R	R
Echinostrephus aciculatus	R		R	C	R	C
Heterocentrotus mammillatus	C	O	O	C	C	C
ASTEROIDEA						
(Starfish)						
Linckia multifora	R				R	
PORIFERA						
misc. sponges	C	C	C	C	C	C

APPENDIX A. continued.

TRANSECT SITE:	QUEENS GOLF COURSE					MEAN CORAL COVER				28.5
TRANSECT ID #:	II-35'					STD. DEV.				7.2
DATE:	9/30/94					SPECIES COUNT				6
						SPECIES DIVERSITY				0.79
SPECIES	QUADRAT									SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	22	12	24	12	21	36	21	11	21	24	20.4
Pocillopora meandrina	1							2	3	1	0.7
Montipora verrucosa						1					0.1
Montipora patula	16	16		10	4		13	3		5	6.7
Pavona duerdeni						4					0.4
Porites brighami			1					1			0.2
QUAD CORAL TOTAL	39	28	25	22	25	41	34	17	24	30	28.5
Basalt	60	70	71	76	75	57	62	83	73	69	69.6
Limestone		2	3	1		2	3		1	1	1.3
Sand	1		1	1			1		2		0.6
Rubble											0.0

TRANSECT SITE:	QUEENS GOLF COURSE					MEAN CORAL COVER				18.4
TRANSECT ID #:	III-20'					STD. DEV.				9.5
DATE:	9/30/94					SPECIES COUNT				6
						SPECIES DIVERSITY				1.10
SPECIES	QUADRAT									SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	13	12	14	4	12	8	24	1	14	22	12.4
Pocillopora meandrina	1	2	1	2							0.6
Montipora flabellata	4										0.4
Montipora patula			14								1.4
Pavona varians						12					1.2
Pavona duerdeni					10	14					2.4
QUAD CORAL TOTAL	18	14	29	6	22	34	24	1	14	22	18.4
Basalt	57	80	56	75	69	48	53	88	51	59	63.6
Limestone	1		3	4	3	6	1	3		4	2.5
Sand	24	2		15	6	12		8	35	15	11.7
Rubble		4	12				22				3.8

TRANSECT SITE:	QUEENS GOLF COURSE					MEAN CORAL COVER				27.1
TRANSECT ID #:	III-26'					STD. DEV.				9.9
DATE:	9/30/94					SPECIES COUNT				7
						SPECIES DIVERSITY				1.04
SPECIES	QUADRAT									SPECIES
	1	2	3	4	5	6	7	8	9	10	TOTAL
Porites lobata	25	10	45		8	22	24	21	8	12	17.5
Pocillopora meandrina	2	2		2	10			6		6	2.8
Pavona varians		4									0.4
Pavona duerdeni	2	14		15	12	13					5.6
Montipora patula								4			0.4
Montipora flabellata		1					2				0.3
Palythoa tuberculosa	1										0.1
QUAD CORAL TOTAL	30	31	45	17	30	35	26	31	8	18	27.1
Basalt	57	69	53	83	44	65	70	48	90	51	63.0
Limestone	1		2		1		4	6	2	6	2.2
Sand											0.0
Rubble	12				25			15		25	7.7

MARINE RESEARCH CONSULTANTS
4467 SIERRA DRIVE
HONOLULU, HI 96816
PHONE: 808-734-4009
FAX: 808-732-1813

September 5, 1996

Mr. Scott Ezer
Heiber Hastert & Fee
Grosvenor Center - PRI Tower
733 Bishop St., Suite 2590
Honolulu, HI 96813

RE: Baseline Pesticide Sampling for Queen's Beach Golf Course

Dear Scott:

Attached are the results for the baseline evaluation of golf course pesticides in the marine environment that may be influenced by the proposed Golf Course at Queen's Beach, Oahu, Hawaii. This baseline study provides information about the existing conditions of pesticide presence in the nearshore area that is the result of operation of the existing Hawaii Kai Golf Course. Such background information will be of great importance in addressing concerns about the potential impacts from the proposed Golf Course.

Analyses were conducted on six sediment samples; two samples from each of the inlets that occur on the site which were covered in my previous studies (Kaloko Inlet, Ka'ili'ili Bay, and Kaho'ohaihai Inlet)(see Figure 1 for sampling locations). As these inlet receive drainage water from upland areas, and have longer water and sediment residence times than open coastal areas, they should have the highest potential to contain residual pesticides. Sediments are chosen as the material to analyze rather than water, as the former is more likely to retain adsorbed chemical material.

Analyses were conducted by Associated Laboratories in Orange California (Lab. No. LL350-04). Analyses were conducted for a variety of biocides that are commonly used on golf courses in Hawaii, and may likely be used on the proposed course at Queen's Beach. These biocides include Roundup; active ingredient Isopropylamine salt of Glyphosate (EPA Method 547), the fungicide Daconil 2787 (active ingredient Chlorothalonil) (EPA Method 8080), Dursban (active ingredient Chlorpyrifos) (EPA Method 8140). As you can see from the results, that while these compounds are the target chemicals, the laboratory analyses methods also provide concentrations for many additional pesticides.

Analytical results indicate that none of the pesticides were detected in any of the samples. Such results indicate that at present, operation of the Hawaii Kai Golf Course and activities in the watershed that drain to the ocean off Queen's Beach do not appear to be contributing biocides to the marine environment.

Sincerely,

Steven Dollar, Ph.D.

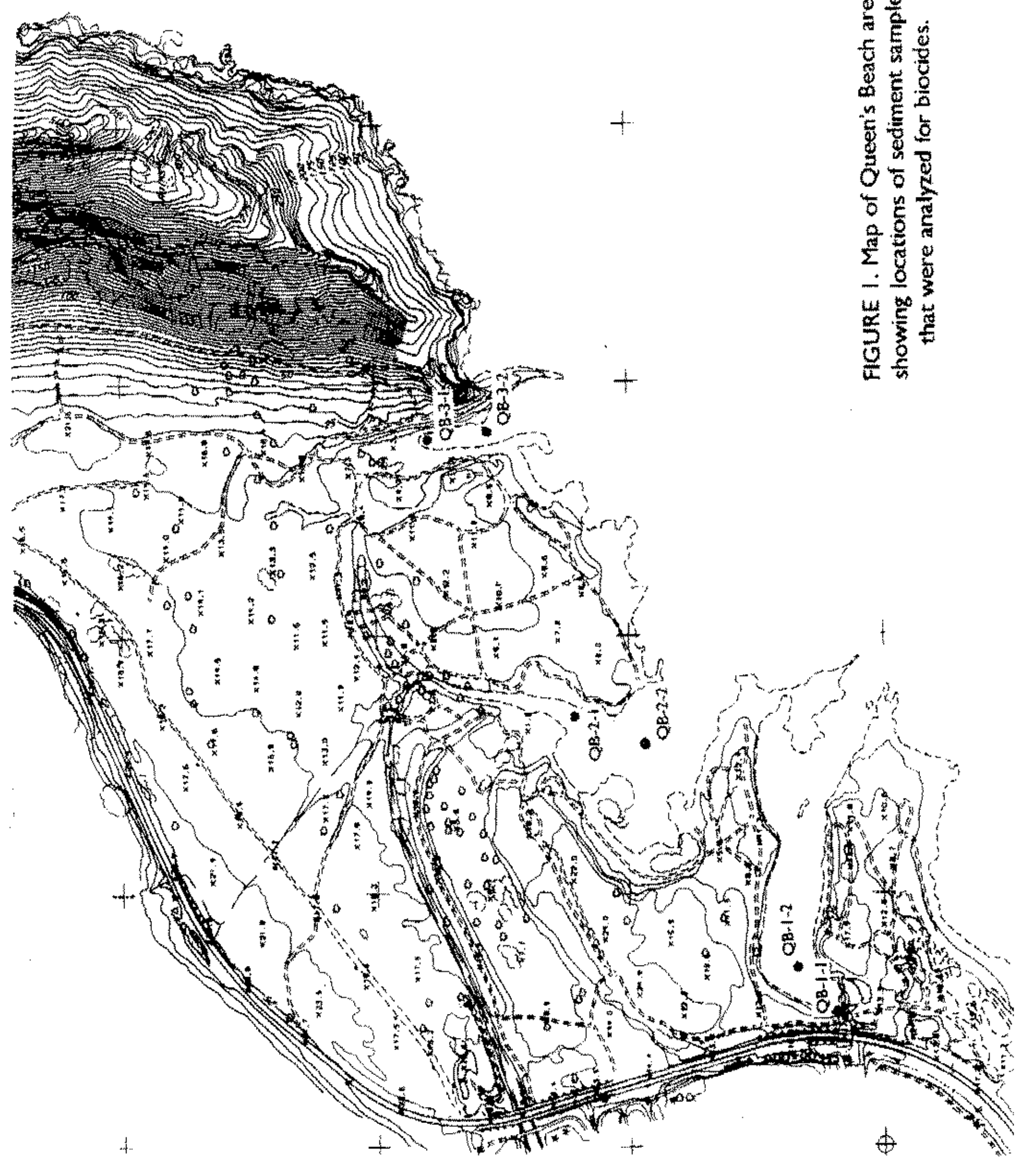


FIGURE 1. Map of Queen's Beach area showing locations of sediment samples that were analyzed for biocides.

ASSOCIATED LABORATORIES

806 North Batavia - Orange, California 92668 - 714/771-6900
FAX 714/538-1209

CLIENT
Marine Research Consultants (5188)
Attn: Steven Dollar
4467 Sierra Dr.
Honolulu, HI. 96816

LAB NO LL0350-04
REPORTED 08/28/96

SAMPLE Soil
RECEIVED 08/07/96

IDENTIFICATION **Sample # QB-1-1**
Date Collected 08/03/96

BASED ON SAMPLE **As Submitted**

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Glyphosate	08/21 SR	547	0.05	ND	mg/kg
Aldrin	08/15 SR	8080	0.002	ND	mg/kg
a - BHC	08/15 SR	8080	0.002	ND	mg/kg
b - BHC	08/15 SR	8080	0.003	ND	mg/kg
c - BHC (Lindane)	08/15 SR	8080	0.011	ND	mg/kg
d - BHC	08/15 SR	8080	0.005	ND	mg/kg
Chlordane	08/15 SR	8080	0.008	ND	mg/kg
Chlorothalonil	08/15 SR	8080	0.05	ND	mg/kg
4,4'-DDD	08/15 SR	8080	0.004	ND	mg/kg
4,4'-DDE	08/15 SR	8080	0.003	ND	mg/kg
4,4'-DDT	08/15 SR	8080	0.003	ND	mg/kg
Dieldrin	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan I	08/15 SR	8080	0.004	ND	mg/kg
Endosulfan II	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan Sulfate	08/15 SR	8080	0.003	ND	mg/kg
Endrin	08/15 SR	8080	0.004	ND	mg/kg
Endrin Aldehyde	08/15 SR	8080	0.004	ND	mg/kg
Heptachlor	08/15 SR	8080	0.002	ND	mg/kg
Heptachlor Epoxide	08/15 SR	8080	0.003	ND	mg/kg
Toxaphene	08/15 SR	8080	0.24	ND	mg/kg
PCB-1016	08/15 SR	8080	0.3	ND	mg/kg
PCB-1221	08/15 SR	8080	0.3	ND	mg/kg
PCB-1232	08/15 SR	8080	0.4	ND	mg/kg
PCB-1242	08/15 SR	8080	0.2	ND	mg/kg
PCB-1248	08/15 SR	8080	0.8	ND	mg/kg
PCB-1254	08/15 SR	8080	0.011	ND	mg/kg
PCB-1260	08/15 SR	8080	0.025	ND	mg/kg

Cont'd on Next page

Client: Marine Research Consultants
Lab No: LL0350-04

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Chlorpyrifos	08/13 SR	8140	0.05	ND	mg/kg
2,4-D	08/13 SR	8150	0.8	ND	mg/kg
2,4-DB	08/13 SR	8150	0.5	ND	mg/kg
2,4,5-T	08/13 SR	8150	0.1	ND	mg/kg
2,4,5-TP	08/13 SR	8150	0.1	ND	mg/kg
Dalapon	08/13 SR	8150	4.0	ND	mg/kg
Dicamba	08/13 SR	8150	0.2	ND	mg/kg
Dichloroprop	08/13 SR	8150	0.5	ND	mg/kg
Dinoseb	08/13 SR	8150	0.05	ND	mg/kg
MCPA	08/13 SR	8150	167.0	ND	mg/kg
MCPP	08/13 SR	8150	129.0	ND	mg/kg

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/04/96 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

ASSOCIATED LABORATORIES
806 North Batavia - Orange, California 92668 - 714/771-6900 **FAX 714/538-1209**

CLIENT
Marine Research Consultants (5188)
Attn: Steven Dollar
4467 Sierra Dr.
Honolulu, HI. 96816

LAB NO. LL0350-05
REPORTED 08/28/96
RECEIVED 08/07/96

SAMPLE Soil

IDENTIFICATION Sample # QB-1-2
Date Collected 08/03/96

BASED ON SAMPLE As Submitted

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Glyphosate	08/21 SR	547	0.05	ND	mg/kg
Aldrin	08/15 SR	8080	0.002	ND	mg/kg
a - BHC	08/15 SR	8080	0.002	ND	mg/kg
b - BHC	08/15 SR	8080	0.003	ND	mg/kg
c - BHC (Lindane)	08/15 SR	8080	0.011	ND	mg/kg
d - BHC	08/15 SR	8080	0.005	ND	mg/kg
Chlordane	08/15 SR	8080	0.008	ND	mg/kg
Chlorothalonil	08/15 SR	8080	0.05	ND	mg/kg
4,4'-DDD	08/15 SR	8080	0.004	ND	mg/kg
4,4'-DDE	08/15 SR	8080	0.003	ND	mg/kg
4,4'-DDT	08/15 SR	8080	0.003	ND	mg/kg
Dieldrin	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan I	08/15 SR	8080	0.004	ND	mg/kg
Endosulfan II	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan Sulfate	08/15 SR	8080	0.003	ND	mg/kg
Endrin	08/15 SR	8080	0.004	ND	mg/kg
Endrin Aldehyde	08/15 SR	8080	0.004	ND	mg/kg
Heptachlor	08/15 SR	8080	0.002	ND	mg/kg
Heptachlor Epoxide	08/15 SR	8080	0.003	ND	mg/kg
Toxaphene	08/15 SR	8080	0.24	ND	mg/kg
PCB-1016	08/15 SR	8080	0.3	ND	mg/kg
PCB-1221	08/15 SR	8080	0.3	ND	mg/kg
PCB-1232	08/15 SR	8080	0.4	ND	mg/kg
PCB-1242	08/15 SR	8080	0.2	ND	mg/kg
PCB-1248	08/15 SR	8080	0.8	ND	mg/kg
PCB-1254	08/15 SR	8080	0.011	ND	mg/kg
PCB-1260	08/15 SR	8080	0.025	ND	mg/kg

Cont'd on Next page

Client: Marine Research Consultants
Lab No: LL0350-05

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Chloropyrifos	08/13 SR	8140	0.05	ND	mg/kg
2,4-D	08/13 SR	8150	0.8	ND	mg/kg
2,4-DB	08/13 SR	8150	0.5	ND	mg/kg
2,4,5-T	08/13 SR	8150	0.1	ND	mg/kg
2,4,5-TP	08/13 SR	8150	0.1	ND	mg/kg
Dalapon	08/13 SR	8150	4.0	ND	mg/kg
Dicamba	08/13 SR	8150	0.2	ND	mg/kg
Dichloroprop	08/13 SR	8150	0.5	ND	mg/kg
Dinoseb	08/13 SR	8150	0.05	ND	mg/kg
MCPA	08/13 SR	8150	167.0	ND	mg/kg
MCPP	08/13 SR	8150	129.0	ND	mg/kg

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/04/96 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

ASSOCIATED LABORATORIES

806 North Batavia · Orange, California 92668 · 714/771-6900
FAX 714/538-1209

CLIENT
Marine Research Consultants (5188)
Attn: Steven Dollar
4467 Sierra Dr.
Honolulu, HI. 96816

LAB NO. LL0350-06
REPORTED 08/28/96

SAMPLE Soil
RECEIVED 08/07/96

IDENTIFICATION Sample # QB-2-1
Date Collected 08/03/96
BASED ON SAMPLE As Submitted

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Glyphosate	08/21 SR	547	0.05	ND	mg/kg
Aldrin	08/15 SR	8080	0.002	ND	mg/kg
a - BHC	08/15 SR	8080	0.002	ND	mg/kg
b - BHC	08/15 SR	8080	0.003	ND	mg/kg
c - BHC (Lindane)	08/15 SR	8080	0.011	ND	mg/kg
d - BHC	08/15 SR	8080	0.005	ND	mg/kg
Chlordane	08/15 SR	8080	0.008	ND	mg/kg
Chlorothalonil	08/15 SR	8080	0.05	ND	mg/kg
4,4'-DDD	08/15 SR	8080	0.004	ND	mg/kg
4,4'-DDE	08/15 SR	8080	0.003	ND	mg/kg
4,4'-DDT	08/15 SR	8080	0.003	ND	mg/kg
Dieldrin	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan I	08/15 SR	8080	0.004	ND	mg/kg
Endosulfan II	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan Sulfate	08/15 SR	8080	0.003	ND	mg/kg
Endrin	08/15 SR	8080	0.004	ND	mg/kg
Endrin Aldehyde	08/15 SR	8080	0.004	ND	mg/kg
Heptachlor	08/15 SR	8080	0.002	ND	mg/kg
Heptachlor Epoxide	08/15 SR	8080	0.003	ND	mg/kg
Toxaphene	08/15 SR	8080	0.24	ND	mg/kg
PCB-1016	08/15 SR	8080	0.3	ND	mg/kg
PCB-1221	08/15 SR	8080	0.3	ND	mg/kg
PCB-1232	08/15 SR	8080	0.4	ND	mg/kg
PCB-1242	08/15 SR	8080	0.2	ND	mg/kg
PCB-1248	08/15 SR	8080	0.8	ND	mg/kg
PCB-1254	08/15 SR	8080	0.011	ND	mg/kg
PCB-1260	08/15 SR	8080	0.025	ND	mg/kg

Cont'd on Next page

TESTING & CONSULTING
Chemical ·
Microbiological ·
Environmental ·

C-1 10M

Client: Marine Research Consultants
Lab No: LL0350-06

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Chlorpyrifos	08/13 SR	8140	0.05	ND	mg/kg
2,4-D	08/13 SR	8150	0.8	ND	mg/kg
2,4-DB	08/13 SR	8150	0.5	ND	mg/kg
2,4,5-T	08/13 SR	8150	0.1	ND	mg/kg
2,4,5-TP	08/13 SR	8150	0.1	ND	mg/kg
Dalapon	08/13 SR	8150	4.0	ND	mg/kg
Dicamba	08/13 SR	8150	0.2	ND	mg/kg
Dichloroprop	08/13 SR	8150	0.5	ND	mg/kg
Dinoseb	08/13 SR	8150	0.05	ND	mg/kg
MCPA	08/13 SR	8150	167.0	ND	mg/kg
MCPP	08/13 SR	8150	129.0	ND	mg/kg

ASSOCIATED LABORATORIES, by:
Robert A. Webber
Vice President

RAW/gk

Rev. 09/04/96 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

ASSOCIATED LABORATORIES
806 North Batavia - Orange, California 92868 · 714/771-6900
FAX 714/538-1209

CLIENT

Marine Research Consultants (5188)
Attn: Steven Dollar
4467 Sierra Dr.
Honolulu, HI. 96816

LAB NO LL0350-07
REPORTED 08/28/96

SAMPLE Soil

RECEIVED 08/07/96

IDENTIFICATION Sample # QB-2-2

BASED ON SAMPLE Date Collected 08/03/96
As Submitted

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Glyphosate	08/21 SR	547	0.05	ND	mg/kg
Aldrin	08/15 SR	8080	0.002	ND	mg/kg
a - BHC	08/15 SR	8080	0.002	ND	mg/kg
b - BHC	08/15 SR	8080	0.003	ND	mg/kg
c - BHC (Lindane)	08/15 SR	8080	0.011	ND	mg/kg
d - BHC	08/15 SR	8080	0.005	ND	mg/kg
Chlordane	08/15 SR	8080	0.008	ND	mg/kg
Chlorothalonil	08/15 SR	8080	0.05	ND	mg/kg
4,4'-DDE	08/15 SR	8080	0.003	ND	mg/kg
4,4'-DDT	08/15 SR	8080	0.003	ND	mg/kg
Dieldrin	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan I	08/15 SR	8080	0.004	ND	mg/kg
Endosulfan II	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan Sulfate	08/15 SR	8080	0.003	ND	mg/kg
Endrin	08/15 SR	8080	0.004	ND	mg/kg
Endrin Aldehyde	08/15 SR	8080	0.004	ND	mg/kg
Heptachlor	08/15 SR	8080	0.002	ND	mg/kg
Heptachlor Epoxide	08/15 SR	8080	0.003	ND	mg/kg
Toxaphene	08/15 SR	8080	0.24	ND	mg/kg
PCB-1016	08/15 SR	8080	0.3	ND	mg/kg
PCB-1221	08/15 SR	8080	0.3	ND	mg/kg
PCB-1232	08/15 SR	8080	0.4	ND	mg/kg
PCB-1242	08/15 SR	8080	0.2	ND	mg/kg
PCB-1248	08/15 SR	8080	0.8	ND	mg/kg
PCB-1254	08/15 SR	8080	0.011	ND	mg/kg
PCB-1260	08/15 SR	8080	0.025	ND	mg/kg

Cont'd on Next page

TESTING & CONSULTING
Chemical ·
Microbiological ·
Environmental ·

C-1 10M

Client: Marine Research Consultants
Lab No: LL0350-07

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Chlorpyrifos	08/13 SR	8140	0.05	ND	mg/kg
2,4-D	08/13 SR	8150	0.8	ND	mg/kg
2,4-DB	08/13 SR	8150	0.5	ND	mg/kg
2,4,5-T	08/13 SR	8150	0.1	ND	mg/kg
2,4,5-TP	08/13 SR	8150	0.1	ND	mg/kg
Dalapon	08/13 SR	8150	4.0	ND	mg/kg
Dicamba	08/13 SR	8150	0.2	ND	mg/kg
Dichloroprop	08/13 SR	8150	0.5	ND	mg/kg
Dinoseb	08/13 SR	8150	0.05	ND	mg/kg
MCPA	08/13 SR	8150	167.0	ND	mg/kg
MCPP	08/13 SR	8150	129.0	ND	mg/kg

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/04/96 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

ASSOCIATED LABORATORIES

806 North Batavia · Orange, California 92868 · 714/771-6900 FAX 714/538-1209

CLIENT

Marine Research Consultants (5188)
Attn: Steven Dollar
4467 Sierra Dr.
Honolulu, HI. 96816

LAB NO LL0350-08

REPORTED 08/28/96

SAMPLE Soil

RECEIVED 08/07/96

IDENTIFICATION **Sample # QB-3-1**

BASED ON SAMPLE Date Collected 08/03/96
As Submitted

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Glyphosate	08/21 SR	547	0.05	ND	mg/kg
Aldrin	08/15 SR	8080	0.002	ND	mg/kg
a - BHC	08/15 SR	8080	0.002	ND	mg/kg
b - BHC	08/15 SR	8080	0.003	ND	mg/kg
c - BHC (Lindane)	08/15 SR	8080	0.011	ND	mg/kg
d - BHC	08/15 SR	8080	0.005	ND	mg/kg
Chlordane	08/15 SR	8080	0.008	ND	mg/kg
Chlorothalonil	08/15 SR	8080	0.05	ND	mg/kg
4,4'-DDD	08/15 SR	8080	0.004	ND	mg/kg
4,4'-DDE	08/15 SR	8080	0.003	ND	mg/kg
4,4'-DDT	08/15 SR	8080	0.003	ND	mg/kg
Dieldrin	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan I	08/15 SR	8080	0.004	ND	mg/kg
Endosulfan II	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan Sulfate	08/15 SR	8080	0.003	ND	mg/kg
Endrin	08/15 SR	8080	0.004	ND	mg/kg
Endrin Aldehyde	08/15 SR	8080	0.004	ND	mg/kg
Heptachlor	08/15 SR	8080	0.002	ND	mg/kg
Heptachlor Epoxide	08/15 SR	8080	0.003	ND	mg/kg
Toxaphene	08/15 SR	8080	0.24	ND	mg/kg
PCB-1016	08/15 SR	8080	0.3	ND	mg/kg
PCB-1221	08/15 SR	8080	0.3	ND	mg/kg
PCB-1232	08/15 SR	8080	0.4	ND	mg/kg
PCB-1242	08/15 SR	8080	0.2	ND	mg/kg
PCB-1248	08/15 SR	8080	0.8	ND	mg/kg
PCB-1254	08/15 SR	8080	0.011	ND	mg/kg
PCB-1260	08/15 SR	8080	0.025	ND	mg/kg

Cont'd on Next page

Client: Marine Research Consultants
Lab No: LL0350-08

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Chlorpyrifos	08/13 SR	8140	0.05	ND	mg/kg
2,4-D	08/13 SR	8150	0.8	ND	mg/kg
2,4-DB	08/13 SR	8150	0.5	ND	mg/kg
2,4,5-T	08/13 SR	8150	0.1	ND	mg/kg
2,4,5-TP	08/13 SR	8150	0.1	ND	mg/kg
Dalapon	08/13 SR	8150	4.0	ND	mg/kg
Dicamba	08/13 SR	8150	0.2	ND	mg/kg
Dichloroprop	08/13 SR	8150	0.5	ND	mg/kg
Dinoseb	08/13 SR	8150	0.05	ND	mg/kg
MCPA	08/13 SR	8150	167.0	ND	mg/kg
MCPP	08/13 SR	8150	129.0	ND	mg/kg

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/04/96 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

ASSOCIATED LABORATORIES

806 North Batavia · Orange, California 92668 · 714/771-6900 FAX 714/538-1209

CLIENT

Marine Research Consultants (5188)
Attn: Steven Dollar
4467 Sierra Dr.
Honolulu, HI. 96816

LAB NO. LL0350-09
REPORTED 08/28/96

SAMPLE Soil

RECEIVED 08/07/96

IDENTIFICATION Sample # QB-3-2 *

BASED ON SAMPLE Date Collected 08/03/96
As Submitted

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Glyphosate	08/21 SR	547	0.05	ND	mg/kg
Aldrin	08/15 SR	8080	0.002	ND	mg/kg
a - BHC	08/15 SR	8080	0.002	ND	mg/kg
b - BHC	08/15 SR	8080	0.003	ND	mg/kg
c - BHC (Lindane)	08/15 SR	8080	0.011	ND	mg/kg
d - BHC	08/15 SR	8080	0.005	ND	mg/kg
Chlordane	08/15 SR	8080	0.008	ND	mg/kg
Chlorothalonil	08/15 SR	8080	0.05	ND	mg/kg
4,4'-DDD	08/15 SR	8080	0.004	ND	mg/kg
4,4'-DDE	08/15 SR	8080	0.003	ND	mg/kg
4,4'-DDT	08/15 SR	8080	0.003	ND	mg/kg
Dieldrin	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan I	08/15 SR	8080	0.004	ND	mg/kg
Endosulfan II	08/15 SR	8080	0.003	ND	mg/kg
Endosulfan Sulfate	08/15 SR	8080	0.003	ND	mg/kg
Endrin	08/15 SR	8080	0.004	ND	mg/kg
Endrin Aldehyde	08/15 SR	8080	0.004	ND	mg/kg
Heptachlor	08/15 SR	8080	0.002	ND	mg/kg
Heptachlor Epoxide	08/15 SR	8080	0.003	ND	mg/kg
Toxaphene	08/15 SR	8080	0.24	ND	mg/kg
PCB-1016	08/15 SR	8080	0.3	ND	mg/kg
PCB-1221	08/15 SR	8080	0.3	ND	mg/kg
PCB-1232	08/15 SR	8080	0.4	ND	mg/kg
PCB-1242	08/15 SR	8080	0.2	ND	mg/kg
PCB-1248	08/15 SR	8080	0.8	ND	mg/kg
PCB-1254	08/15 SR	8080	0.011	ND	mg/kg
PCB-1260	08/15 SR	8080	0.025	ND	mg/kg

Cont'd on Next page

Client: Marine Research Consultants
Lab No: LL0350-09

Constituent	Date/ Analyst	EPA Method	Method Detection Limit	Results	
Chlorpyrifos	08/13 SR	8140	0.05	ND	mg/kg
2,4-D	08/13 SR	8150	0.8	ND	mg/kg
2,4-DB	08/13 SR	8150	0.5	ND	mg/kg
2,4,5-T	08/13 SR	8150	0.1	ND	mg/kg
2,4,5-TP	08/13 SR	8150	0.1	ND	mg/kg
Dalapon	08/13 SR	8150	4.0	ND	mg/kg
Dicamba	08/13 SR	8150	0.2	ND	mg/kg
Dichloroprop	08/13 SR	8150	0.5	ND	mg/kg
Dinoseb	08/13 SR	8150	0.05	ND	mg/kg
MCPA	08/13 SR	8150	167.0	ND	mg/kg
MCPP	08/13 SR	8150	129.0	ND	mg/kg

* Sample Container Cracked

ASSOCIATED LABORATORIES, by:

Robert A. Webber
Vice President

RAW/gk

Rev. 09/04/96 RAW/gk

NOTE: Unless notified in writing, all samples will be discarded by appropriate disposal protocol 30 days from date reported.

TABLE 5. Coral species percent cover, non-coral substrata cover, and coral community statistics from transect surveys off the proposed Queens Beach Golf Course site conducted in September 1994. For transect locations, see Figure 1.

CORAL SPECIES	TRANSECT I-13	I-38	II-11	II-35	III-20	III-26
Porites lobata	0.5	1.0	3.5	20.4	12.4	17.5
Porites compressa			0.4			
Pocillopora meandrina	1.8	19.0	5.3	0.7	0.6	2.8
Montipora patula		0.2		6.7	1.4	0.4
Montipora verrucosa				0.1		
Pavona varians					1.2	0.4
Pavona duerdeni	0.2	1.3	0.9	0.4	2.4	5.6
Palythoa tuberculosa		0.5				0.1
Montipora flabellata	0.2		1.7		0.4	0.3
Porites brighami				0.2		
TOTAL CORAL COVER (%)	2.7	22.0	11.8	28.5	18.4	27.1
NUMBER OF SPECIES	4	5	5	6	6	7
CORAL COVER DIVERSITY	0.968	0.562	1.31	0.785	1.1	1.037
NON-CORAL SUBSTRATA						
Limestone	1.6	21.0	3.1	5.6	2.5	2.2
Sand		2.0			11.7	
Basalt	95.7	55.0	82.7	76.6	63.6	63.0
Rubble			2.4		3.8	7.7

TABLE 6. Reef fish abundance on transects off the proposed Queens Beach Golf Course.

FAMILY Species	TRANSECT I-13	I-38	II-11	II-35	III-20	III-26
MURAENIDAE						
Gymnothorax meleagris					1	
KYPHOSIDAE						
Kyphosus bigibbus		16				
CIRRHITIDAE						
Cirrhitus pinnulatus		1				
MULLIDAE						
Mulloides vanicolensis		16				
Parupeneus multifasciatus	3	12	2	3	3	6
P. bifasciatus		10				
P. cyclostomus					1	
CARANGIDAE						
Caranx melamphygus					1	
LUTJANIDAE						
Lutjanus kasmira		2				
LETHRINIDAE						
Monotaxis grandoculis		9				
CHAETODONTIDAE						
C. quadrimaculatus					2	
C. ornatissimus		2			2	
C. multicinctus				2		
Forcipiger flavissimus		2				
C. miliaris		8				
C. unimaculatus		2				
C. fremblii		2				
POMACANTHIDAE						
Abudefduf abdominalis	20					
Plectro. johnstonianus			2		2	2
P. imparipennis			3	1	1	
Stegastes fasciolatus			5		1	
Chromis vanderbilti			12		45	35
C. ovalis		20				3
LABRIDAE						
Bodianus bilunulatus					1	
Coris gaimard		2		2		1
C. flavovittata		2		2		
Thalassoma duperrey	5	17	9	11	17	8
T. ballieui		1				2
T. trilobatum	3		11			
Halichoeres ornatissimus					2	
SCARIDAE						
S. perspicillatus		2			1	
S. psittacus					2	2
S. rubroviolaceus		2				1
juvenile Scarus		8				12
ACANTHURIDAE						
Zebrasoma flavescens		17			8	8
Acanthurus triostegus	32				12	25
A. leucopareius						15
A. olivaceus				12	30	15
A. blochii			2	6		12
A. nigrofuscus	19					15
Ctenochaetus strigosus		31				17
Naso lituratus		30				6
N. hexacanthus		100				
ZANCLIDAE						
Zanclus cornutus	2	3			1	1
BALISTIDAE						
Rhinecanthus rectangulus			1	3		
Sufflamen bursa		2		1	2	2
Melichthys vidula	2	15	3		3	6
BLENNIIDAE						
Plagiotremus goslinei					2	
NUMBER SPECIES	8	27	10	10	22	21
NUMBER INDIVIDUALS	86	338	60	43	140	194
SPECIES DIVERSITY	1.62	2.59	2.02	1.95	2.2	2.64

QUEEN'S BEACH GOLF COURSE

Appendix

C

Geochemistry, Soil Chemistry and Potential Chemical Impacts from Construction and Maintenance of a Proposed Golf Course at Queen's Beach

(William J. Walker, Ph.D.)

GEOCHEMISTRY, SOIL CHEMISTRY AND POTENTIAL CHEMICAL IMPACTS FROM CONSTRUCTION AND MAINTENANCE OF A PROPOSED GOLF COURSE: QUEEN'S BEACH, OAHU, HAWAII

April 10, 1995

Prepared for:

Helber Hastert and Fee, Planners
733 Bishop Street, Suite 2590
Honolulu, Hawaii 96813

Prepared by:

William J. Walker, Ph.D.
Environmental Chemistry
530 21st. Street
Sacramento, CA 95814

EXECUTIVE SUMMARY

1.0 Introduction

This report is prepared in preparation for, and in support of, an overall Environmental Impact Report (EIR) for a proposed golf course at Queen's Beach, Oahu, Hawaii. This portion of the study focuses on the potential chemical impacts from the proposed golf course.

The purpose of this phase of the EIR is to accurately assess the potential chemical impacts of a golf course in the proposed development area. The report presents the assessment of numerous impacts anticipated at the site. Some of the major issues addressed in the report, on a site specific basis include:

1. Leaching and runoff losses of nutrients and pesticides from the golf course during construction and after turfgrass establishment;
2. Use of effluent water for irrigation, and water re-use issues;
3. Degradation of surface and groundwater quality resulting from application of pesticides and fertilizers; and
4. The basis of design of an Integrated Turf Management System (TMS) for controlling chemical impacts at the site.

2.0 Methods and Materials

The study was designed to address the following concerns. The methods used to address each element are noted. The reader is referred to the corresponding section of the report for detail.

1. Site Backgound Description: A site visit was conducted to assess the degree of accuracy of previously published information concerning the soils and geology of the area.

2. Soils and Groundwater Investigation: Soil samples and groundwater samples were collected and analyzed to establish background conditions and to provide a basis for assessing potential chemical impact to soil and water quality.

3. Turfgrass Selection: This was based on the scientific literature reviews of turfgrass appropriate for the site conditions.

4. Effect of Nutient and Pesticide Application on Soils, Surface Water and Groundwater Quality: Chemical impact to soils and water quality was assessed by the use of laboratory column studies and on simulations of chemical loss under worst case scenarios.

5. Effect of Wastewater Effluent Use on Groundwater Quality: The impact of water reuse at the site was explored by collection of effluent samples, analysis of samples and simulation/calculations for assessment of possible soil or water quality degredation.

3.0 KEY FINDINGS

3.1 Background Information: Soils and Groundwater

- The predominant soils of the site are of the LuA series (90% of the site) and are composed of clay and clay-rock mixtures. The clays are primarily montmorillonite which exhibit high shrink-swell capacity. The clays will likely provide a significant barrier to subsurface transport of chemicals (and water) due to the very fine texture of the soils and the low permeability. The low permeability of the soils will be a benefit for subsurface movement but may enhance surface runoff transport processes.

- The composition of groundwater is presented below:

pH	7.4		
Ca	4.59	mmol/L	183 mg/l
Mg	8.00	"	192 mg/l
Na	56.5	"	1695 mg/l
K	1.10	"	35 mg/l
NO_3	0.29	"	18.6 mg/l
SO_4	4.52	"	415 mg/l
Cl	55.9	"	2145 mg/l

As noted, the water is near saline in composition as would be expected in this near marine shore environment.

3.2 Candidate Pesticide and Turfgrass Selection

- Other golf courses in the area (specifically Hawaii Kai Golf Course) have noted the use of several common turfgrass pesticides. Insect infestations are not a common problem in the area and as such insecticides are only used occasionally. The main herbicide used at Hawaii Kai (and in Hawaii) is MSMA; primarily for the control of broadleaf grasses and weeds such as goosegrass and crabgrass. The use of MSMA is not recommended, but was included due to its wide use in Hawaii. The pestides chosen, excluding MSMA, are:

Pesticide	Ks (days-1)	Half-life (days)	Persistence Class
Chlorpyrifos	0.017-0.046	15-42	2-4
Chlorothalonil	0.008-0.05	14-90	2-4
2,4-D	0.023-0.139	5-30	3-4
MSMA	0.001	1000	1
Dicamba	0.02-0.214	3-35	2-5

- Of the different potential warm season grasses, it is likely that the best candidates for the proposed golf course at the site would be bermudagrass for greens and Zoysiagrass for fairways.

3.3 Use of Effluent Water for Golf Course Irrigation

- Analysis of effluent water from a nearby waste water treatment plant showed several important and unexpected results. First, the salt content of the effluent is extremely saline. In fact, the composition of the water from the treatment plant is almost identical to the groundwater samples collected at the site which are "brackish" to near seawater in composition. The high salinity of the wastewater suggests that a salt tolerant turfgrass will be a requirement for at least the fairways. In addition, the Cl content of the samples is in excess of 2000 mg/L. This is substantially higher than can be tolerated by bermudagrass. Thus, irrigation of the greens will likely require blending wastewater with domestic water source to bring the Cl content near to 800 mg/l, a level that can be tolerated by bermudagrass. Finally, the high Na content of the effluent water may adversely affect soil properties such as structure and infiltration.

- Prior to examining the effect of effluent water on soils and turfgrass species, some estimate of effluent use is required. The approximate amount of water needed by different turf species was determined and then compared to the amount of rainfall generally occurring at the site on a monthly basis. The difference between water needs and rainfall would then be an estimate of the amount of extra water needed for irrigation. Water requirements for several species decreased in the order Bermudagrass > Paspallum > Zoysiagrass. Bermudagrass will require about 106 inches per year while Zoysiagrass will require only about 84 inches per year. Assuming average annual rainfall of about 27 inches, then approximately 80 inches of effluent will need to be applied to greens while 72 inches per year will need to be applied to fairways.It is reasonable to expect that a minimum of 700,000 gal of water per day will be used to irrigate the course.

- Expected changes to soil chemistry due to effluent use were simulated and found not to seriously disturb the sodium (Na) content of the soils. Thus soil structure and permeability should remain in a favorable state.

- However, due to the high salt content of the effluent water, it will be necessary to blend potable water with effluent water at approximately a 50/50 ratio to avoid injuring the Bermudagrass. Based on earlier estimates of greens acreage (about 5 acres), this will likely approach 30,000 gallons per day. The high salt content is not likely to disturb the Zoysiagrass.

3.4 Nitrogen Use and Impact to Soil and Groundwater

- Nitrogen (N) is a relatively easily managed component at the site. It is expected that N fertilization at the site will entail use of relatively insoluble (slow-release) materials for fertilization of turf. Application will be based on initial soil test results, turf requirement, and turf condition throughout the year. Treated effluent will be used as both a source of water at the site and as an additional source of nitrogen.

- Soil column studies showed that even under worst case situations both nitrate and ammonium are primarily contained within the 0-2.5" increment of soil, again due to the low permeability of the soils with no nitrate found below 5" in the columns. This was true even for N movement from the simulated greens (ie. sand/peat mixtures).

- The N runoff simulation shows that all observed maximum concentrations of nitrate and ammonium are generally less than 25 mg/L. Currently the United States Environmental Protection Agency (USEPA) sets acceptable nitrate levels in water at 45 mg/L or less. Thus, while significant nitrate levels can be observed in this scenario, the levels are well below acceptable drinking water standards. Thus runoff and subsequent water quality are not adversely affected.

3.5 Pesticide Use and Impact to Water Quality

- Pesticide partitioning data showed that greater than 90% of the pesticide added to the columns remained in the upper 2.5" of the LuA soil. This layer also contained thatch from the bermudagrass turf. The thatch and soil organic matter provided a significant sink for pesticide and clearly prevents significant downward migration of all the pesticides. Even dicamba, a compound that is widely recognized as a potential threat to groundwater was attenuated such that only a few ppb was found in leachate from the columns.

- Leaching from the sand/peat mixtures was, in general, higher than the LuA soils, but still quite low considering the solubility and mobility of dicamba, 2,4-D and MSMA. Under normal conditions even Dicamba will be attenuated effectively. Careful management will, however, be required.

- Pesticide degradation followed predictable patterns. Dicamba, 2,4-D and chlorpyrifos degraded quickly to less than 2% of the amount added in only 28 days. The only chemical that did not degrade quickly was MSMA which is known to have a half-life of about 1000 days.

- Some arsenic (from MSMA) was detected in column leachate. Because MSMA is persistent, considerable leaching may occur over long periods of time. This compound is not recommended.

- Based on laboratory data and simualtion analysis the following conclusions can be drawn: The loss of chemical residue by runoff decreased from Dicamba >> 2,4-D > Chlorthalonil > Chlorpyriphos > MSMA. In general, only Dicamba loss was significant compared to the total applied. Runoff concentrations were less than 2 ppb for all compounds except Dicamba. Dicamba concentrations in runoff were very high, approaching 1 ppm (625 ppb). MSMA appears to be the least hazardous chemical in terms of leachate and runoff potential. However, MSMA is a persistent compound and may pose long-term problems due to subsurface accumulation of arsenic. The ultimate fate of arsenic in soils from the site is unknown. Thus MSMA must not be used.

1.0 TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

2.0 INTRODUCTION

This report is prepared in preparation for, and in support of, an overall Environmental Impact Report (EIR) for a proposed golf course at Queen's Beach, Oahu, Hawaii. This portion of the study focuses on the potential chemical impacts from the proposed golf course.

The purpose of this phase of the EIR is to accurately assess the potential chemical impacts of a golf course in the proposed development area. The report presents the assessment of numerous impacts anticipated at the site. Some of the major issues addressed in the report, on a site specific basis include:

1. Leaching and runoff losses of nutrients and pesticides from the golf course during construction and after turfgrass establishment;

2. Use of effluent water for irrigation, and water re-use issues;

3. Degradation of surface and groundwater quality resulting from application of pesticides and fertilizers; and

4. The basis of design of an Integrated Turf Management System (TMS) for controlling chemical impacts at the site.

3.0 BACKGROUND INFORMATION

Information regarding the physical setting of the proposed golf course was derived from two sources: The recent "Ka Iwi Master Plan - Chapter IX" which describes much of the area where the proposed golf course will be located on Queen's Beach; and a site visit and investigation which allowed for verification, and where necessary, modification of the information contained within that report. The results of the two assessments are described below.

3.1 PHYSICAL SETTING

3.1.1 Climate

Because Oahu is in the tropics, where surface temperature of the surrounding ocean ranges between 73 F and 80 F, inland air temperatures are stabilized by wind blowing off the ocean. The National Oceanic and Atmospheric Administration, Environmental Data Center, has recorded temperature and rainfall at Makapu'u in their publication, *Climate of Makapu'u Point, Hawaii*. According to this record, the warmest month is September, with average daily temperatures at sea level ranging between 83° F and 74° F. The coolest month is February, with average daily temperatures ranging between 76° F and 67° F. From 1951 through 1973, the maximum temperature was 97° F and the minimum temperature was 53° F.

The area is usually sunny and dry. Between 1951 and 1973, average annual rainfall was 31.8 inches. Rainfall is chiefly from a few heavy winter storms between October and April. Rainfall from tradewind showers is negligible. On the average, there are only 15 days a year where rainfall is 0.5 inches or more.

Between May and October, tradewinds predominate with wind mostly from the northeast or east. Wind direction is more variable during the rest of the year. During tradewind conditions, seaward facing cliffs and the shoreline at Queen's Beach are exposed to strong, steady gusts while the areas lee of Makapu'u Head receive very little or no breeze. The strength and constancy of the tradewinds is evident in plant life on the headland, which exhibits a form referred to as windshear. Tradewinds funneled through Kealakipapa Valley sometimes produce light offshore breezes at Kaho'ohaihai Inlet and Ka'ili'ili Bay.

3.1.2 Topography

The site area can be divided into four topographic regions (Figure 3-1): (1) a coastal zone (referred to in this report as Queen's Beach); (2) a valley (Kealakipapa Valley); (3) a rocky headland (Makapu'u Head); (4) and the coastal bench trail. The coastal plain which makes up Queen's Beach and the lower portion of Kealakipapa Valley has gentle slopes of 5% or less with maximum elevation of about 24 feet Mean Sea Level (MSL). Any variation in slope is mostly due to drainage ways which feed Kaloko Inlet and Ka'ili'ili Bay, and to boulders deposited throughout this area.

The mouth of Kealakipapa Valley at Queen's Beach is wide and narrows to its head near Makapu'u Lookout at 160 feet MSL. Slopes in the valley range from 5% to 10%. Again, any other variation in topography is mostly due to scattered boulders. From the lowest point of Kealakipapa Valley to the tip of the 669-footsummit, the west slope of Makapu'u Head ranges from 10% to 60% slope. The slope of Makapu'u Head's north facing cliffs ranges from 100% to 360%, and its east facing cliffs range from 75% to 125% slope. The terrain is rugged and the cliffs are hazardous for climbing. A fairly level shore bench along the eastern side of Makapu'u extends for about 4,500 feet from the rock groin at Kaho'ohaihai Inlet.

The knoll near the southern end of the headland is named Pu'u o Kipahulu. Sticking up from the southern foot

of this headland is an unusual rock formation named Kapaliokamoa which stands about 30 feet high.

3.1.3. Shoreline

The shoreline begins at the old Wawamalu Ranch Wall and extends towards Kapaliokamoa, then stretches for approximately 9,000 feet around the coastal rim of Makapu'u Head (Figure 3-2). This shoreline is characterized by beach and dune sand, three inlets, low lava shelves strewn with rock and gravel, mudflats, and a coastal lava bench, most of which is inaccessible.

From the Wawamalu Ranch Wall to Kaloko Point, beach and dune sand has been deposited by storms behind the rocky shoreline to create what is known as Kaloko Beach. This is the only portion of shoreline at Queen's Beach where natural wave action and currents carry offshore sand to the shoreline. From Kaloko Point, Kaloko Inlet heads inland, becoming an estuary which has been artificially extended to reach a small gulch under Kalanianaole Highway. Parts of Kaloko Inlet, like all three inlets, are filled with poorly sorted rubble, gravel, and sand and are awash at low tide.

On the opposite side of the mouth of Kaloko Inlet, lava rock juts out at Ka'ili'ili Point. As for Ka'ili'ili Bay, stands of mangrove occupy mudflats in the furthest inland portion of the bay, while other areas of shoreline are covered in rubble and gravel. The bay is about 400 feet wide at its widest point.

A drainage canal has been dredged from the Hawaii Kai Championship Golf Course to enter the bay from the north, contributing silt to the mudflats in the bay's shallow water. Although there is sand within Kaloko Inlet and Ka'ili'ili Bay, it has a high debris/silt content.

North of Ka'ili'ili Bay, the shoreline becomes jagged lava again. A coral and lava cobble beach has been deposited behind this shoreline from Ka'ili'ili Bay to a third inlet, called Kaho'ohaihai. This inlet was artificially created by the Hawaii Kai Development Company during the early 1960's and now shelters a modest sand beach. A large man-made rock groin on the east side and a groin and revetment on the west side of Kaho'ohaihai Inlet at one time were intended to protect a boat channel. Under most conditions they shelter the mouth of the inlet from wave action. In contrast, during kona winds, there are usually breaking waves in the mouths of Kaloko Inlet and Ka'ili'ili Bay.

Beyond Kaho'ohaihai Inlet, the shoreline is a rough discontinuous lava bench, 3 to 10 feet above sea level, strewn with talus from the steep slopes of Makapu'u Head. During calm seas, it is possible, though still hazardous, to walk along the shore bench and over low sea cliffs to the base of Makapu'u Point. There is also a rough discontinuous lava bench on the north face of Makapu'u Head similar to the shore bench on the east side of the headland. Steep sea cliffs between gaps in the bench make it impossible to walk all the way from Makapu'u Beach to the base of Makapu'u Point.

3.1.4 Geology and Soils

Makapu'u Head is the southernmost end of the Ko'olau Range. The Ko'olau Volcano was initially shield-shaped, like Mauna Loa on the Island of Hawaii, and extended several miles seaward of Makapu'u. When volcanic activity ended, about 2.5 million years ago, the highest part of the Ko'olau Range was northeast of the existing crest. Subsequently, fluvial erosion carved a series of valleys in the Ko'olau shield which may have reduced its height by as much as 1,000 feet.

Coastal areas of Oahu also underwent a series of submergences and emergences resulting from changes in the ocean level during glacial and interglacial phases.

Long ago, during much higher stands of the sea, ocean waves eroded away all ridgelines dividing windward valleys from Makapu'u through Wiamanalo, cut a sea cliff around Makapu'u Head, and scattered blocks of marine limestone between the Makapu'u lookout and the summit of Makapu'u Head. The shore bench along the north and east sides of Makapu'u Head was probably cut by wave action in relatively recent times when sea level was slightly higher than at present. Wind, rain, and salt spray battering the face of Makapu'u Head have eroded the softer layers of exposed lava flows and left the harder layers standing in relief. There are several features of geologic interest on the shore bench east of Makapu'u Head including a blowhole, a filled lava tube, exposed dikes, and several small caves.

The Koko Rift is part of a landscape that was added to the Southeastern edge of the Ko'olau Range about 30,000 years ago. It is one of the last areas of volcanic activity on Oahu. From an aerial perspective, the Koko Rift is an easily discernable linear chain of tuff cones which extends from Koko Head to the offshore islands of Kaohikaipu and Manana (Figure 3-3). Consolidated ash from explosive eruptions formed huge tuff cones makai of the then existing shoreline at Koko Head, Hanauma Bay, and Koko Crater.

Most of the coastal plain southwest Pu'u o Kipahulu was also submerged until Kalama Crater erupted. Lava from Kalama Crater flowed to the sea and formed a rocky shoreline extending from Sandy Beach through Kapaliokamoa. Subsequent wave action reshaped this shoreline and deposited sand and cobble beaches. The Koko Head eruptions are dated at about 34,000 to 41,000 B.C., the Kalama flows at about 30,000 to 34,000 B.C., and the Kaupo flows (at Sea Life Park) at about 29,000 to 31,000 B.C.

Most of the naturally formed soils are either extremely rocky or very sticky and very plastic clay. Neither of these characteristics is suitable for intensive landscaping. Boulders, soil, and dredge spoil have been stockpiled over about half of the coastal plain of Kalanianaole Highway. Soil Conservation Service classification of soil types and a map of the area where boulders are stockpiled are shown in Figure 3-4.

3.1.5 Drainage

Runoff from rainfall on the leeward side of the Ko'olau Range between Kamehame Ridge and the Hawaii Kai Golf Course, including all of Kalama Valley and the Queen's Gate subdivision, is directed toward a 40-foot wide trapezoidal concrete channel which passes under Kalanianaole Highway and into a 15-foot wide dirt ditch which extends to Ka'ili'ili Bay. Since only a small portion of the peak storm flow can be carried by this earth ditch, a shallow 200-foot wide overflow channel parallels the ditch to handle larger flows (Figure 3-5).

Off-site runoff from the area between the Hawaii Kai Golf Course and Kealakipapa Valley collects in swales mauka of Kalanianaole Highway and is carried under the road through five separate culverts. Once makai of the highway, this water flows along natural depressions into Ka'ili'ili Bay. South of the concrete drainage channel, off-site runoff from the Hawaii Kai Golf Course is carried by swales to Kaloko Inlet. Storm flow from Kealakipapa Valley and the west side of Makapu'u Head discharges into the Kaho'ohaihai Inlet. During storms, intense downpours can occur at Makapu'u. It is estimated that on the average, the worst storm in 100 years could produce 3 inches of rain in one hour and over 13 inches of rain in 24 hours.

During storms, runoff from about 1,500 acres flows into Kaloko inlet, Ka'ili'ili Bay, or Kaho'ohaihai inlet. Estimated storm flows into these inlets range from 2000 cfs (cubic feet per second) for 10 year storms to 2700 cfs for 100 year storms . The approximately 365 acres comprising the Makapu'u area contributes relatively little of the runoff (400 cfs to 600 cfs).

Apart from the dirt drainage channels crossing Kealakipapa Valley, on-site drainage poses no problems for development. However, improvements to these channels might be warranted to reduce erosion.

3.1.6 Wastewater

All sewage from the Hawaii Kai area is collected and treated at the Hawaii Kai Sewage Treatment Plant located mauka of Sandy Beach, across Kalanianaole Highway. Following secondary treatment, effluent is discharged

through an outfall 3,000 feet offshore in 35 feet of water.

Beginning at the concrete drainage channel in the Hawaii Kai Golf Course, an 18-inch sewer line runs along the mauka side of Kalanianaole Highway, funnelling into Sewage Pumping Station #6 located just north of Kaloko Inlet. Although the sewage system is privately owned and operated, the State Public Utilities Commission requires that the sewage treatment plant accept any sewage from private or public sources in the approved service area should any wastewater-generating uses be established there.

4.0 SOILS INVESTIGATION

In October of 1994, Environmental Chemistry conducted a site visit and performed soil borings and sample collection in order to verify the occurrence and distribution of soils at the project site. The investigation also included sample analysis for soil chemical characterization that would be used as a baseline for assessing future chemical impacts both on soil chemistry and groundwater chemistry at the site. This investigation is described in detail below.

4.1 METHODS AND MATERIALS

Soil distribution and soil sampling locations were initially selected based on the soil map noted in Figure 3.4. Sample locations are noted on the map and were originally located such that representative samples could be obtained of the most commonly occurring soils of the area. Other borings were done at various locations to ensure the accuracy of the existing map.

At each sample location, a 6" bucket auger was used to obtain samples to a depth of approximately 3' in each location. The samples were laid end-to-end in order to describe the major lithologic features (horizons) of each soil type and to ensure conformity with the Soil Conservation Service modal profile descriptions. Subsamples of the major soil types and horizons were taken for chemical and mineralogical analysis and column experiments for assessing chemical impacts.

4.2 SOILS AND HORIZON DESCRIPTION

Based on the mapping exercise and the site investigation, the following soils predominate at the site. The characteristics of the soils are described below.

Jaucas Series: This series consists of excessively drained, calcareous soils that occur as narrow strips on coastal plains, adjacent to the ocean. These soils occur on all the islands of this survey area. They developed in wind- and water- deposited sand from coral and seashells. They are nearly level to strongly sloping. Elevations range from sea level to 100 feet; but locally on West Molokai, the elevation is as high as 650 feet. The annual rainfall amounts to 10 to 40 inches. The mean annual soil temperature is 75 F. Jaucas soils are geographically associated with Pulehu, Mokuleia, Kaloko, and Lualualei soils.

In this survey a dark variant of the Jaucas series was mapped. This soil, Jaucas loamy fine sand, dark variant, 0 to 8 percent slopes, is described in alphabetical order, along with other mapping units of this series.

These soils are used for pasture, sugarcane, truck crops, alfalfa, recreational areas, wildlife habitat, and urban development. The natural vegetation consists of kiawe, koa haole, bristly foxtail, bermudagrass, fingergrass, and Australian saltbrush.

Jaucas sand, 0 to 15 percent slopes (JaC): The slope range of this soil is 0 to 15 percent, but in most places on site, the slope does not exceed 4 percent. Included in mapping were narrow strips of Beaches.

In a representative profile, the soil is single grain, pale brown to very pale brown, and more than 60 inches deep. In many places the surface layer is dark brown as a result of accumulation of organic matter and alluvium. The soil is neutral to moderately alkaline throughout the profile.
Permeability is rapid, and runoff is very slow to slow. The hazard of water erosion is slight, but wind erosion is a severe hazard where vegetation has been removed. The available water capacity is 0.5 to 1.0 inch per foot of soil. In places roots penetrate to a depth of 5 feet or more. Wokability is slightly difficult because the soil is loose and lacks stability for use of equipment.

Because the proposed golf course site is composed of extremely small amounts of this soil, it is not considered further.

Rock Land (rRK): is made up where areas of exposed rock covers 25 to 90 percent of the surface. The rock outcrops and very shallow soils (less than a few millimeters (mm)) are the main characteristics. The rock outcrops are mainly basalt and andesite. This land type is nearly level to very steep. Elevations range from nearly sea level to more than 6,000 feet.

This land type is also used for urban development. In many areas, especially on the island of Oahu, the soil material associated with the rock outcrops is very sticky and very plastic. It also has high shrink-swell potential. Buildings on the steep slopes are susceptible to sliding when the soil is saturated. Foundations and retaining walls are susceptible to cracking.

The rRK soils cover extensive areas of the eastern portion of the proposed golf course. Other smaller pockets of rRK soils occur mainly between Kaloko Inlet and Ka'ili'ili' Bay

Koko Series: This series consists of well-drained soils on fans and volcanic spurs on the island of Oahu. These soils developed in alluvium washed from deposits of volcanic ash, cinders and tuff. They are gently sloping to moderately steep. Elevations range from nearly sea level to 200 feet. They are geographically associated with Lualualei soils.

This soil occupies the far western portion of the site east of the Wawamalu Ranch wall to the stone bridge used to enter the site at the mouth of Kaloko Inlet.

Koko silt loam, 2 to 6 percent slopes (KsB): This soil occupies smooth slopes. Included in mapping were small eroded spots, small nearly level areas, and small areas that have a buried profile. Gravelly soils are on foot slopes and along drainageways.

In a representative profile the surface layer is dark reddish-brown silt loam about 16 inches thick. The subsoil, about 32 inches thick, is dark reddish-brown or dark-brown silt loam, loam, or clay loam that has subangular blocky structure. The substratum consists of cinders and tuff. The soil is neutral in reaction throughout the profile.

In a representative profile the surface layer is dark reddish-brown silt loam about 16 inches thick. The subsoil, about 32 inches thick, is dark reddish-brow or dark-brown silt loam, loam, or clay loam that has subangular blocky structure. The substratum consists of cinders and tuff. The soil is neutral in reaction throughout the profile.

Permeability is moderate. Runoff is slow, and the erosion hazard is slight. The available water capacity is 2.1 inches per foot of soil. In places roots penetrate to a depth of 5 feet or more.

A representative profile is:

Ap - 0 to 8 inches, dark reddish-brown (5YR 3/3) silt loam, reddish brown (5YR 4/4) when dry; weak, very fine and fine, granular structure; slightly hard, very friable, nonsticky and slightly plastic; plentiful very fine, and few medium roots ; common, very fine, interstitial pores ; neutral ; gradual, smooth boundary. 5 to 9 inches thick.

A1 - 8 to 16 inches, dark reddish-brown (5YR 3/3) silt loam, reddish brown (5YR 4/4) when dry ; weak, fine and medium, subangular blocky structure breaking to weak, fine, granular ; slightly hard, very friable, slightly sticky and slightly plastic : plentiful very fine and medium roots ; common, very fine and medium, tubular pores ; neutral ; clear, smooth boundary. 8 to 10 inches thick.

B21 - 16 to 25 inches, dark reddish-brown (5YR 3/4) silt loam, reddish brown (5YR 4/4) when dry ; weak, fine and medium, subangular blocky structure ; slightly hard, very friable, sticky and plastic ; plentiful very fine and medium roots ; common, very fine and medium, tubular pores ; neutral ; gradual, smooth boundary. 8 to 11 inches thick.

B22 - 25 to 33 inches, dark reddish-brown (5YR 3/4) clay loam, reddish brown (5YR 4/4) when dry ; moderate, fine to coarse, subangular blocky structure ; slightly hard, friable, sticky and plastic ; plentiful fine, and few medium and coarse roots ; common, fine, tubular pores and few, medium and coarse, tubular pores ; neutral ; gradual, smooth boundary. 6 to 10 inches thick.

B23 - 33 to 41 inches, dark reddish-brown (5YR 3/4) clay loam, yellowish red (5YR 4/6) when dry ; moderate, fine and medium, subangular blocky structure ; hard, firm, sticky and plastic ; plentiful very fine and fine, common fine, and few coarse roots ; common fine and medium, tubular pores and few, coarse, tubular pores ; neutral ; clear, wavy boundary. 6 to 8 inches thick.

B3 - 41 to 48 inches, dark-brown (7.5YR 4/4) loam, strong brown (7.5YR 5/6) when dry ; weak, fine and medium, subangular blocky structure ; slightly hard, friable, sticky and plastic ; few fine roots ; few, fine and medium, tubular pores ; common fine cinder fragments ; neutral. 4 to 8 inches thick.

I I C - 48 inches, cinders and tuff.

The depth to tuff and cinders ranges from 37 to 56 inches. Fragments of tuff are common in the profile on the windward side of craters. The texture of the solum is silt loam is silt loam, loam, clay loam, or silty clay loam. The B horizon ranges from 5YR to 7.5YR in hue, from 3 to 4 in value when moist and 4 to 5 when dry. It ranges from 4 to 5 in chroma when moist and from 4 to 8 when dry.

Lualualei Series: This series consists of well-drained soils on the coastal plains, alluvial fans, and on talus slopes on the islands of Kauai, Oahu, Molokai, and Lanai. These soils developed in alluvium and colluvium. They are nearly level and gently sloping. Elevations range from 10 to 125 feet. Lualualei soils are geographically associated with Honouliuli, Jaucas, and Kekaha soils.

The two most commonly occurring soils of the series on site are described below.

Lualualei clay, 0 to 2 percent slopes (LuA): This soil is on alluvial fans. In a representative profile the surface layer, about 10 inches thick, is very grayish-brown, very sticky and very plastic clay that has prismatic structure. The next layer, 37 to more than 42 inches thick, is very dark grayish-brown, very sticky and very plastic clay that has prismatic structure. In addition, it has gypsum crystals. The soil is underlain by coral, gravel, sand, or clay at depths below 40 inches. This soil cracks widely upon drying. It is neutral in the surface layer and medium acid to moderately alkaline in the underlying layers.

Permeability is slow. Runoff is slow, and the erosion hazard is no more than slight. The available water capacity is about 1.4 inches per foot of soil. In places, roots penetrate to a depth of 5 feet or more. The shrink-swell potential is high.

Representative profile:

A11 - 0 to 1 inch, very dark grayish-brown (10YR 3/2) clay,very dark gray (10YR 3/1) when moist ; strong, fine and very fine, granular structure ; very hard, firm, very sticky and very plastic ; abundant fine roots ; many, fine, interstitial pores ; few light-colored sand grains ; vertical cracks up to 2 1/2 inches wide ; strong effervescence with hydrogen peroxide ; neutral ; abrupt, smooth boundary. 1/2 inch to 1 1/2 inches thick.

A12 - 1 inch to 10 inches, very dark grayish-brown (10YR 3/2) clay, very dark gray (10YR 3/1) when moist ; moderate, coarse, prismatic structure breaking to moderate, medium, subangular blocky ; very hard, firm, very sticky and very plastic ; abundant fine roots ; many, fine, tubular pores ; some organic litter in the cracks ; strong effervescence with hydrogen peroxide ; neutral ; gradual, smooth boundary. 8 to 12 inches thick.

AC - 10 to 22 inches, very dark grayish-brown (10YR 3/2) clay, very dark grayish brown (10YR 3/2) when moist ; moderate, coarse, prismatic structure breaking to moderate, medium, subangular blocky ; very hard, firm, very sticky and very plastic ; abundant fine roots ; many, fine, tubular pores ; common slicken-slides ; few black specks ; few coral sand grains ; strong effervescence with hydrogen peroxide ; neutral ; clear, smooth boundary. 10 to 12 inches thick.

C1 - 22 to 30 inches, very dark grayish-brown (10YR 3/2), moist and dry, clay ; moderate, medium and coarse, subangular blocky structure ; hard, firm, very sticky and very plastic ; plentiful fine and medium roots, mainly matted between cleavage planes ;few, fine and very fine, tubular pores ; many weakly grooved slickenslides ; common black stains in pores and in dendritic pattern on ped faces ; few light-colored sand grains ; common shiny specks ; strong effervescence with hydrogen peroxide ; neutral ; gradual, smooth boundary. 7 to 10 inches thick.

C2cs - 30 to 49 inches, very dark grayish-brown (10YR 3/2), moist and dry, clay ; strong, medium and coarse, subangular blocky structure ; hard, firm, very sticky and very plastic ; few fine roots matted between faces ; few, fine, tubular pores ; many deeply grooved slickenslides ; many, fine and medium, gypsum crystals ; common black stains in pores and on peds ; common shiny specks ; few light-colored sand grains ; strong effervescence with hydrogen peroxide ; medium acid ; abrupt, smooth boundary. 17 to 20 inches thick.

C3 49 to 60 inches, very dark grayish-brown (10YR 3/2), moist and dry, clay ; strong, coarse, subangular blocky structure ; extremely hard, very firm, very sticky and very plastic ; few fine roots matted between peds ; few, fine tubular pores ; many deeply grooved slickenslides ; common, medium and coarse, gypsum crystals ; few shiny specks ; strong effervescence with hydrogen peroxide ; medium acid.

The A11 horizon is granular when dry but massive when wet. Because of the type of clay, there is considerable swelling and shrinking of the soil as a result of alternate wetting and drying. When the soil dries, it cracks and forms huge blocks 1 foot or more in diameter. When it is wet there is no evidence of the blocks. The A and C horizons range from 7.5YR to 10YR in hue and from 2 to 4 in value. Chroma is either 1 or 2. Gypsum crystals 1/3 inch to 3 inches in diameter are common in the profile, generally below a depth of 30 inches.

Lualualei extremely stony clay, 3 to 35 percent slopes (LPE): This soil occurs on talus slopes on Oahu and Kauai. The slope range is 3 to 35 percent, but in most places the slope is moderately sloping to steep. This soil is similar to Lualualei clay, 0 to 2 percent slopes, except that there are many stones on the surface and in the profile. It is impractical to cultivate this soil unless the stones are removed. Runoff is medium to rapid, and the erosion hazard is moderate to severe.

4.3 SOIL CHEMICAL AND PHYSICAL CHARACTERISTICS

In order to assess possible impacts to the soils and groundwaters of the site due to the construction and maintenance of a golf course, baseline soil chemistry had to be established. The baseline data was then used to predict the possible changes in chemistry that would occur under different environmental scenarios such as changes with respect to cultivation, fertilization, and to the addition of pesticides.

4.3.1 Chemical Characterization

Soil samples used for the assessment of chemical impact were limited to the Lualualei soil series since these soils cover about 90% of the area that is available for golf course development. The samples were analyzed for clay mineralogy, pH (water), cation exchange capacity, % carbon, % nitrogen, texture, and bulk density. All analyses were performed by Environmental Chemistry and the University of California - Davis. The results are noted below:

TABLE 4.1 SOIL CHEMICAL CHARACTERISTICS

Sample (Soil Type)	Depth (inches)	pH	% C	% N	CEC (meq/100g)	Extractable Cations (meq/100g)
LuA	0-1"	7.3	0.93	0.09	31.8	33.9
	1-10"	7.0	0.54	0.073	33.6	34.7
	10-22"	7.0	0.25	0.07	30.1	33.1
	22-30"	6.7	0.20	0.047	28.9	29.9
LPE	0-1"	7.8	0.71	0.06	38.9	41.2
	1-10"	7.3	0.54	0.04	33.0	34.7
	10-22"	7.2	0.33	0.03	31.6	36.6
	22-30"	6.4	0.12	0.017	31.4	32.3

The soils have slightly alkaline to near neutral surface pH with moderate levels of both carbon and nitrogen. The cation exchange capacities are high which is indicative of high clay and organic matter contents. Extractable cations are nearly equal to the exchange capacities and are composed primarily of calcium (Ca) with smaller amounts of magnesium (Mg) and sodium (Na).

4.3.2 Mineralogical Characterization

Subsamples of the bulk samples were also analyzed by X-ray diffraction for qualitative and semi-quantitative clay mineral identification. Random powder mounts were prepared from the less than 10 micron (μm) fraction of the samples on quartz slides and examined. Minerals were identified from the Mineral ID software associated with the diffractometer.

TABLE 4.2 SOIL MINERALOGY

Sample	Depth	Major (>25%)	Minor (<5%)	Trace (5%)
LuA	0-1"	Mont	Kaol	Al, Fe, Gypsum
	1-10"	Mont	Kaol	Al, Fe, Gypsum
	10-22"	Mont	Koal	Al, Fe, Gypsum
	22-30"	Mont	Kaol	Al, Fe, Gypsum
LPE	0-1"	Mont	Kaol	Al, Fe, Gypsum
	1-10"	Mont	Kaol	Al, Fe, Gypsum
	10-22"	Mont	Kaol	Al, Fe, Gypsum
	22-30"	Mont	Kaol	Al, Fe, Gypsum

The samples were uniform in their clay mineral composition. The dominant clay mineralogy consisted of montmorillonite, lesser amounts of kaolinite and traces of iron (Fe) and aluminum (Al) oxides that usually occurred as surface coatings on and within clay agglomerations. Crystals of gypsum were noted in all samples probably formed from evaporation and precipitation of soil pore water high in both calcium and sulfate.

4.3.3 Soil Physical Characteristics

The soils were examined for certain important physical characteristics that assist in describing and predicting the movement of water and solute in the soils of the area. The physical parameters of interest are described below.

TABLE 4.3 SOIL PHYSICAL CHARACTERISTICS

Sample	Depth	Texture	Bulk Density (1/3 bar) (g/cc)	Water Content (1/3 bar) (%)	Water Content (15 bar) (%)
LuA	0-1"	Clay	1.12	32.1	27.8
	1-10"	Clay	1.22	42.1	28.9
	10-22"	Clay	1.30	37.3	28.4
	22-30"	Clay	1.32	34.9	30.1
LPE	0-1"	Clay/Rock	1.33	33.7	26.5
	1-10"	Clay/Rock	1.35	38.9	28.8
	10-22"	Clay/Rock	1.30	35.6	31.1
	22-30"	Clay Loam	1.31	34.5	30.4

4.4 SIGNIFICANCE OF CHEMICAL AND PHYSICAL DATA

The soil characterization data can be used to draw some initial, tentative conclusions regarding the soils and their role in chemical fate and transport. These are:

1. The predominant soils of the site are of the LuA series (90% of the site) and are composed of clay and clay-rock mixtures. The clays are primarily montmorillonite which exhibit high shrink-swell capacity.

2. The clays will likely provide a significant barrier to subsurface transport of chemicals (and water) due to the very fine texture of the soils and the low permeability.

3. The low permeability of the soils will be a benefit for subsurface movement but may enhance surface runoff transport processes.

5.0 GROUNDWATER GEOCHEMISTRY

Groundwater samples from the site were collected by Mr. Tom Nance of Tom Nance Water Resource Engineering (WRE) during the drilling and development of monitoring wells. All reference to collection and location of samples is noted in the hydrological report prepared as part of this study.

5.1 METHODS AND MATERIALS

Samples from WRE were collected on November 18, 1994, placed in polyethylene bottles, packed in ice and shipped overnight to Environmental Chemistry in Sacramento, CA. The samples were refrigerated at 4°C prior to analysis. Environmental Chemistry measured conductivity and pH, and then sent the samples to the University of California - Davis for major cation and anion analyses. The results are noted in Section 5.3.1.

5.2 GROUNDWATER CHEMISTRY

The first step in characterizing the groundwater at the site was to determine the major cation and anion chemistry of the samples in order to provide baseline information upon which future chemical impacts could be compared.

5.2.1 Solute Composition

The solute composition is noted below:

TABLE 5.1 SOLUTE COMPOSITION OF GROUNDWATER

Sample	pH	EC	Ca	Mg	Na	K	SO4	Cl	NO3
		dS/M	-----	-----	-----	mmol/L	-----	---	---
QB1	7.4	9.4	9.35	14.6	98	2	5.7	89	.12
QB2	7.5	18.0	14.5	25.5	197	3.15	17	211	.51
QB3	7.4	5.8	4.59	8.02	56.5	1.19	4.52	55.9	.29
QB4	7.7	6.8	7.53	7.57	69.5	1.39	3.89	66.4	.23

The samples had typically near neutral to slightly alkaline pH as expected both from the soil pH described earlier and due to the fact that the groundwater would be expected to be "brackish" to near seawater in composition based on proximity to ocean water. As expected the water samples are dominated by Na and chloride (Cl) followed by Ca, Mg and sulfate (SO_4).

5.2.2 Geochemical Controls on Solute Composition

The groundwater data was used as input data to the geochemical model MINTEQA2. The objectives of this exercise were to:

1. Ascertain the mineral controls on solute composition. For example, gypsum ($CaSO_4$) crystals were found in many of the soil samples taken from the site and thus groundwater in contact with the soil material might display saturation with respect to gypsum which then would control the concentrations of both calcium and sulfate due to gypsum dissolution and precipitation.

2. Provide a baseline of groundwater and soil chemistry for predicting future impacts due to chemical usage at the site. The groundwater samples will, in part, reflect the composition of the soil pore water.

One way of examining the groundwater chemistry data is to determine from the solution or pore water chemistry what solids in the subsurface may be in contact with the solution. The same data can also be speciated, that is the various forms (complexes, ion pairs, etc) that the different cations and anions may be in. Once the data has been speciated, changes in its composition may be more accurately predicted (see Section 7).

The input data used in the analyses represents the composition of groundwater sample QB3. This sample was chosen simply because all samples were very similar. The data is presented below:

pH	7.4		
Ca	4.59	mmol/L	183 mg/l
Mg	8.00	"	192 mg/l
Na	56.5	"	1695 mg/l
K	1.10	"	35 mg/l
NO_3	0.29	"	18.6 mg/l
SO_4	4.52	"	415 mg/l
Cl	55.9	"	2145 mg/l

Cation Speciation: The MINTEQ model output is summarized below. The water soluble cations exist primarily as the following species:

Free divalent Ca^{2+}	92%
$CaSO_{4(aqueous)}$	8%
Free divalent Mg^{2+}	92.6%
$MgSO_{4(aqueous)}$	7.4%

Calcium Solid Phases: Once the solution was speciated, the speciated data were used to compute ion activity products for various Ca solids that could exist in the samples. The ion activity products were then compared to the solubility products of the same minerals as a saturation index where:

$$\text{Saturation Index} = \log (IAP/Ksp)$$

where IAP = Ion activity product observed
Ksp = Theoretical solubility product for the mineral

Therefore, when the Saturation Index (SI) is equal to zero, a mineral has been found whose solubility matches the observed solution activity of Ca. If the SI is negative, then the solution is considered undersaturated with respect to the mineral and if positive, the solution is considered oversaturated with respect to the solid. Obviously, caution must be observed in the interpretation of results as some of the solid phases used in the program will not occur in many types of samples. Thus some knowledge of the sample mineralogy is helpful.

For these samples the following saturation indices were noted:

SI = -0.87, gypsum ($CaSO_4$)

Conclusions: Based on the geochemical modeling, Ca tends to exist primarily as a free ion species at the high pH of the solutions with much smaller amounts of Ca sulfate. The solutions were only slightly undersaturated with respect to gypsum, a solid that was found in many of the samples. The apparent control on mineral solubility suggests that gypsum crystals form in the surface of soils at the site due to evapoconcentration. Under this process, groundwater that is slightly undersaturated with respect to gypsum migrates upward to the surface soils due to the high gradient created by both evaporation and transpiration. As this water migrates upward, the volume tends to decrease due to evaporation which then increases the solute concentration of the remaining water. Eventually the solubility product of gypsum is reached and precipitates begin to form. Excess Ca in the solution is also continually taken up the exchange complex of the soils which explains the high Ca saturation of the clay particles observed in the mineralogical investigation. In addition, it was noted that the groundwater samples were very low in both dissolved nitrate and ammonium. The projected influence of nitrate fertilization on groundwater composition is discussed in subsequent sections of this report.

6.0 PESTICIDES, NUTRIENTS, TURFGRASS AND WATER USE FOR THE PROPOSED GOLF COURSE

6.1 PESTICIDES AND RELATED ISSUES

In order to assess the potential for degradation of environmental quality due to applied chemicals, the processes governing their behavior in the environment needs to be understood. This section provides the framework for evaluating the potential for offsite transport of applied chemicals from the site. The assessment begins with a discussion of candidate pesticides that might be used at the site. Their properties are noted and then evaluated for potential off site transport based on existing and assumed site conditions.

6.1.1 Identification of Potential Pesticides to be Used

Below is a list of pesticides that may be used at the proposed golf course. The list was selected based on information from the following sources:

1. Other golf courses in the area (specifically Hawaii Kai Golf Course) have noted use of several of the pesticides. Insect infestations are not a common problem in the area and as such insecticides are only used occasionally. The main herbicide used at Hawaii Kai (and in Hawaii) is MSMA; primarily for the control of broadleaf grasses and weeds such as goosegrass and crabgrass.

2. Publications from the University of Hawaii. In a survey of Hawaiian golf courses it was found that MSMA was the most commonly used herbicide in Hawaii. An evaluation of MSMA behavior in soil from the site has been included soley because of the common use of this pesticide. It is not recommended due to the high persistence of the compound and to the toxicity and potential health impacts of the breakdown products which include inorganic arsenic (As) (III) and inorganic As (V). These breakdown products could pose serious problems from a water quality perspective years after application. Other common herbicides used in Hawaii, and noted in the survey were 2,4-D and dicamba.

3. Peer reviewed scientific literature. The use and fate of the pesticides noted below has largely been derived from studies that demonstrate their efficiency and suitability in similar climatic/soil zones. Other recent studies (some not yet published) funded by the United States Golf Association were also available for review.

TABLE 6.1-1 PESTICIDE SELECTION

Name	Trade Name	CAS Number	Category	Family
Chlorpyrifos	Dursban	2921-88-2	I	Organo-phosphate
Chlorothalonil	Daconil 2787	1897-45-6	F	Halo-benzene
2,4-D	Many	94-75-7	H	Organo-phosphate
MSMA**	Daconate 6	2163-80-6 6484522	H	Arsenical
Dicamba	Banvel	2300-66-5	H	Arylaliph acid

* I = Insecticide F = Fungicide H = Herbicide N = Nematocide
** Not recommended for use in Hawaii

6.1.2 Pesticide Characteristics

Important chemical and physical properties of the proposed pesticides are noted below.

Chlorpyrifos: Chlorpyrifos is also an insecticide widely used to control ants, armyworms, billbugs, chinch bugs, fall armyworms, cut worms, mole crickets, sod webworms, turfgrass weevil, and selected species of white grubs. It has a molecular weight of 350.6, a vapor pressure of 1.2-2.3E-3, a water solubility ranging from 0.3-4.8 ppm and a soil adsorption coefficient ranging from 2,500-14,800.

Chlorothalonil: Chlorothalonil is also a fungicide used to control brown patch, copper spot, dollar spot, Fusarium patch, Dreschlera and Bipolaris disease, Pythium blight, red thread, rust, slime mold, and Fusarium snow mold. Its molecular weight is 265.9, has a vapor pressure of 1.3 Pa, water solubility of 0.6 ppm, and soil adsorption coefficient of 1380-5800.

MSMA: MSMA is an organic arsenical used to control broadleaf grasses such as goosegrass, crabgrass and bahiagrass. Its molecular weight is 183.9, has a vapor pressure that is considered negligible, water solubility of 570,000 to 1,400,000 ppm and a soil adsorption coefficient of 100,000 to 300,000.

Dicamba: Is a selective, systemic postemergent herbicide used to control mainly broadleaf species. Its molecular weight is 221.1, vapor pressure is 2.7E-3-4.9E-1, water solubility of 5000 to 850000 ppm (depending on form), a soil adsorption coefficient less than 6.

2,4-D: Also systemic, selective postemergent herbicide. Its molecular weight is 221-333 (depending on form), has a vapor pressure of 1.3E-5 to 1.1E-3 Pa, a water solubility of 900 (acid) ppm to 3,000,000 ppm (dimethyl amine salt). It has a soil adsorption coefficient of 20 for the acid form and from 1000 to 68000 for the ester forms.

6.1.3 Decomposition and Persistence

In terms of potential environmental impact, the use and application of pesticides is the single most crucial issue of concern to regulatory agencies and to the public at large. Choice of pesticide to be used, application practices and timing, and efficacy of the pesticide to be used must always be considered in conjunction with site specific characteristics in order to reduce or eliminate any potential health risk and offsite transport. One of the first evaluations that should be made with regard to pesticide choice and application is to determine the persistence and degradation rates of the compounds under consideration.

Degradation of applied pesticide is the only process that permanently reduces the total environmental load of pesticide. All pesticides applied to turfgrass are degraded, but their rates of degradation, and hence persistence, are variable. These rates are a complex function of soil, climatic, chemical, microbiological, and physical factors that should be evaluated based solely on the characteristics of the area of proposed application.

Chemical persistence of applied pesticides has a critical influence on their fate and movement in the environment. Degradation and sorption by organic matter and soil colloidal particles are two of the most critical processes controlling potential pesticide leaching and runoff losses. Chemical half-life serves as one yardstick for assessing potential environmental impacts of applied compounds. Short-lived compounds (those that degrade rapidly) are less likely to be transported in surface water runoff and groundwater than highly persistent compounds. Persistent compounds, including some highly adsorbed compounds, may eventually be leached to groundwater under certain conditions.

For this initial assessment of proposed pesticides, a list of pesticide degradation rates was compiled from which five different categories or classes of persistence have been derived. The classes and ranges for each class expressed as Ks (where Ks is the rate of degradation in units of days-1). The smaller the number the slower the

rate of degradation or the greater the persistence of the compound.

The classes are:

Class 1: Highly persistent, Ks <0.007
Class 2: Moderately persistent, Ks=0.007 to 0.023
Class 3: Moderately short-lived, Ks=0.023 to 0.046
Class 4: Short-lived, Ks=0.046 to 0.139, and
Class 5: Very short-lived, Ks > 0.139.

For the chemicals noted above the following degradation rates and persistence classes are noted:

TABLE 6.2 PESTICIDES AND PERSISTENCE CLASSIFICATION

Pesticide	Ks (days-1)	Half-life (days)	Persistence Class
Chlorpyrifos	0.017-0.046	15-42	2-4
Chlorothalonil	0.008-0.05	14-90	2-4
2,4-D	0.023-0.139	5-30	3-4
MSMA	0.001	1000	1
Dicamba	0.02-0.214	3-35	2-5

As noted in Table 6.2, most of the compounds, with the exception of MSMA, are moderately to very short-lived compounds. The actual and projected persistence of several compounds are discussed in Section 9 of this report.

6.2 NITROGEN: USE AND CHEMICAL PROPERTIES

Nitrogen is one of the essential plant nutrients required in substantial amounts to maintain adequate crop growth. Nitrogen is contained in turfgrass protein, nucleic acids, and protoplasm. It is absorbed by turfgrass primarily through the roots as ammonium (NH_4^+) or as nitrate (NO_3^-). Nitrogen promotes above ground vegetative growth, regulates phosphorus and potassium uptake, and turfgrass color. Oversupply of nitrogen delays maturation, causes stem weakness, possible accumulation of thatch, and increases nitrogen available for offsite transport to surface water and groundwater.

One of the guiding principles of sound nutrient management is to provide sufficient nutrient to meet turfgrass needs while minimizing surface and subsurface losses. The chemical form of the different nitrogen species determines the mode of nitrogen transport from the field to surface water or groundwater. The inorganic forms in soil and water include nitrate, nitrite, ammonium, nitrogen oxide (N_2O) and nitrogen gas (N_2). Nitrate is chemically unreactive in dilute solutions and has a relatively low tendency to form complexes with dissolved metals or to sorb on the surface of soil colloids.

The high solubility of nitrate in soil solutions make it particularly susceptible to subsurface leaching and surface transport in the solution phase of runoff. Once past the zone of biological activity at the soil surface, there are few mechanisms that will attenuate the transport of nitrates to groundwater. Limited levels of denitrification have been observed in the lower portion of the vadose zone (unsaturated zone of the soil column) and groundwater. Although initial infiltration during storm events generally leach nitrates in beyond the surface zone, changing form and application techniques, amount of thatch, root uptake activity, and incorporation practices will affect the levels of nitrate lost in surface runoff.

Over 90% of nitrogen occurring in the surface layer of soils is in the form of organic nitrogen. Organic nitrogen is directly available for release into soil solution, but has a microbially mediated exchange with inorganic soil nitrogen through the processes of mineralization and immobilization. Organic nitrogen is a component of all phases of soil organic matter including humin, humic and fulvic acids and is often the primary form of nitrogen in surface runoff.

Nitrogen will escape from local nutrient cycling systems in turfgrass through: a) gaseous processes including volatilization of applied fertilizer and denitrification; b) leaching from the root zone; and 3) surface runoff. Subsurface and surface runoff transport of soluble and sediment bound phosphorus are the primary mechanisms of phosphorus loss from turfgrass systems. Removal and offsite disposal of grass clippings is potentially another significant source of nutrient loss from the turfgrass nutrient cycle.

Nitrogen is best applied as a slow release, non-nitrate form in most turfgrass fertilization schemes. The reason for this is that nitrate is extremely mobile in soils and will tend to appear in groundwater in very short periods of time. The amount leached will be dependent on the amount applied, the level of rainfall or irrigation or both and on soil physical and textural properties. Because of the high leaching potential of nitrate, it is usually recommended that slow release nitrogen fertilizers be added in which nitrogen occurs as a non-nitrate form in either organic or inorganic formulations. For the Queen's Beach site, nitrogen fertilization with one of the following formulations is recommended:

- Ammonium sulfate ($(NH_4)_2SO_4$)
- Sulfur coated urea (SUC)
- Urea formaldehyde

Each of these formulations provides nitrogen in a form that will be converted to nitrate in the soil. Indigenous soil bacteria will convert the organic forms (urea) to nitrate through a process called mineralization. Once the ammonium from mineralization has been formed, other soil bacteria will convert it to nitrate (called nitrification) for plant uptake. In the case of ammonium sulfate, bacteria will directly convert the ammonium to nitrate. In this way the nutritional status of the turf can be maintained, but water resources can be protected due to the slower availability of nitrogen in these sources. Nitrogen fate and leachate studies with soils of the site have been conducted and described in full in Section 8 of this report.

6.3 SELECTION OF CANDIDATE TURFGRASSES

Turfgrass selection was derived from consideration of several types of warm season turfgrasses commonly used in Hawaii and the arid western US. Warm season turfgrasses are those species having a temperature optimum of 80 to 95°F. They are widely distributed throughout the warm humid, warm subhumid, and warm semiarid climates. The winter temperature is a very important influence on the distribution and use of warm season turfgrasses. Approximately 14 warm season species are utilized for turfgrass purposes throughout the world.

Of the different potential warm season grasses, it is likely that the best candidates for the proposed golf course at the site would be bermudagrass for greens and Zoysiagrass for fairways.

6.3.1 Bermudagrass Use

Bermudagrass appears to be the most likely candidate since it is widely used in the area and hence expresses adaptability to the climatic/soil/environmental conditions of central Oahu.

Bermudagrass is best adapted to moderately well drained, fertile soils of relatively fine texture but will tolerate a wide range of soil types. Bermudagrass growth is usually better on fine textured than coarse textured soils because of the higher fertility level and soil moisture retention associated with fine textured soils. Bermudagrass tolerates a wide range in soil pH (usually 5.5 to 7.5). Salt tolerance is also quite good.

The improved bermudagrasses form a very dense, uniform turf of high quality when grown under proper conditions (climatic and cultural). It is utilized in the warm humid regions on lawns, parks, golf courses (fairways, greens, tees, roughs), roadsides, airfields, athletic fields, general lawn areas. It is especially suited for golf courses due to its excellent wear tolerance and recuperative potential.

6.3.2 Bermudagrass Culture

Bermudagrass does require a medium to high intensity level of cultivation. Tolerance to close mowing is good because of its prostrate growth habit. Since bermudagrass is responsive to fertilization and irrigation, a high intensity of culture is generally needed to obtain optimum turfgrass quality. Bermudagrass is quite prone to thatching because of the vigorous growth rate. Common disease problems of bermudagrass include Helminthosporium, brown patch, dollar spot, Fusarium patch, Pythium blight, and spring dead spot. Common pests include sod bedworms, armyworms, mole crickets, mites, fruit flies, and nematodes. It is also intolerant of the triazine herbicides.

6.3.3 Bermudagrass Cultivar Selections

Several possible cultivars could be used at the site.. Some of the characteristics of these cultivars are noted below.

TABLE 6.3 COMPARISON OF CULTIVAR CHARACTERISTICS

Cultivar	Characteristics	Use
Tidwarf	Dark green color, fine texture, high shoot density, slow growth rate. Medium culture intensity.	Improved shade tolerance, superior tolerance to low mowing, used on greens.
Tifgreen	Dark green color, very fine texture, high shoot density, high intensity culture.	Excellent drought and wear tolerance, good recuperative potential, prone to 2,4-D injury, used on greens.
Tifway	Dark green, medium texture, high shoot density, vigorous growth, prone to thatching.	Used widely on fairways and tees.

Based on this initial assessment, we would recommend Tifgreen for use on greens, since selection of a cultivar that can be maintained with lower inputs of fertilizer and pesticide is a desirable quality from an environmental perspective. If 2,4-D is used on greens at the site, it will have to be used in low quantities as Tifgreen is prone to 2,4-D injury. Zoysiagrass (see below) is recommended for tees and fairways.

6.3.4 Use of Zoysiagrass for Fairways

Zoysiagrass forms a uniform, dense, high quality turf with excellent drought and heat hardiness. It grows well on soils similar to those of the site (moderately acid to neutral with fine texture and moderate to slow drainage characteristics). It also exhibits excellent salt tolerance. Its most desirable feature for this site, would be the moderate level of cultivation required to maintain high quality. Its N requirement is much lower than bermudagrass (roughly one-half to two-thirds) and as such may be used in buffer strips, in areas around sandtraps, and even around the aprons of bermudagrass greens. Zoysiagrass is also free of major disease problems relative to the other turfgrasses. Zoysiagrass also has a slightly yellow tint compared to Bermudagrass and may fit into the overall planning scheme from this perspective. As such it could be used in many areas on the course to decrease the overall input of water, fertilizer and pesticide at the proposed golf course site. Zoysiagrass is not recommended as a green turf due to the extent and quality of the stems produced by Zoysiagrass which affects the overall playability expected on high quality greens.

6.4 WATER USE AT THE PROPOSED GOLF COURSE

A water source now being used for irrigating golf courses and which will be of considerable interest in the future is effluent water. Turf irrigation offers one of the best approaches to disposing of certain types of effluent water. In addition, many golf courses are in reasonable delivery distance of treatment plants. The proposed course will make use of this type of water in order to minimize pressure on limited groundwater supplies.

Sewage treatment plants have three levels of possible treatment. The primary level is concerned with solids removal. The secondary level removes many dissolved impurities, while the tertiary level removes even more impurities. Each level is more expensive. In contrast, soils function as very efficient water filters and offer an economical means of advanced water treatment. Soils have a great capacity to handle organic wastes.

Chemical analyses of typical effluent have shown that nitrogen, chiefly in the form of ammonia and nitrate, is present in an amount of 60 to 100 pounds per acre foot of water, while potassium is in the 200 pound range and phosphates between 60 and 100 pounds. Thus, effluent water may serve as a bonus source of N,P and K. Obviously, if effluent is used, it should be consistently monitored for these nutrients and figured in to the total nutrient requirement of the turf in order to avoid application of excess N and P.

Use of effluent water at the site will have to take into consideration the following factors related to safe use of effluent:

- Some chemicals present in effluent may be injurious to turfgrass growth, and for this reason the water used for irrigation should be continually monitored as suggested by EPA regulations. The main chemical problems arise from industrial contaminants such as brine, heavy metals, and stable organic compounds.
- Five elements are of particular concern and should be frequently monitored in the effluent water. These are cadmium (Cd), copper (Cu), nickel (Ni), zinc (Zn) and boron (B). Current guidelines suggest the following maximum levels for turfgrass:

  Cd: 5 ppb
  Cu: 200 ppb
  Ni: 500 ppb
  Zn: 5 ppm
  B: 1 ppm

There is a waste water treatment plant (WWTP) operating within 2 miles of the site which is proposed to supply about 98% of the irrigation water for the golf course at Queen's Beach. Currently, state of Hawaii regulations require that treated wastewater be delivered via subsurface irrigation systems and not through overhead sprinklers. Subsurface irrigation is required in this case due to the requirement that secondary effluent water cannot be applied within 500 feet of any area where people could be potentially exposed to irrigation spray. If effluent is brought up to the tertiary treatment levels, surface sprinklers or sprayers would be permitted.

The possible chemical impacts due to the exclusive use of waste water for irrigation are discussed fully in Section 7.

7.0 EFFECT OF EFFLUENT REUSE ON GROUNDWATER CHEMISTRY AT THE PROPOSED GOLF COURSE

7.1 EFFLUENT CHARACTERISTICS

Effluent sample chemistry was obtained from the East Honolulu Waste Water Treatment Plant at Hawaii Kai (WWTPHK). Typical element composition is shown below. Arsenic, Cd, Cr,, Pb, and Hg were not detected in the effluent samples while Cu, Ni, Se, and Zn were detected but in levels less than the discharge permit allows.

TABLE 7.1 EFFLUENT COMPOSITION

Analyte	Concentration (mg/L)
Ca	766-774
Mg	257-282
Na	983-1186
K	62-70
Cl	1857-2150
NH_4	1-23
NO_3	14-20
PO_4	1-3
Ni	<0.1
Cu	<0.1
Zn	<0.1
Pb	<0.1
Cd	<0.1
pH	6.8-7.4
Salt	3.3 o/oo

The sample analysis demonstrates several important and unexpected results. First, the salt content of the effluent is extremely saline. In fact, the composition of the water from the treatment plant is almost identical to the groundwater samples collected at the site by WRE which are "brackish" to near seawater in composition. The high salinity of the wastewater suggests that a salt tolerant turfgrass will be a requirement for at least the fairways.

In addition, the Cl content of the samples is in excess of 2000 mg/L. This is substantially higher than can be tolerated by bermudagrass. Thus, irrigation of the greens will likely require blending wastewater with domestic water source to bring the Cl content near to 800 mg/l, a level that can be tolerated by bermudagrass.

Third, the high Na content of the effluent water may adversely affect soil properties such as structure and infiltration.

7.2 IMPACTS TO SOILS AND WATER QUALITY DUE TO EFFLUENT USE

Three important assessments with respect to the use of effluent water at the site are required. These are: (1) potential impacts to soil chemical changes, especially the distribution of Na and Ca on the soil exchange complex; (2) impacts to groundwater from effluent percolate; and (3) impacts to turfgrass species used at the site. Each of these is discussed in detail below.

7.2.1 Expected Water Usage

Prior to examining the effect of effluent water on soils and turfgrass species, some estimate of effluent use is required. The approximate amount of water needed by different turf species was determined and then compared to the amount of rainfall generally occurring at the site on a monthly basis. The difference between water needs and rainfall would then be an estimate of the amount of extra water needed for irrigation. The results are presented in Table 7.2. As noted, water requirements for several species decreased in the order Bermudagrass > Paspallum > Zoysiagrass. Bermudagrass will require about 106 inches per year while Zoysiagrass will require only about 84 inches per year. Assuming average annual rainfall of about 27 inches, then approximately 80 inches of effluent will need to be applied to greens while 72 inches per year will need to be applied to fairways. Table 7.2 also gives projections on gallons of water per day, but these can only be considered as estimates until more precise acreages of greens and fairways can be determined. It is reasonable to expect, however, that a minimum of 700,000 gal of water per day will be used to irrigate the course.

7.2.2 Impacts to Soil

Expected changes to soil chemistry were simulated by simply determining the present relationship between soil pore water and then calculating the changes that would occur when the pore water mixes and is eventually replaced by effluent water. The results of this are presented in Appendix A. The calculations were performed based on the following model.

The primary constituents of the input water, as noted in the Appendix, are the major cations Na, Ca, and Mg. Because Mg is typically selected over any other major cation in soil solutions, its composition on the soil exchange complex is expected to remain relatively constant or increase, causing no adverse effects on soil from a soil physical perspective. Thus, the real concern is whether the exchanger will have any preference for the high concentrations of Na in the solutions. If Na increases significantly on the exchange complex, to greater than 30%, then significant deterioration of the soil structure, due to dispersion, would be expected to occur. Therefore, this process was examined in more detail.

TABLE 7.2 WATER BALANCE FOR QUEEN'S BEACH PROJECT

Means of Rainfall by Month from 1907 to 1973

Month	Rainfall (In.)	Pan Evaporation (In.)	Projected Water Use by Bermuda	Projected Water Use by Zoysia	Projected Water Use by Paspallum	Monthly Water Needs - Greens	Monthly Water Needs - Fairways
January	4.41	4.13	7.67	6.14	7.44	3.26	3.03
February	3.03	4.13	7.79	6.26	7.56	4.76	4.53
March	3.74	5.41	7.91	6.38	7.67	4.17	3.93
April	2.1	5.97	8.15	6.61	7.91	6.05	5.81
May	1.02	7.15	10.4	7.11	8.14	9.38	7.12
June	0.6	8.75	10.6	8.31	9.33	10	8.73
July	0.79	8.45	10.5	8.05	9.2	9.71	8.41
August	0.87	7.47	10.1	8.01	9.08	9.23	8.21
September	0.83	7.3	8.75	7.32	8.97	7.92	8.14
October	2.5	6.45	8.56	7.11	8.49	5.96	5.89
November	2.83	4.33	7.91	6.71	7.71	5.08	4.88
December	3.86	4.06	7.67	6.31	7.54	3.81	3.68
Annual Totals	26.68	73.59	106.01	84.32	99.04	79.33	72.36

Total Water Use for Golf Course

	Fairways	Greens
Acres	114	5
Inches water	72	80
Total Gal	223754594.4	10904220
Gal/day	613026.29	29874.58

In order to determine the exchange complex composition, the selectivity coefficient was calculated that describes Na/Ca exchange. This was done by inserting the exchange compostion determined from earlier measurements and solution Na and Ca concentrations into the following expression:

$$Ca + 2\ NaX = CaX + 2Na$$

and

$$K = (CaX)(Na)^2 / (Ca)(NaX)^2$$

where K = exchange selectivity coefficient
(Ca) = Ca in solution (mol/L)
(Na) = Na in solution (mol/L)
(CaX) = Ca on the exchanger (mol/kg)
(NaX) = Na on the exchanger (mol/kg)

Based on this calculation, the coefficient was found to be near 100 suggesting that the soils of the site have a much higher preference for Ca compared to Na. The Appendix also includes simulations with K = 50 and 10 to look at worst case scenarios.

Once the selectivity coefficient was determined, water with any Na and Ca concentrations could be introduced and new exchange and solution composition at equilibrium be predicted. Thus the change in soil chemistry could be simulated as the effluent water became the prime source of water at the site. To do this the following expression was derived:

Necessary equations: K
Mass Balance
Total (Ca) = (CaX) + (Ca)
Total (Na) = (NaX) + (Na)

Constant exchange capacity and electroneutrality
CEC = 2(CaX) + (NaX)

Substitute above expressions into selectivity exchange equation to solve for NaX:

(CaX) = (Total Ca - NaX)/2
(Ca) = Total Ca - 0.5(CEC) + 0.5(NaX)
(Na) = Total Na - (NaX)

Substitution into the exchange equation yields:

$$a(NaX)^3 + b(NaX)^2 + c(NaX) + d = 0$$

where:

$a = 0.5\ (K + 1)$
$b = K(\text{Total Ca}) - 0.5K(CEC) - 0.5\ (CEC) - (\text{Total Na})$
$c = (CEC)(\text{Total Na}) + 0.5(\text{Total Na})^2$
$d = -0.5(CEC)(\text{Total Na})^2$

The equation was solved using a Newton-Raphson iterative technique based on the ratio of the first derivative of the expression to the 3rd degree polynomial. Once exchangeable Na was calculated, the rest of the variables could then be solved.

Interpretation of the Table is simple. Water with a new composition (effluent) enters the soil and displaces the old pore water. The exchange complex responds to the new input water and comes to equilibrium. Next, more

water enters the soil and the soil again enters a new equilibrium with the effluent water. Eventually the effluent water has brought the soil column to a steady state condition, wherein water that percolates through the soil will have exactly the same composition as the input water. In this case, assuming that depth of soil is approximately 10 feet, such a change would require percolation of effluent water for approximately 40 years. Obviously the upper soil zone will come to equilibrium with the effluent water much more quickly or approximately in 4 years (assuming effluent water composition remains about the same).

The most important feature of the simulation is that in no case does Na on the exchange complex exceed 25%. Thus little change in soil physical structure would be expected.

7.2.3 Impacts to Groundwater

Based on the water balance described above, it is likely that irrigation will proceed at a rate of 1.2 to 1.5 times the amount of water needed to insure adequate soil moisture. If about 80 inches per year is needed by the turf then it is likely that about 16 to 40 inches of water per year could leave the irrigation zone as percolate and eventually reach groundwater. The expected solute composition of the percolate water reaching groundwater is:

Analyte	Concentration mg/L	Comment
Ca	750	Based on exchange data
Na	1100	Based on exchange data
Mg	100	Based on exchange data
K	40	Based on exchange data
Cl	1800	Conservative ion
Phosphate	<0.5	Based on soil adsorption
Metals	<0.001	Based on soil adsorption
Nitrate	<1.0	Most taken up by turf

The impact that this may have on groundwater quality is discussed in the WRE Final Report.

7.2.4 Impacts to Turfgrass Fertility

Due to the high salt content of the effluent water, it will be necessary to blend potable water with effluent water at approximately a 50/50 ratio to avoid injuring the Bermudagrass. Based on earlier estimates of greens acreage (about 5 acres), this will likely approach 30,000 gallons per day. The high salt content is not likely to disturb the Zoysiagrass.

8.0 EFFECT OF NITROGEN FERTILIZERS ON SOILS AND GROUNDWATER QUALITY AT THE PROPOSED GOLF COURSE

8.1 METHODS AND MATERIALS

In order to assess the effect of nitrogen fertilizer use at the proposed course, a set of laboratory column studies with soils collected from the site were conducted (Series LuA). Two paired experiments were conducted. In one set, N, as ammonium sulfate, was applied to two columns, each containing 2 kilograms (kg) of the 0-10" LuA soil. Nitrogen was applied at a rate of 200 kilograms/hectare (kg/ha) or approximately 182 mg N/kg. This rate is high but not necessarily untypical for annual N fertilizer requirements for Bermudagrass. Each column also had a fresh layer of Bermudagrass turf purchased locally. In addition, one set of columns had no N applied and served as a control. Irrigation was applied as "rainfall" and was equal to about 3600 ml of water for the column (6" diameter). The LuA soil has a saturation water holding capacity of approximately 45% by weight and thus application of 3600 ml of water was roughly equal to 4 pore volumes of solution. Water was applied to the column after the addition of fertilizer and effluent from the bottom of the column was collected continuously. Nitrogen (ammonium and nitrate-N) was analyzed in the effluent after the collection of each of the 4 pore volumes. At the end of the experiment (about 4 weeks due to the low permeability of the soils), the columns were cut into 4 sections and N (ammonium and nitrate-N) determined in each section. This allowed for estimates of N mass balance.

A replicate study was conducted using the same amounts of fertilizer on Bermudagrass, but with a sand/peat mixture (85-15) in order to simulate N movement in the greens.

8.2 RESULTS

The results of the N study for the LuA columns are noted below. The effluent concentrations of nitrate detected in the leachate was extremely low, less than 2 mg/l, for all pore volumes. The low leaching potential is due to the fact that the soils are relatively impermeable, such that nutrient and ion movement is severely restricted. Comparison of the data to the control sample illustrates the fact that there is considerable nitrogen (as nitrate) in the soils which is consistent with the generally high fertility status of these heavily textured soils.

Table 8.2 illustrates the partitioning behavior of both nitrate and ammonium in the soil columns at the end of the study. As noted, both nitrate and ammonium are primarily contained within the 0-2.5" increment of soil, again due to the low permeability of the soils. Here nitrate was found to be about 181 mg/kg while ammonium was much lower at only 16 mg/kg. Both species are found in much lower concentrations below the 2.5" depth interval with no nitrate found below 5" in the column.

TABLE 8.1 NITRATE LEACHING FROM LUA SOILS

Sample	Pore Volume	Concentration (nitrate/pore)	Cumulative mass (mg)	% Recovered (Cumulative)
196 kg/ha	1	0.54 ug/ml	0.49	0.1
	2	1.97 ug/ml	2.27	0.6
	3	0.61 ug/ml	2.82	0.7
	4	0.11 ug/ml	2.92	0.8
196 kg/ha reps	1	0.62 ug/ml	0.56	0.1
rep	2	2.30 ug/ml	2.63	0.7
rep	3	0.49 ug/ml	3.07	0.8
rep	4	<.10 ug/ml	3.07	0.8
Control	1	0.21 ug/ml	0.19	-
	2	0.91 ug/ml	1.01	-
	3	0.22 ug/ml	1.21	-
	4	<0.10 ug/ml	1.21	-

TABLE 8.2 NITRATE AND AMMONIUM AS A FUNCTION OF DEPTH IN LUA SOIL COLUMNS

Depth (inches)	Nitrate (mg/kg)	Ammonium (mg/kg)
0 -2.5"	181	16
2.5 - 5"	1	3
5 - 7.5"	0	2
7.5 - 10"	0	2

The data in Table 8.2 is also presented in Figure 8.1. The figure emphasizes the low leaching potential for these soils, as both ammonium and nitrate only occur in significant concentrations in the top 2 inches of soil material. Very little (less than 10 mg/kg) of either species had leached below the top 2 inches of soil.

We also examined N movement from the simulated greens (ie. sand/peat mixtures). This data is presented in the Table 8.3. In contrast to the LuA soils, much more leaching of nitrate has occurred in these sandy mixtures, although the amounts in terms of total nitrate are still less than 10% of the amount applied. Table 8.4 and Figure 8.2 shows the distribution of the two species in depth increments. The data are similar to that observed for the LuA soils; the top 2 inches of soil has effectively tied up both species. Leaching potential in the sandy peat mixtures is much greater than the LuA soils but still appears to have significant attenuation abilities, no doubt due to the adsorptive capacity of the thatch layer and the presence of the peat in the mixture.

TABLE 8.3 NITRATE LEACHING FROM SAND/PEAT MIXTURES

Sample	Pore Volume	Nitrate in leachate (mg/l)	Cumulative N recovered (mg)	% N recovered (Cumulative)
Sand/peat	1	6.95	6.23	1.61
	2	11.99	17.02	4.41
	3	6.88	23.21	6.01
	4	4.16	26.95	6.98

TABLE 8.4 NITRATE AND AMMONIUM AS A FUNCTION OF DEPTH IN SAND/PEAT MIXTURES

Depth (inches)	Nitrate (mg/kg)	Ammonium (mg/kg)
0-2.5"	128	27
2.5-5.0"	11	3
5.0-7.5"	5	2
7.5-10.0"	2	1

8.3 IMPACT OF NITROGEN ON RUNOFF WATER QUALITY

Based on the column leaching studies it was shown that only small concentrations of either nitrate or ammonium were leached from the columns under applications of water similar to annual rainfall. To assess the impact on water quality of runoff from the site, the amount of runoff water that could occur at the site under the worst case situation was calculated. It was then assumed that all nitrate and ammonium in the upper 2.5" could react with this runoff. This calculation would then provide estimates of nitrate and ammonium concentrations in runoff. By comparing these values to accepted water quality criteria, assessment of whether water quality would be adversely affected could be made. The conditions for this simulation were:

1. The occurrence of a 100-year storm which results in 13" rainfall over a 24 hour period. In most months, especially April through October, evapotranspiration at the site is equal to or greater than rainfall. Thus little or no runoff occurs at the site.

2. Runoff water is determined from the difference between precipitation rate and soil infiltration rate. When precipitation exceeds the ability of the soil to absorb water, runoff occurs. The infiltration rate is roughly only 0.008 cm/min. Rainfall under the 100-year storm event is 0.023 cm/min. Thus runoff is approximately 65% of incoming rainfall in cm.
3. The simulation is performed on a square meter basis.

4. All nitrate and ammonium in the upper 2.5" is available for dissolution and mixing with runoff water.

Based on these initial conditions the following results were observed.

Scenario	Species	Total Mass/m^2	Maximum Concentration in Runoff
Greens	Nitrate	3.55 kg	16.5 mg/L
	Ammonium	0.75 kg	3.5 mg/L
Fairways	Nitrate	5.01 kg	23.3 mg/L
	Ammonium	0.44 kg	2.1 mg/L

The simulation shows that all observed maximum concentrations of nitrate and ammonium are generally less than 25 mg/L. Currently the United States Environmental Protection Agency (USEPA) sets acceptable nitrate levels in water at 45 mg/L or less. Thus, while significant nitrate levels can be observed in this scenario, the levels are well below acceptable drinking water standards. Thus runoff and subsequent water quality are not adversely affected.

8.4 SUMMARY

On the basis of this study and site specific information, several conclusions can be inferred:

1. Nitrogen (N) is a relatively easily managed component at the site. It is expected that N fertilization at the site will entail use of relatively insoluble (slow-release) materials for fertilization of turf. Application will be based on initial soil test results, turf requirement, and turf condition throughout the year. Treated effluent will be used as both a source of water at the site and as an additional source of nitrogen.

2. If nitrogen residues are present in a soluble form above a concentration that can be used by the turfgrass and if water moves through thatch or soil, leaching of nitrogen past the root zone can occur. If the nitrogen is not in a soluble form, such as urea, leaching losses of nitrogen are significantly reduced.

3. Increasing the rate of nitrogen application to highly sandy greens will lead to a deterioration in drainage water quality. On sandy loam greens, increased nitrogen fertilization commensurate with uptake capacity of specific turfgrass species should not further reduce water quality.

4. The leaching of fertilizer nitrogen applied to turfgrass at the site will be related to: soil texture and degree of conductivity of soil water; the amount of subsurface movement of water; nitrogen source, formulation, rate, and timing; and irrigation and rainfall. Significant leaching of nitrate will occur when soluble nitrogen is applied at a rate higher than normal on turfgrass grown on sandy soil. The potential for subsurface loss of nitrogen is further increased when fertilization exceeds plant demand or soil storage or both

5. If fertilization of turfgrass at the site does pose a threat to surface water and groundwater quality, several management options are available to minimize or eliminate the problem. Limiting irrigation to replacement of soil moisture used by the cover, use of slow release sources of nitrogen, and less sandy soils would significantly reduce or eliminate nitrate leaching from turfgrass. Timing of fertilizer application in relation to active uptake and potential runoff events as well as the use of realistic nitrogen application rates are primary methods to reduce nonpoint source losses of nitrogen from turfgrass systems. These recommendations are clarified in the Turf Management System.

9.0 EFFECT OF PESTICIDE USE ON SOILS AND GROUNDWATER AT THE PROPOSED GOLF COURSE

The use of pesticides is a common practice for maintaining the health and vigor of turfgrass. However, numerous studies conducted over the past 20 years have shown that over-application and inappropriate application of pesticides can lead to significant and persistent degradation of soils, surface water and groundwater. In order to determine if pesticide use at the site will have such an impact, Two simultaneous studies were conducted. The first of these was a laboratory column study similar in nature to the nitrogen study described in Section 8. Pesticides that could be used at the site were applied to soils from the area and their leaching and degradation patterns noted. The data from the study will allow characterization of pesticide behavior on the short term. For example, pesticides that degrade quickly are considered non-persistent and may pose only short term water quality problems if sufficient leaching occurs for mobilization. **It is important to note that the simulations performed here represent worst-case scenarios. If pesticide loss is minimal under these conditions, then under more normal conditions little or no loss is likely to occur.**

9.1 PESTICIDE LEACHING POTENTIAL

Use of basic pesticide properties and site specific partitioning (Koc) data for determining chemical leaching potential is a valuable means of assessing the likelihood of chemical loss through subsurface water movement. In this exercise the Groundwater Ubiquity Score or GUS was used. This score is based on a weighted logarithmic function such that

$$GUS = \log(t1/2) \times (4 - \log(Koc))$$

where

t1/2 = degradation half-life (in days)
Koc = organic matter partition coefficient derived from site soils.

The GUS provides a consistent index of leachability based on pesticide mobility and persistence. Chemicals with a GUS greater than 2.8 are considered "leachers" and chemicals with a GUS less than 1.8 as "nonleachers". Transition compounds have values between 1.8 and 2.8. Using the Koc values derived earlier and the degradation rates derived from the column experiments in section 9.2, we derived GUS values for the compounds suggested for use at the site. The results are noted below:

TABLE 9.1 GUS LEACH TEST RESULTS

Compound	Koc (ml/g)	t1/2 (days)	GUS	Classification
MSMA	142,000	1000	-3.5	nonleacher
2,4-D	3600	8	0.40	nonleacher
Dicamba	1.2	11	4.08	leacher
Chlorpyrifos	5200	14	0.33	nonleacher
Chlorthalonil	4620	7	0.28	nonleacher

Based on this classification, only Dicamba represents a leaching threat due to the low Koc value and potentially high water solubility. All other compounds are considered to be nonleachers. The results are interesting in that MSMA is considered to be a nonleacher, yet inorganic breakdown products from this compound can have low soil adsorption affinity and high water solubility. The laboratory column study discussed next, addresses this question on a more site specific basis.

9.2 PESTICIDE IMPACT (PERSISTENCE AND LEACHING) FROM LABORATORY COLUMN STUDIES

Five different pesticides were evaluated in columns constructed exactly as noted before for the nitrogen study (Bermudagrass turf underlain by 2kg of LuA soil in 6" diameter columns 10 " in length). Prior to the examination of leachate composition or column sectioning for residue analysis, a small adsorption study was conducted for the compounds. In this study, several different concentrations (ranging from 0 to 1 mg/L) of the pesticide formulations were made and added to 2 grams of the 0-10" LuA soil (soil/solution ratio was 2 grams/10 mL). The mixtures were agitated for 24 hours in the dark and centrifuged. The supernatants were collected and analyzed for pesticide. The difference between the original concentration of added solution and the equilibrated mixtures was considered sorbed to soil particles and organic matter. From these data, soil adsorption coefficients could be developed. The results are noted below:

TABLE 9.2 Koc RESULTS FOR CANDIDATE PESTICIDES

Compound	Koc (ml/g)	Literature Koc
MSMA	142,000	100,000 -300,000
2,4-D ester	3,600	1000 - 68,000
Dicamba	1.2	<6
Chlorpyriphos	5,200	2500 - 14,800
Chlorthalonil	4620	1380 - 5800

Koc = soil organic matter partition coefficient.

Pesticide was then added at the same rate in 4 different columns for degradation studies. Total amount of chemical added to each of the columns was:

Compound	Amount added/column (mg)
MSMA	3.5
Dicamba	3.5
2,4-D	3.5
Chlorthalonil	3.5
Chlorpyriphos	3.5

All compounds were added after mixing with water. The formulations were sprayed onto the surface of the columns, and then irrigation with water was started. Leachate was collected continuously over the 28 days of the study. Irrigation occurred with only 10 inches of water compared to the 30 inches in the nitrogen study or about 1200 mL of water in order to keep the columns developing a head of water. At 1, 7, 21, and 28 days, a column was harvested and sectioned into 4 equal lengths (each 2.5") and the soil analyzed for residue. From this we could estimate degradation rates for the compounds and also observe the distribution of pesticide with depth.

9.3 COLUMN RESULTS

9.3.1 Distribution as a Function of Time

Results of the column study are presented in Table 9.3 and Figures 9-1 to 9-5. Dicamba residues were primarily found in the 0-2.5" depth increment at all sampling dates. This suggests that the turf thatch and soil organic matter effectively tied up the dicamba. Although residues were found in the upper soil samples, they decreased very quickly from initial amounts of almost 3000 ug to only 122 ug in just 28 days. The half-life appears to be on the order of 7-10 days. 2,4-D residues also decreased quickly from initial amounts of about 3100 ug to less than 75 ug by the end of the 28 day sampling period with a half-life estimated at about 7 days. As with dicamba most of the residues were confined to the top 2.5" segment. Chlorthalonil distribution over time was similar to the dicamba results where the initial amount of 3000 ug degraded to only 121 ug over the 28 day sampling period. Chlorpyriphos and MSMA represented the two most persistent compounds. Chlorpyriphos residues were still on the order of 1000 ug after 28 days, while MSMA residues had not decomposed to any significant degree even after 28 days. This is consistent with the half-life noted for the two compounds of 20 and 1000 days for chlorpyriphos and MSMA, respectively.

9.3.2 Distribution with Depth

All chemicals used in the study showed similar attenuation patterns with depth. The majority of chemical (usually greater than 90%) was always tied up in the top 2.5" of soil and thatch. Over time (7 days in most cases) some chemical leached to lower depths. Chlorthalonil and chlorpyriphos did not reach the bottom of the columns even after 28 days and MSMA was not detected in the bottom of the column until the last sampling date. The two most mobile compounds, dicamba and 2,4-D both were detected at the bottom of the columns after 7 and 14 days respectively with concentrations ranging from 3.3 ppb to 16 ppb for dicamba and 1.3 to 3.2 ppb for 2,4-D.

TABLE 9.2 PESTICIDE REMAINING (IN UG) AS A FUNCTION OF TIME AND DEPTH IN LUA SOIL COLUMNS

Compound		Time (Days)			
Dicamba	Depth (in)	1	7	14	28
	2.5	2860	2234	1192	122
	5	420	119	31	14
	7.5	71	11	3	2.5
	10	0	7.4	2.5	3.5
	Leachate	ND*	8 ppb	16 ppb	3.3 ppb
2,4-D	2.5	3112	1811	859	72
	5	310	81	11	8
	7.5	16	4	6	3
	10	ND	2	8	5
	Leachate	ND	ND	3.2 ppb	1.3 ppb
Chlorpyrifos	2.5	2650	1712	1422	1212
	5	111	56	31	18
	7.5	3.2	1	2	1
	10	ND	2.1	1.1	ND
	Leachate	ND	ND	ND	ND
Chlorthalonil	2.5	2996	1514	867	121
	5	41	11	15	20
	7.5	ND	2	2	3
	10	ND	ND	ND	ND
	Leachate	ND	ND	ND	ND
MSMA	2.5	3400	3327	3333	3250
	5	140	127	156	100
	7.5	ND	31	42	60
	10	ND	ND	8	15
	Leachate	ND	ND	ND	3.2 ppb

9.3.3 Pesticide Fate in Sand/Peat Mixtures

A similar but abbreviated study was conducted with the chemicals in sand/peat mixtures (80/15) which simulates green conditions. Sampling and analysis occurred on the same time intervals but only leachate concentrations were measured and compound remaining in the top 2.5". The results are presented in Table 9.4. As noted in the results, there was typically more pesticide found in leachate from the sand/peat columns due to the more porous nature of the material. Highest leachate concentrations were observed for dicamba (3-40 ppb), MSMA (2-19 ppb), and 2,4-D (non detectable (and)-18 ppb) and much lower amounts for chlorthalonil and chlorpyriphos (and-1.1 ppb). In general, we observed about 10 times more pesticide in leachate from the sand/peat columns than was observed for the LuA soil columns. The concentrations were still quite low; no doubt due to the adsorptive capacity of the peat and thatch layer in the columns.

TABLE 9.4 PESTICIDE REMAINING (IN UG) IN THE TOP 2.5" OF SAND/PEAT COLUMNS UNDER BERMUDAGRASS. LEACHATE CONCENTRATIONS IN PPB (UG/L).

Compound		Time (days)			
	Depth (in)	1	7	14	28
Dicamba	2.5	2990	2117	1091	96
	Leachate	3.5	15	22	39
2,4-D	2.5	3220	1692	731	47
	Leachate	ND	11	7	18
Chlorpyrifos	2.5	358	1865	1501	1117
	Leachate	ND	0.5	1	1.1
Chlorthalonil	2.5	3201	1599	901	89
	Leachate	ND	ND	ND	ND
MSMA	2.5	3119	3220	2988	2872
	Leachate	1.8	13	19	17

* ND = None Detected
** Leachate concentrations are reported in ug/L (ppb)

9.4 SIGNIFICANCE OF FINDINGS

The column data provided extremely useful information concerning the expected behavior of the pesticides in soils at the site. This information can be summarized as follows:

1. Pesticide partitioning data showed that greater than 90% of the pesticide added to the columns remained in the upper 2.5" of the LuA soil. This layer also contained thatch from the bermudagrass turf. The thatch and soil organic matter provided a significant sink for pesticide and clearly prevents significant downward migration of all the pesticides. Even dicamba, a compound that is widely recognized as a potential threat to groundwater was attenuated such that only a few ppb was found in leachate from the columns.

2. Leaching from the sand/peat mixtures was, in general, higher than the LuA soils, but still quite low considering the solubility and mobility of dicamba, 2,4-D and MSMA. Under normal conditions even Dicamba will be attenuated effectively. Careful management will, however, be required.

3. The fact that downward migration of the pesticides is low and that much of the pesticide remains in the top several inches does suggest that pesticide movement from the surface via surface water runoff is possible. An evaluation of this mechanism of transport is presented later in this section of the report.

4. Pesticide degradation followed predictable patterns. Dicamba, 2,4-D and chlorpyrifos degraded

quickly to less than 2% of the amount added in only 28 days. The only chemical that did not degrade quickly was MSMA which is known to have a half-life of about 1000 days.

5. Some arsenic (from MSMA) was detected in column leachate. Because MSMA is persistent, considerable leaching may occur over long periods of time. This compound is not recommended.

6. Leachate potential was predicted by GUS indexing. Only Dicamba consistently showed detectable groundwater leachate concentraions. As noted, it can be used with careful management.

9.5 PREDICTING PESTICIDE RUNOFF

In order to predict surface runoff loss, data from the column studies was used along with climatic data obtained from the site representing rainfall conditions for the last 70 years. In this way, the effect of excess rainfall mixing with chemical residue in the surface of soil to produce chemically impacted runoff could be simulated. In order to make this a meaningful exercise initial conditions were set as described below:

1. The chemical residue available for impacting runoff would be limited to that occurring in the upper 2.5" of soil/thatch. Residue occurring below this would not mix with incoming rainfall to produce runoff.

2. Rainfall was set to occur 1 day after pesticide application. This would represent the worst possible case, as pesticide application is always applied under zero rainfall conditions. Since only 1 day would elapse between application and precipitation, most of the chemical would still be present and confined to the upper soil zone, an additional worst case scenario.

3. Rainfall data was used that mimics a 100-year storm event. Under this scenario 13" of rain would fall in a 24 hour period.

4. 1 years worth of pesticide was applied (or 1.94 kg/ha) at one time. This also represents a worst case situation.

5. Pesticide volatilization was accounted for by noting the difference between the chemical applied and the amount of residue recovered after 1 day. Significant microbial degradation would not occur in 24 hours, thus any pesticide loss would be likely due to volatilization.

6. The amount of rainfall available for runoff would be calculated by the difference between infiltration or hydraulic conductivity and the amount of precipitation.

7. Initial conditions: Summarized:

Rainfall	13"/24 hrs (1000-year storm) or 0.023 cm/min
Infiltration rate	0.008 cm/min
Area of site	1 m^2
Runoff	21.5 cm
Volume of runoff/m2	215 L
Application rate 194 mg/m^2	
Mass of soil/m^2 27.8 kg	

Based on these initial conditions, the mass and concentration of each chemical expected in the 215 L of runoff occurring under this scenario could be predicted. This was done by substituting the initial conditions into the expression for Koc which predicts the new partitioning of chemical from the solid phase into the volume of runoff water that interacts with the top 2.5 cm of water in the $1m^2$ area. The results are summarized below.

TABLE 9.5 PESTICIDE LOSS IN RUNOFF

Compound	ug removed in runoff (m^2)	% of residue loss as runoff	Runoff concentration (ppb)	% loss through volatilization
MSMA	10.6	0.005	0.049	0.00
2,4-D	369	0.21	1.71	1.80
Dicamba	134,505	85.5	625	4.31
Chlorpyriphos	216	0.15	1.00	21.1
Chlorthalonil	275	0.17	1.29	13.3

Based on this analysis the following conclusions can be drawn:

1. The loss of chemical residue by runoff decreased from Dicamba >> 2,4-D > Chlorthalonil > Chlorpyriphos > MSMA. In general, only Dicamba loss was significant compared to the total applied.

2. Runoff concentrations were less than 2 ppb for all compounds except Dicamba. Dicamba concentrations in runoff were very high, approaching 1 ppm (625 ppb).

3. MSMA appears to be the least hazardous chemical in terms of leachate and runoff potential. However, MSMA is a persistent compound and may pose long-term problems due to subsurface accumulation of As. The ultimate fate of As in soils from the site is unknown. Thus MSMA must not be used.

4. Dicamba appears to pose the most problems at the site in terms of groundwater leaching and surface runoff potential. This compound must only be used under arid conditions where no immediate precipitation is expected. If used in this way, degradation will rapidly diminish the amount of Dicamba residues occurring in soils at the site.

5. Volatile loss of pesticide at the site is expected to be significant due to the strong trade winds. Volatile losses in the laboratory decreased in the order chlorpyriphos > chlorthalonil > dicamba > 2,4-D > MSMA. Pesticide application measures for minimizing drift are noted in section 10.

9.6 SUMMARY

Based on the different approaches used for assessing chemical impact at the site, the following summary can be derived.

The column data provided extremely useful information concerning the expected behavior of the pesticides in soils at the site. This information can be summarized as follows:

1. Pesticide partitioning data showed that greater than 90% of the pesticide added to the columns remained in the upper 2.5" of the LuA soil. This layer also contained thatch from the bermudagrass turf. The thatch and soil organic matter provided a significant sink for pesticide and clearly prevents significant downward migration of all the pesticides. Even dicamba, a compound that is widely recognized as a potential threat to groundwater was attenuated such that only a few ppb was found in

leachate from the columns under worst case conditions.

2. Leaching from the sand/peat mixtures was in general higher than the LuA soils, but still quite low considering the solubility and mobility of dicamba, 2,4-D and MSMA. Careful management of Dicamba is required, while MSMA should not be used.

3. Pesticide degradation followed predictable patterns. Dicamba, 2,4-D and chlorpyrifos degraded quickly to less than 2% of he amount added in only 28 days. The only chemical that did not degrade quickly was MSMA which is known to have a half-life of about 1000 days. Some arsenic (from MSMA) was detected in column leachate. Because MSMA is persistent, considerable leaching may occur over long periods of time. This compound must not be used.

Simulations provided a powerful tool for assessing leaching potential and runoff potential under worst case scenarios. Application of GUS indexing revealed the following:

Compound	Koc (ml/g)	t1/2 (days)	GUS	Classification
MSMA	142,000	1000	-3.5	nonleacher
2,4-D	3600	8	0.40	nonleacher
Dicamba	1.2	11	4.08	leacher
Chlorpyrifos	5200	14	0.33	nonleacher
Chlorthalonil	4620	7	0.28	nonleacher

Based on this classification, only Dicamba represents a leaching threat due to the low Koc value and potentially high water solubility. MSMA should be avoided due to potential inorganic As leaching which GUS cannot predict.

Runoff simulations were also performed and the following conclusions drawn:

1. The loss of chemical residue by runoff decreased from Dicamba >> 2,4-D > Chlorthalonil > Chlorpyriphos > MSMA. In general, only Dicamba loss was significant compared to the total applied.

2. Runoff concentrations were less than 2 ppb for all compounds except Dicamba. Dicamba concentrations in runoff were very high, approaching 1 ppm (625 ppb).

3. As noted earlier, Dicamba can be problematic if applied under the wrong environmental conditions. In general, its use is appropriate for the site due to the low rainfall, and low runoff and leaching conditions usually observed.

10.0 PROPOSED INTEGRATED TURF MANAGEMENT PLAN FOR THE PROPOSED GOLF COURSE: MINIMIZATION OF CHEMICAL AND WATER QUALITY IMPACTS

10.1 INTRODUCTION

Selection of appropriate chemical practices for nutrient and pest management is an essential component of a Turf Management System (TMS). Continued availability of both multicomponent chemical and nonchemical control strategies are necessary to avoid future pest resistance, pest resurgence, and to maintain turfgrass health and quality. The aesthetic standards for turfgrass in North America are so high that even limited insect and disease damage is considered intolerable. Despite advances in alternate control strategies, application of insecticides and fungicides may still be the only effective response to heavy infestations of insects and disease. Pesticides and fertilizers can be applied using management practices to reduce adverse water quality and environmental effects. Many of these practices have been proposed for use in agricultural, urban, and turfgrass systems.

The following discussion of management practices is intended as an outline of general principles that should be incorporated at the site. Specific management of pesticides and fertilizers must be designed based on site specific conditions, as well as federal, state, and local regulations. Managing the type, amount, formulation, placement, and timing of pesticide and fertilizer applications will help to accomplish pest control, nutrient, water quality, and environmental goals.

10.2 PESTICIDE USE AND CONTROL

1. Label. Only pesticides specifically labeled for application should be applied; and then only by properly registered, certified, and trained personnel. **All pesticide use should comply strictly with local, state, and federal regulations.** Following label recommendations, obtaining certification to apply pesticides, and training in the appropriate pesticide application techniques are essential components for continued use of pesticides in TMS.

2. Selection criteria for the type of pesticide should include consideration of the target species or disease, pesticide characteristics, and site characteristics. Important pesticide properties include efficacy, solubility, formulation, degradation rate, volatility, adsorption, potential toxicity to natural pest enemies, and toxicity to wildlife, nontarget or beneficial organisms. Critical site characteristics and soil properties related to pesticide efficacy and fate are soil texture and organic matter content, local and regional geology, depth to groundwater, proximity to well heads and surface water, topography, and climate. Pesticides that minimize the pollution potential should be selected.

Site Recommendations:

1.) Construction phase: If topsoil is brought in for green construction, then a fumigant may be needed. Based on pesticide history at the site, a pre-emergent pesticide may be necessary during construction. In general, it would be advisable to avoid this practice.

2.) Maintenance phase: Initial pesticide selection has been made, but modifications can be made as more information becomes available based on observed behavior and efficacy in the field.

3.) Reducing the frequency of pesticides applied to turfgrass may be the single most effective practice to reduce potential adverse environmental effects.

4.) Selection of less toxic, less mobile, and less persistent pesticides, or use of alternate control strategies will help reduce potentially adverse environmental effects. Depending on site characteristics, consideration of the potential mode of chemical loss could reduce environmental loading, potential for contamination of water resources, and adverse effects on non-target organisms.

5.) Controlling the timing and amount of a pesticide application in relation to local environmental conditions, especially rainfall, determines the potential for offsite movement and degradation characteristics. Restricting application prior to anticipated storm events is effective in reducing surface and subsurface losses of pesticides.

6.) Action thresholds permit control of pests within economic constraints and reduced levels of pesticides. Other factors to consider are the use of resistant turfgrass species and cultivars and TMS concepts. **Applying pesticides only when and where necessary will significantly decrease chemical loading and adverse effects on the environment.**

7.) Selection of pesticide formulations also influences pesticide fate and losses. Wettable powders, dusts, and microgranules are generally most susceptible to surface and leaching losses.

8.) Application methods influence the partitioning and potential effectiveness of pesticides. Proper application rates, equipment selection and calibration, and careful application to the target site will ensure effective use of the applied pesticide. Spot applications will reduce the amount of chemical applied to turfgrass and limit total environmental loading.

9.) Incorporation of pesticides, placement below the soil/thatch surface, and 'watering in' reduces exposure to runoff process and enhances soil adsorption.

10.) Proper equipment maintenance and calibration is essential for even applications at the volumes intended by the user. All label instructions, storage requirements, and regulations must be followed to insure safe handling of pesticides. Proper mixing, handling, and loading prior to application will reduce fill-site contamination. Closed systems for loading and mixing pesticides are especially useful in reducing contamination of the site and nearby waters.

11.) Proper disposal of unused chemicals and containers will ensure safety of the user, water resources, and non-target organisms. Pesticide applicators should avoid chemical exposure by safe handling practices including use of protective clothing, respirators, gloves, and shoes.

Specific recommendations pertaining to items 3-11 should be based on site conditions as they occur. A prescription approach to problem solving will result in an inflexible schedule that cannot incorporate new information or case by case assessments. Guidelines have been established for these concerns by the Golf Course Superintendents Association and can be incorporated based on the judgement of the Golf Course Supervisor.

12.) Chemigation. Use of anti-back-siphoning devices in chemigation equipment will reduce potential for pesticide contamination of groundwater or other water supplies during irrigation. Pesticides should be applied through irrigation equipment only when appropriate and when specific label instructions are available. Environmentally safe chemigation practices include: 1) flushing of injection equipment to prevent pesticide accumulation; 2) flushing the irrigation system after pesticide injection; 3) use of properly calibrated equipment; 4) preventing runoff of water-pesticide mixture; 5) avoiding application to permanent or semi-permanent standing water on or near fields; and 6) periodic monitoring of equipment to ensure proper application to the intended target.

13.) Assessment of potential offsite transport of chemicals by runoff or leaching losses prior to application will provide essential information on selection of pesticides appropriate for a specific site. Computer models and qualitative indexes could be adapted for this approach (See Pesticide Section).

15.) Quality Assurance/Quality Control (QA/QC). Development and implementation of quality control and quality assurance guidelines for pest management will ensure that TMS practices are used with reasonable accuracy by field personnel.

10.3 NUTRIENT MANAGEMENT AND CONTROL

The critical principles of nutrient management at the site consistent with TMS programs are:

1.) Using minimal rates of nitrogen and phosphorus to maintain nutrient levels needed to sustain turfgrass quality is one of the primary management practices used to minimize both surface and subsurface losses of nutrients.

2.) Improved Efficacy. Decreased environmental loading of nutrients requires improvements in turfgrass uptake efficiency. This is achieved through a) selection of realistic goals for turfgrass quality; b) selection of application rates to meet these quality goals; c) use of soil and tissue tests to establish proper application rates; and d) use of nutrient application history or credits. Records of all forms and sources of nutrients applied to turfgrass is essential to determine rates of fertilizer application. Records of nutrient applications should include the types and amounts commercial fertilizers, clippings returned, effluent water used, as well as other organic sources such as compost and topdressing.

3.) Timing. Application of nutrients at the times and amounts commensurate with turfgrass growth requirements is one of the single most important management practices used for reduction of offsite transport of nutrients and mitigation of adverse environmental effects. The optimum time of application depends on turfgrass species and cultivar, climate, soil conditions, and chemical formulation of the fertilizer. Application of nitrogen after turfgrass uptake of nitrogen has ceased may lead to possible surface and subsurface losses of nitrogen.

4.) Patterns and intensity of traffic on golf courses can affect turfgrass density, soil compaction, and the rates and timing required for fertilization. These factors could affect pollution potential, especially for surface runoff. Management of traffic on golf courses to minimize surface runoff, soil compaction, pest infestations, and the need for frequent fertilizer and pesticide applications will reduce potential losses of water and applied chemicals.

5.) Application techniques that will reduce surface and leaching losses include nutrient incorporation into soil when possible and frequent applications of reduced amounts of fertilizer. These techniques reduce movement of nutrients in solution and increase application efficiency.

6.) The source and formulation of fertilizer used also influences the potential for offsite transport. Where leaching is a problem, slowly available sources of nitrogen should be used in place of readily available sources. Urea, though chemically an organic compound, is readily available and subject to movement in water. Many organic sources of nutrients offer slower release and may delay nutrient availability until required for turfgrass growth. The organic forms of nitrogen are released at rates commensurate with the rate of turfgrass growth. However, appropriate rates and placement are critical even for organic sources of nutrients. Overapplication of slow release and organic forms of nitrogen must be avoided to reduce the long-term potential for groundwater contamination.

7.) Slow release nitrogen fertilizers and nitrification inhibitors have potential for reducing the environmental impacts resulting from losses of nitrates. However, slow release fertilizers may have problems in matching timing of release with critical turfgrass growth periods. Some nitrification inhibitors (e.g. nitrapyrin) have proven effective in slowing conversion of ammonium to nitrate. However, the effectiveness of the inhibitor for reducing nitrogen losses in runoff, leaching, and by volatilization is dependent on climatic conditions, soil conditions, and water management practices.

8.) Proper calibration of equipment will ensure proper placement and rate of nutrient delivery. Improper calibration and equipment maintenance will result in over or under application and uneven distribution of nutrients. Appropriate handling and loading procedures will prevent localized spills and concentrations of fertilizers.

9. Irrigation, drainage, water management, and traffic effects are critical factors in potential leaching and surface runoff of nitrogen. Leaching losses are increased with irrigation of shallow rooted crops on sandy soils. Accumulated nitrates in irrigated soils will be leached past the rooting zone when excess irrigation water is applied to reduce salt accumulation in the surface soil. On sandy soils excess nitrates will accumulate in the soil during years with normal fertilizer application, but with low moisture input and poor turfgrass development. In subsequent years with normal levels of precipitation or irrigation, excess nitrates accumulated in the soil may be available for leaching. Subsurface losses are reduced if turfgrass or microbial population recovers the nitrogen from the soil or adequate nutrient credits are applied in determining rates of additional nitrogen application.

10.) Maintaining good turfgrass growing conditions will reduce both surface runoff losses and subsurface losses of plant nutrients. Preventing pest damage to turfgrass, adjusting soil pH for optimum growth, providing good soil tilth for root development, planting suitable turfgrass species and cultivars, and improving water management practices will increase turfgrass efficiency of nutrient uptake.

11.) Assessment of potential offsite transport of chemicals by runoff or leaching losses prior to application will provide essential information on selection of nutrient management practices appropriate for a specific site. Site characteristics such as soil texture and organic matter content, geology, depth to groundwater, proximity of loading areas to well heads, proximity to surface water, topography, climate, and the effect of traffic on turfgrass density and soil compaction provide qualitative indications of site potential for runoff and leaching losses of nutrients. Computer models and qualitative indexes currently could easily be adapted for this approach.

12.) QA/QC. Again, development and implementation of quality control and quality assurance guidelines for nutrient management will insure that integrated practices are used with reasonable accuracy by field personnel.

10.3.1 Suggested Fertilization Guidelines

The following is a summary of typical fertilizer management practices used for different parts of a golf course.

Putting Greens Preplant incorporation of fertilizer into the putting green zone is required in almost all situations. The specific rate of application and ratio of fertilizer incorporated is usually based on soil test guidelines. Phosphorus and potassium are the two nutrients whose application rates should be based on soil test results. Nitrogen is usually applied at a rate between 1.5 and 3 pounds of nitrogen per thousand square feet. Golf course supervisors frequently suggest a range of nitrogen application from 0.3 to 1.2 pounds of nitrogen per thousand square feet per growing month. Actual rates of application depend on turfgrass species, climatic conditions, and cultural management objectives. The higher rate of nitrogen is preferred, with 40 to 60 percent of the nitrogen being in a slow release form. Fertilizer is usually applied just prior to planting and incorporated into the upper 3 to 4 inches of the soil root zone.

The nutrient requirements of established putting greens vary with the amount of water applied, nutrient holding capacity, climate, and turfgrass species/cultivar. Nitrogen must be applied to maintain turfgrass shoot density, adequate recuperative potential, moderate shoot growth rate, and to lesser extent, color. Fertilization rates typically range from 6-18 pounds per year on bermudagrass greens. Application is usually at one to three week intervals during periods of normal shoot growth. Specific intervals depend on type of nitrogen carrier used.

Potassium is prone to leaching through the soil, especially in sand root zones. Potassium fertilization is best determined by the results of soil test. Potassium is often applied at 75% the level of applied nitrogen, although higher levels are sometimes applied. Potassium can also be applied at 20 to 30 day intervals during heat, drought, and water stress periods.

Compared to nitrogen and potassium, phosphorus is required in much smaller amounts on greens. The rate should be based on soil test results. Phosphorus is usually applied one or two times per year as one component of a complete fertility treatment. Application of phosphorus fertilizers is preferable just after coring to achieve deep soil penetration of this relatively immobile nutrient. It is sometimes questionable whether application of phosphorus is required, particularly since visible growth responses are seldom observed. High phosphate levels are quite common on older greens.

<u>Tees</u> The philosophy of tee fertilization is slightly different from that of greens. Extensive damage caused by divots dictates the need for rapid shoot growth rate to enhance turfgrass recovery. Sufficient nitrogen must be applied to maintain adequate turfgrass color, shoot density, and recuperative rate in terms of lateral shoot growth and tillering. The nitrogen fertilization rate ranges from 5-10 pounds/1000 sq. ft. on bermudagrass. The frequency of application typically ranges from 15 - 30 growing days. The rate of fertilization utilized on individual tees also may vary even though root zone mix and irrigation practices are similar for all tees. Tees that receive exhaustive divots, such as the par 3s and the first tee, may require up to twice the amount of nitrogen applied to larger tees. The larger tees are subject to considerably less stress. Seasonal timing of application are essentially the same as those described for putting tees.

<u>Fairways</u>. The nutrient requirements for fairways vary with soil type, soil nutrient holding capacity, amount of water applied, climate, turfgrass species, and amount of play. Sufficient nitrogen must be applied to fairways to maintain proper turfgrass density, recuperative potential, moderate shoot growth rate, and to a lesser extent, color. Bermudagrass requires 10 to 40 pounds of nitrogen per acre per growing month. The higher level of nitrogen fertilizer is commonly used on coarse textured soils, where leaching is a greater problem. This practice may be associated with undesirable loss of nitrogen, constituting a potential nonpoint pollution problem in natural or designed subsurface drainage systems.

Phosphorus application is based, as before, solely on the results of soil tests and applied 1 or 2 times per year as part of a complete fertilizer. Potassium applications may be made at supplemental rates above the level indicated by soil tests. The same rules for supplemental phosphorus and potassium application to greens generally are followed on fairways.

<u>The Rough</u>. Optimum fertilizer treatment should be applied during the establishment of roughs. A relatively high fertility level is maintained through the first growing season or until a mature sod is established. At this point, fertilization is reduced to a lower level. The fertility level required for maintenance of the rough depends on species, soil conditions and climate. Roughs on fertile soils not prone to nutrient loss usually require less fertilization than roughs on sandy soils with intense nutrient leaching losses. A typical fertilization program on high quality rough turfgrass is one application per year of a complete fertilizer.

10.4 MONITORING

Another important component of the TMS will be the development of a comprehensive monitoring network that will be used to quickly and accurately assess any deterioration to onsite or offsite water ways. Components of the monitoring system should include the following:

1. Water quality evaluation prior to site construction and development in order to establish existing (baseline) conditions. This should be conducted by collection of groundwater samples from various site locations, especially areas where shallow ground water aquifers may exist. In addition, surface water runoff during storm conditions should be collected and analyzed. All routes of water loss from the site should be sampled. The choice of analytes to be measured should be constructed around recommendations from the State of Hawaii's 12 conditions for golf course development.

2. Water quality and air quality data should be collected during construction phases to monitor loss of potentially harmful chemicals from the site. This will be conducted at an interval recommended by the State of Hawaii. Groundwater and surface water quality should be assessed to ensure that construction activities are having a minimal influence on water quality.

3. After course construction, a permanent monitoring network should be constructed. Sample collection devices should include groundwater observation wells, surface water catchments or weirs, drainage samplers (especially from greens), soil lysimeters, and several high volume air samplers. The number and placement of the devices should be determined from climatic and hydrologic information and with consultation from the State of Hawaii.

4. The golf course superintendent should select a laboratory to perform the analyses based on results of blind samples sent to a number of potential laboratories. Those performing best on the samples should be considered for contracts based on cost, sample turn around, and over all reliability.

5. Data should be analyzed quickly and then integrated into other TMS information. Based on results, cultural or chemical practices at the site can be altered to remedy the situation.

6. Appropriate data documentation, chain of custody, and other Contract Laboratory Practices (CLP) should be employed such that data collected will be of known accuracy and precision.

7. Monitoring frequency should be established after consultation with representatives of the State of Hawaii based on specific site information.

10.5 TMS AND CONSTRUCTION ACTIVITIES

10.5.1 Sediment and Runoff Control with Turfgrass: Processes and Control for Established Turfgrass

Use of turfgrass and forage grasses in pastures and crop rotations, reduced tillage systems, construction sites, highway right-of-way, stabilization of mine spoils, and agricultural buffer strips have mitigated serious erosion and sediment loss in both rural and urban environments.

Turfgrass is especially effective in reducing runoff and sediment losses in comparison to bare soil and conventional systems. Factors controlling the extent of erosion and runoff from turfgrass are:

1. Rainfall intensity and timing of initiation of runoff,
2. Antecedent soil moisture conditions,
3. Sod vs seeded turfgrass,
4. Soil texture and structure, and
5. Site topography and landscape design.

The favorable results of studies demonstrating reduced surface runoff, sediment, and chemical losses from turfgrass plots should be extrapolated to the field, golf course, or watershed level with care. Many of the hydraulic and transport processes operating at the field scale are difficult to predict compared to relatively small (20-150 m^2) and well-tended plots. Although runoff and sediment losses from turfgrass plots studies indicate surface losses are in general very low, none the less, runoff and some sediment losses still can occur from turfgrass systems. The reduced volume and velocity of runoff from turfgrass conservation systems will selectively erode small soil particles. Compared to the bulk soil, the smaller eroded soil particles have a higher capacity per unit area to absorb nutrients and organic chemicals. Also in well-drained turfgrass soils, rapid filtration and leaching reduces surface runoff, but increases the potential for subsurface transport. This drainage water will eventually (1) migrate to tile drains and emerge as translocated surface runoff or (2) percolate past the root zone. Displacement of drainage water with entrained chemicals or sediment is not necessarily the intention of conservation and environmental quality practices. During intense rainfall events or antecedent soil saturation with irrigation water, sufficient runoff could occur to transport sediment or relatively mobile chemicals. Movement of water and chemical partitioning at the field scale should be considered when evaluating the potential edge of golf course losses of water, sediment, and applied chemicals.

10.5.2 Runoff and Sediment Control During Site Construction and Turfgrass Establishment

Land disturbance during residential construction or construction of new golf course facilities exposes bare soil to water and wind erosion, surface crusting, and loss of soil physical structure. These conditions may result in significant surface loss of water, sediment, and nutrients. After turfgrass has been established, the level of runoff water, sediment, and chemical transport by surface processes is significantly reduced. Reduction in sediment losses during construction, sediment losses from altered drainage systems, and thermal pollution of waterways is needed for protection of aquatic environments.

10.5.3 Design Considerations to Reduce Runoff and Erosion

Immediate coverage of bare soil surfaces by seeding with turfgrass or placement of sod reduces the risk of erosion. Surface coverage provides important protection against wind erosion. Restoration of turfgrass, wooded areas along streambanks, and adapted natural vegetation are some of the best means for long-term control of erosion.

Potential adverse environmental impacts, including surface runoff, flooding, and erosion, should be an *essential consideration in golf course design. Design criteria should minimize the need for site disturbance and reshaping of natural landscape elements.* The intensity of site disturbance and reshaping with heavy equipment is directly related to serious short- and long-term erosion and runoff problems. Loss of topsoil and compaction, resulting from construction and equipment traffic, will significantly increase sediment transport from the construction site. Avoiding design elements that encourage development of gullies, reroute streams, or change the natural surface and subsurface drainage is critical for long-term site stability. Long steep slopes with smooth surfaces and compaction of surface soils are conditions especially

conducive to erosion problems.

During construction, temporary erosion control devices will mitigate offsite transport of eroded sediment. These practices include: (1) constructing of temporary silt fences to stop particle transport; (2) construction of small check dams or weirs to flatten upstream slopes and decrease the velocity of runoff; and (3) use of temporary mulches, matting, or blankets to reduce erosive forces until vegetation or long-term measures are in place.

Long-term erosion and runoff control techniques should be used on sites with highly erosive soils, steep banks, or design elements conducive to rapid runoff and sediment transport. A wide range of techniques include the following:

1. Planting of native vegetation with soil stabilizing canopies and root systems.
2. Placement of short (6 in.) silt fences on steep slopes to trap sediment, reduce runoff velocity, and allow development of vegetation.
3. Use wattling on sites with highly erosive soils.
4. Construction of terraces on steep slopes with drainage swales that collect and divert runoff water.
5. Construction of detention ponds within drainage channels which reduce runoff velocity and provides temporary storage for eroded sediment.
6. Avoid irrigation rates or duration which may cause runoff of water, resulting from irrigation of turfgrass at rates greater that soil infiltration rates and soil storage capacity.
7. Repair leaking irrigation systems to reduce potential erosion problems on steep or unstable slopes.

Golf courses also should be constructed to minimize disturbance of vegetation in the vicinity of drainage ditches or stream banks. Disturbed embankments will be susceptible to erosion from stream scour and slumping. On areas with concentrated flow velocities, permanent stream bank and shoreline stabilization should be practices. Long-term stabilization structures include interlocking block walls, riprap, gabion walls, and planting trees with stabilizing root systems.

10.6 ADDITIONAL WATER QUALITY ISSUES RELATED TO TMS

10.6.1 Water Conservation and Cultural Practices: Mowing, Fertilization, and Irrigation

Mowing, fertilization, and irrigation are the primary cultural practices used to minimize water losses and increase water conservation on golf courses. Mowing height, frequency of cutting, and mowing equipment affect water use on golf courses. Increased water use has been observed for warm-season and grasses with increased mowing height. High cut turfgrass with an open canopy, lower shoot density, and greater leaf area has lower canopy resistance to ET and increased water consumption. Although the effects of mowing frequency are not always consistent, reducing the leaf area, shoot size, and rooting depth by more frequent mowing decreases water consumption.

The relationship of mineral nutrition and water use is complicated, yet very important. Turfgrass managers should consider fertility programs that meet the needs of turfgrass, but also avoid excessive growth and unnecessary water stress. Water use efficiency of turfgrass should be considered in relation to turfgrass quality, the ability of turfgrass to recuperate from stress, and reduced water use. Production of dry matter should not be a water use issue for turfgrass on golf courses, residential lawns, and conservation turfgrass systems. Additional research on the relationship of (1) rate of potassium application, (2) nitrogen carrier, (3) timing of application, and (4) drought resistance is needed.

Depth of soil wetting affects water use and drought avoidance by turfgrass. Light applications of water encourage shallow rooting, while deep wetting encourages deep root growth. With deeper and more extensive root systems, turfgrass are able to use moisture from a greater portion of the soil profile. Deep rooting enhances the ability of turfgrass to avoid stress, wilt, and the need for increased supplemental irrigation as compared to shallow rooted turfgrass.

Irrigation systems and design methods which are state-of-the-art irrigation systems that when properly designed, programmed correctly, and installed within design criteria, conserve water and apply it in accordance with the actual needs of the turfgrass plant. Further, systems equipped with single-head controls and a recycling capacity apply water commensurate with infiltration and percolation capacity of the soil. Appropriate integration of sprinkler heads, valves, and controllers are important criteria for conserving irrigation water.

Controllers are the key to water conservation in irrigation systems. Controllers are electrical timing devices used to open or close valves that regulate the flow of water to the sprinkler heads. They usually are of two types: (1) solid state and (2) electromechanical. Electronic (solid state) controllers are usually accurate within 1 min, an obvious saving of water over the 1-4 min accuracy range of electromechanical types. Computer-controlled systems may be operated from ET rates calculated from on-site weather stations or other programs based on regional ET values. The California Irrigation and Management Information System (CIMIS) is an example of a program that supplies regional ET values for computer-controlled irrigation systems. These generalized ET values are based on generalized average solar radiation and historical data. Annual savings of up to 40% water use and 40% energy cost have been speculated when using low pressure sprinkler heads with a computerized controller.

Use of soil moisture sensing devices to determine the frequency of operation for controllers is another means of effective conservation of water for irrigation of turfgrass. These devices may be used to cancel preselected start and stop times of irrigation systems when soil moisture levels reach a preselected level. Soil moisture sensors are subject to soil variability. However, when properly programmed, the combination of sensors and controllers have been shown to conserve 25-40% of the water recommended for home lawns.

10.7 CONCLUSIONS

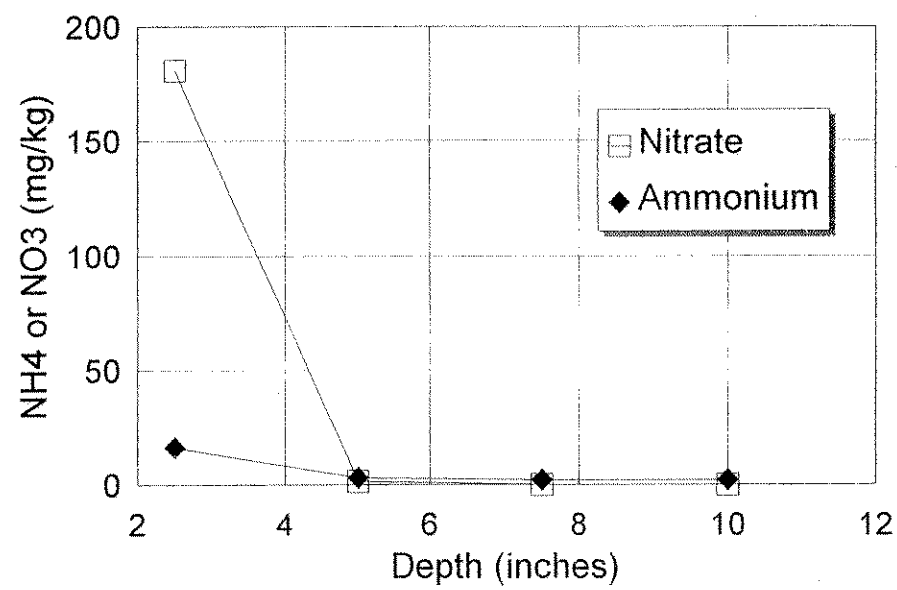
The use of TMS would be very effective for growing of high quality turfgrass and for reducing potentially adverse environmental quality effects. TMS practices would coordinate all factors required for long-term sustained productivity and quality of turfgrass, golf course profitability, and ecological soundness of selected management options. The critical components for planning and implementing TMS must include:

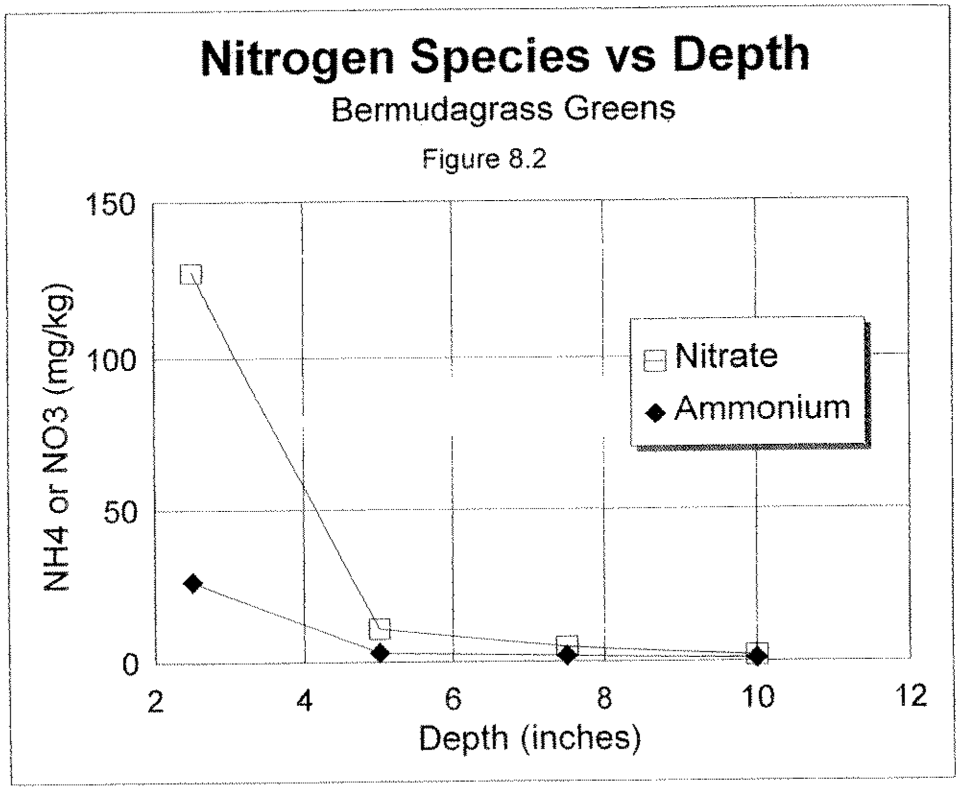
1. Proper design and construction of golf courses.
2. Selection of appropriate turfgrass species and cultivars.
3. Selection of timely soil and cultural practices.
4. Integrated planning of water, nutrient, and pest management in relation to other management goals.
5. Consideration of alternate chemical, biological, and cultural pest, nutrient and water management practices when possible.
6. Conservation of soil, water, energy, and natural resources during construction and maintenance of golf courses.

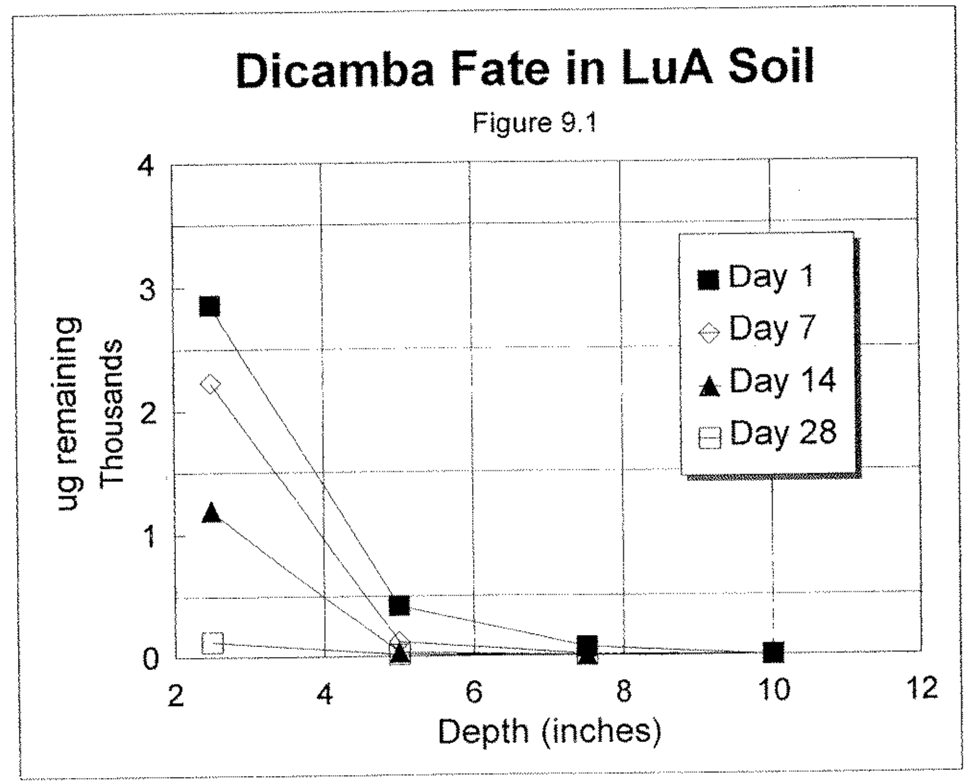
Nitrogen Species vs Depth

LuA Soil (Fairway Simulation)

Figure 8.1

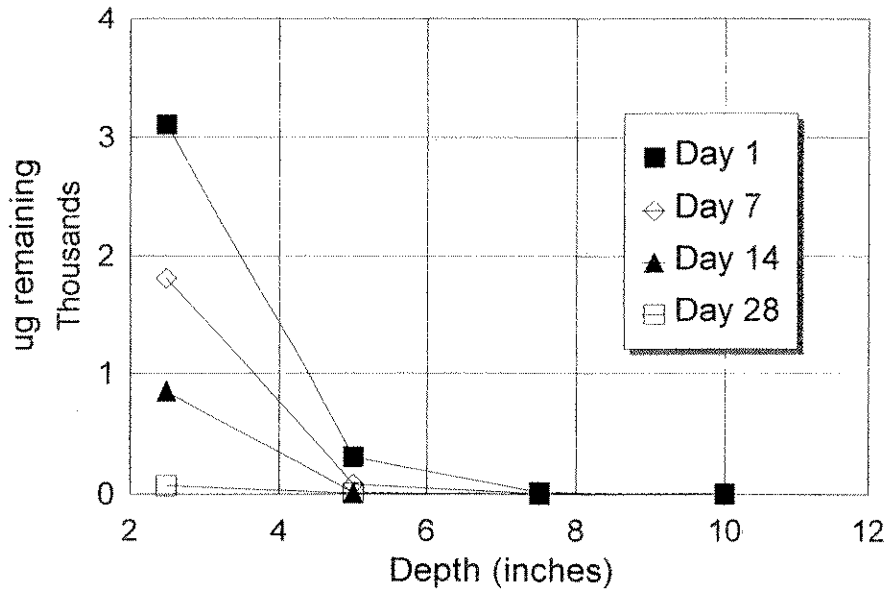



Nitrogen Species vs Depth
Bermudagrass Greens
Figure 8.2
NH4 or NO3 (mg/kg)
150
100
50
0
2
4
6
8
10
12
Depth (inches)
Nitrate
Ammonium


Dicamba Fate in LuA Soil
Figure 9.1
ug remaining
Thousands
4
3
2
1
0
2
4
6
8
10
12
Depth (inches)
Day 1
Day 7
Day 14
Day 28

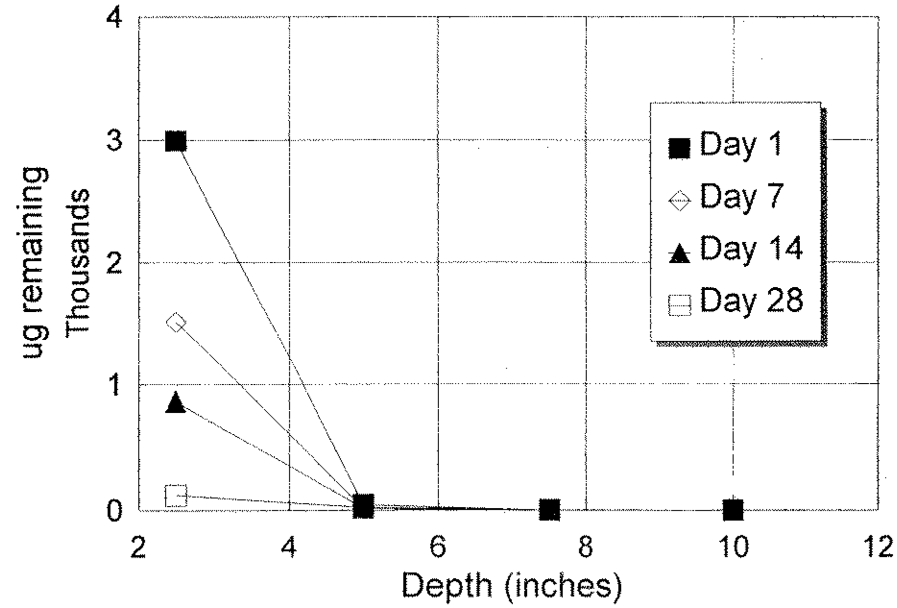
2,4-D Ester Fate in LuA Soil

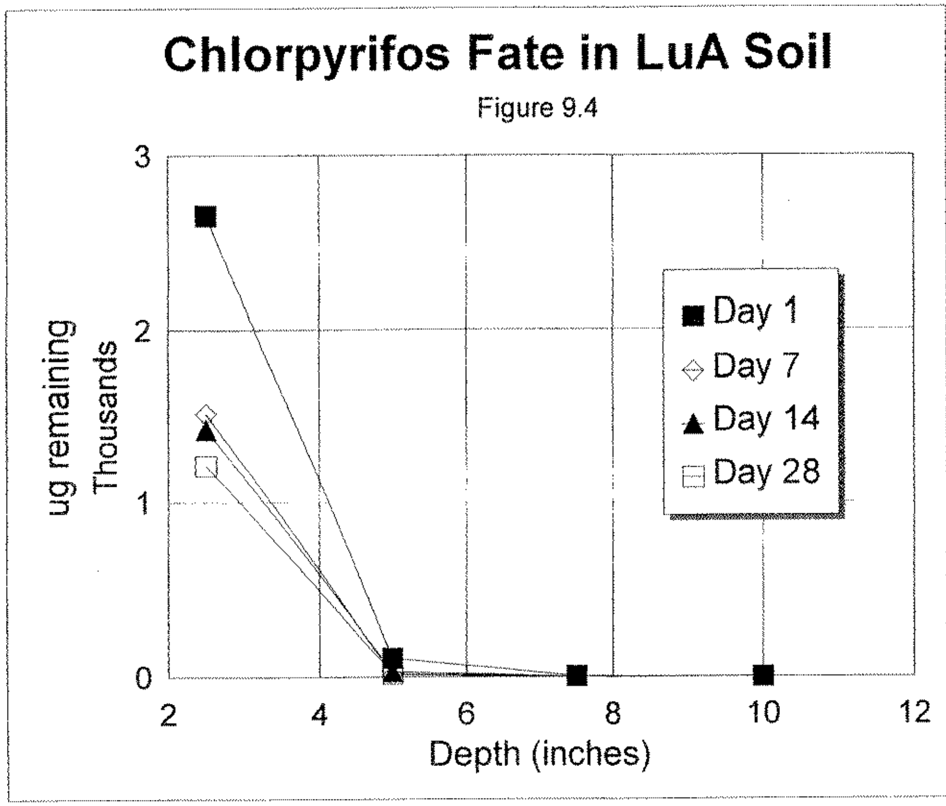
Figure 9.2

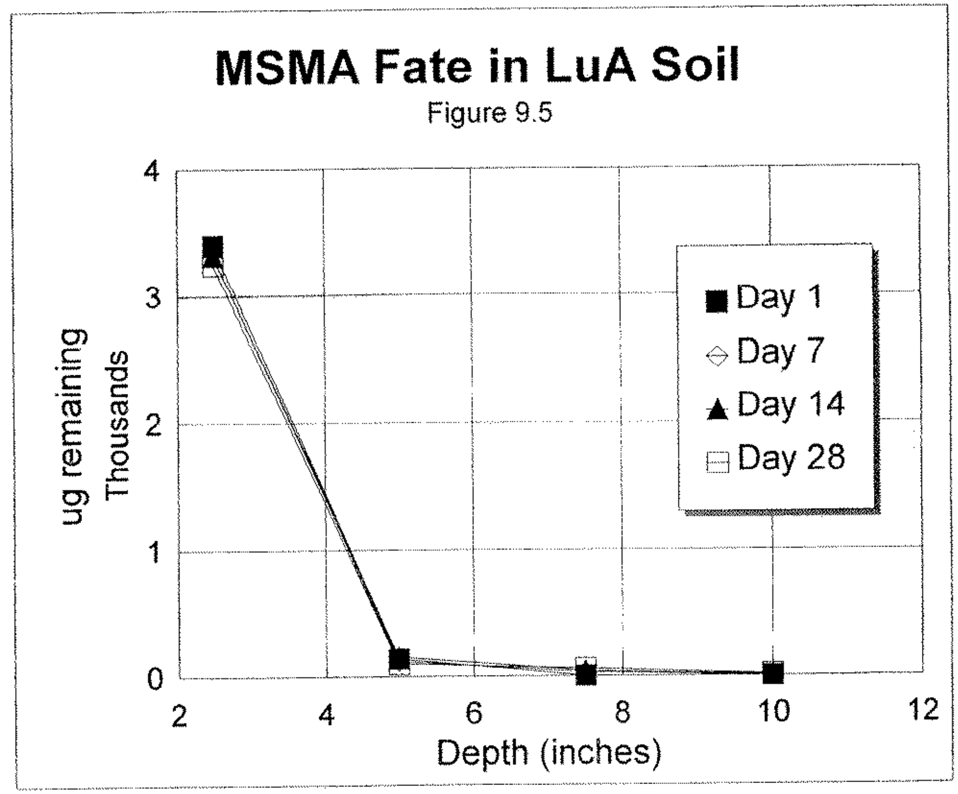


Chlorthalonil Fate in LuA Soil

Figure 9.3




Chlorpyrifos Fate in LuA Soil
Figure 9.4
ug remaining
Thousands
3
2
1
0
2
4
6
8
10
12
Depth (inches)
Day 1
Day 7
Day 14
Day 28


MSMA Fate in LuA Soil
Figure 9.5
ug remaining
Thousands
4
3
2
1
0
2
4
6
8
10
12
Depth (inches)
Day 1
Day 7
Day 14
Day 28

EFFECT OF EFFLUENT WATER USE ON SOIL CHEMISTRY AND PERCOLATE WATER
Simulation 1
Initial Conditions:

Mass of Soil	1kg
Volume of Soil Water	1L
CEC	305meq/kg
Ex Ca	75mml/l
Ex Na	25mmol/l
(Ca)	40 mmol/l
(Na)	110 mmol/l
Ex K*	36.3

* K = Exchange Constant for Ca/Na Exchange by Montmorillonite

Input Water from Effluent

(Mg)	18 mmol/L
(Ca)	22 mmol/l
(Na)	50 mmol/l

To Calculate Changes in Exchange Complex and Solution Chemistry, the Following Expression Was Derived

Input Equation

The Equation solves for exchangeable Ca and is 3rd order polynomial: (ax3 + bx2 +cx + d)
To determine coefficients a, b, c, and d use the following spread sheet

Case #	K	Total Na	Total Ca	CEC	a	b	c	d	New Ex Na	New Ex Ca	New Na	New Ca	ESP	SAR
1	36.3	75	97	175	18.65	182.35	15937.5	-492187.5	18.9	78.05	56.10	18.95	10.8	4.56
2	36.3	68.9	100.05	175	18.65	299.16	14431.11	-415380.875	16.9	79.05	52.00	21	9.66	4.01
3	36.3	66.9	101.05	175	18.65	337.47	13945.31	-391615.875	16.2	79.40	50.70	21.65	9.26	3.85
4	36.3	66.2	101.4	175	18.65	350.87	13776.22	-383463.5	15.9	79.55	50.30	21.85	9.09	3.80
5	36.3	65.9	101.55	175	18.65	356.62	13703.91	-379995.875	15.8	79.60	50.10	21.95	9.03	3.78
6	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
7	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
8	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
9	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
10	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
11	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
12	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
13	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
14	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
15	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
16	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
17	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
18	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
19	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77
20	36.3	65.8	101.6	175	18.65	358.53	13679.82	-378843.5	15.8	79.60	50.00	22	9.03	3.77

* From Root Finder

APPENDIX

Simulation 2: In this case the selectivity of the exchanger is only 10 (K)

Case #	K	Total Na	Total Ca	CEC	a	b	c	d	New Ex Na	New Ex Ca	New Na	New Ca	ESP	SAR
1	10	75.00	97.00	175	5.5	-67.50	15937.5	-492187.5	27	74.00	48.00	23	15.42857	3.54
2	10	77.00	96.00	175	5.5	-79.50	16439.5	-518787.5	28	73.50	49.00	22.5	16.00	3.65
3	10	78.00	95.50	175	5.5	-85.50	16692	-532350	28.45	73.28	49.55	22.225	16.26	3.72
4	10	78.45	95.28	175	5.5	-88.20	16805.95	-538510.219	28.65	73.18	49.80	22.1	16.37	3.75
5	10	78.65	95.18	175	5.5	-89.40	16856.66	-541259.469	28.74	73.13	49.91	22.045	16.42	3.76
6	10	78.74	95.13	175	5.5	-89.94	16879.49	-542498.915	28.78	73.11	49.96	22.02	16.45	3.76
7	10	78.78	95.11	175	5.5	-90.18	16889.64	-543050.235	28.8	73.10	49.98	22.01	16.46	3.77
8	10	78.80	95.10	175	5.5	-90.30	16894.72	-543326	28.81	73.10	49.99	22.005	16.46	3.77
9	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
10	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
11	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
12	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
13	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
14	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
15	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
16	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
17	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
18	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
19	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77
20	10	78.81	95.10	175	5.5	-90.36	16897.26	-543463.909	28.81	73.10	50.00	22	16.46	3.77

* From Root Finder

Simulation 3: The selectivity coefficient is now only 3 (the exchanger preference for Na is nearly equal that of Ca)

Case #	K	Total Na	Total Ca	CEC	a	b	c	d	New Ex Na	New Ex Ca	New Na	New Ca	ESP	SAR
1	2	75.00	97.00	175.00	1.50	-143.50	15937.50	-492187.50	38.99	68.01	36.01	29.00	22.28	2.36
2	2	88.99	90.01	175.00	1.50	-171.48	19532.86	-692931.76	46.65	64.08	42.14	25.93	26.77	2.93
3	2	96.85	86.08	175.00	1.50	-187.20	21638.71	-820743.22	51.36	61.82	45.49	24.26	29.35	3.27
4	2	101.36	83.82	175.00	1.50	-196.22	22874.92	-898961.84	53.98	60.51	47.38	23.31	30.85	3.47
5	2	103.98	82.51	175.00	1.50	-201.46	23602.42	-946036.04	55.51	59.75	48.47	22.77	31.72	3.59
6	2	105.51	81.75	175.00	1.50	-204.52	24030.43	-974081.51	56.42	59.29	49.09	22.46	32.24	3.66
7	2	106.42	81.29	175.00	1.50	-206.34	24286.11	-990956.44	56.95	59.03	49.47	22.27	32.54	3.71
8	2	106.95	81.03	175.00	1.50	-207.40	24435.40	-1000851.47	57.26	58.87	49.69	22.16	32.72	3.73
9	2	107.26	80.87	175.00	1.50	-208.02	24522.85	-1006661.91	57.45	58.76	49.81	22.10	32.83	3.75
10	2	107.45	80.78	175.00	1.50	-208.40	24576.50	-1010231.47	57.56	58.72	49.89	22.06	32.89	3.76
11	2	107.56	80.72	175.00	1.50	-208.62	24607.58	-1012300.94	57.62	58.69	49.94	22.03	32.93	3.76
12	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
13	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
14	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
15	2	107.52	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
16	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
17	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
18	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
19	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77
20	2	107.62	80.69	175.00	1.50	-208.74	24624.53	-1013430.64	57.62	58.69	50.00	22.00	32.93	3.77

* From Root Finder

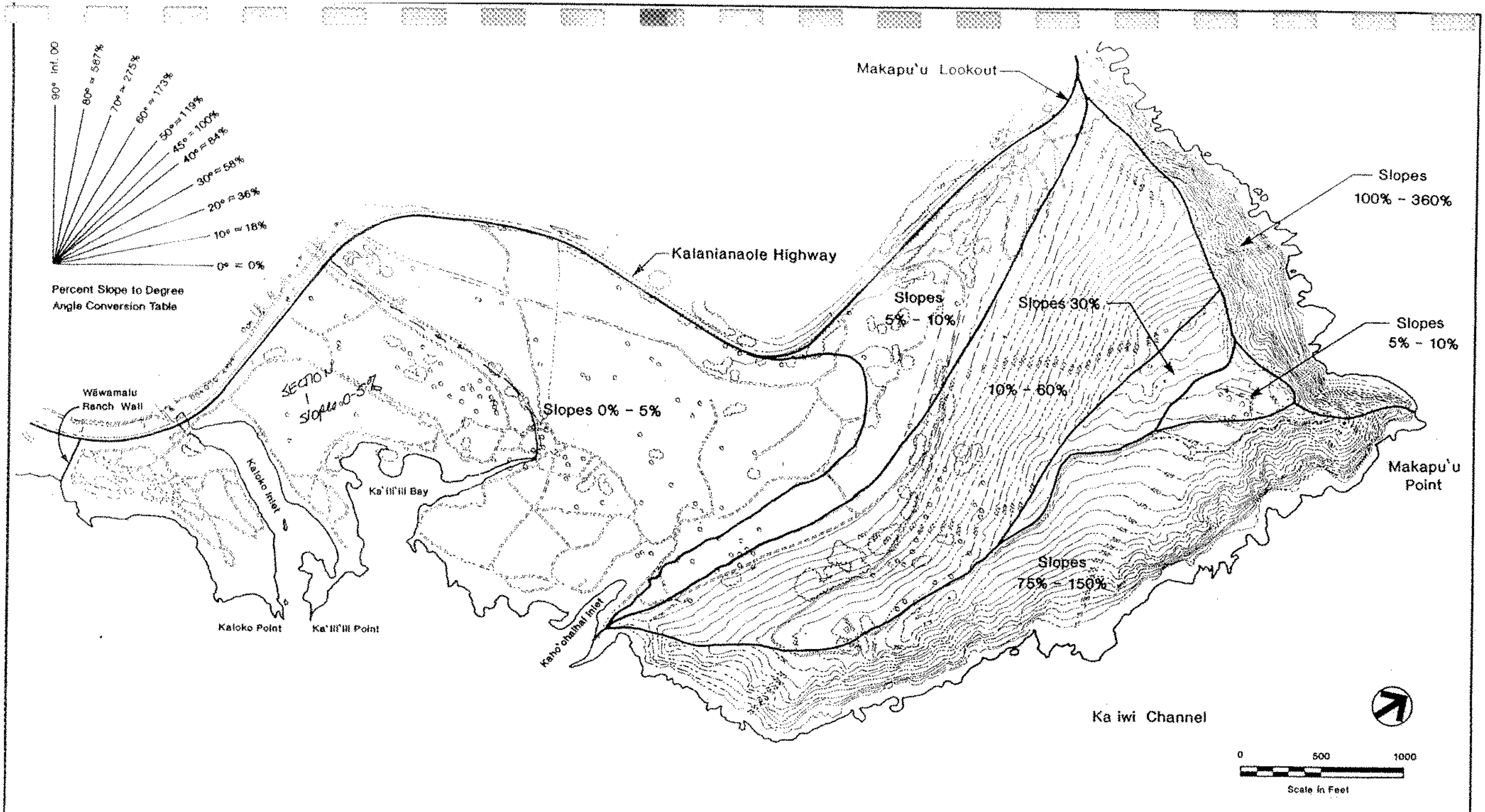


Fig. 3.1

Topography at the
Proposed Golf Site

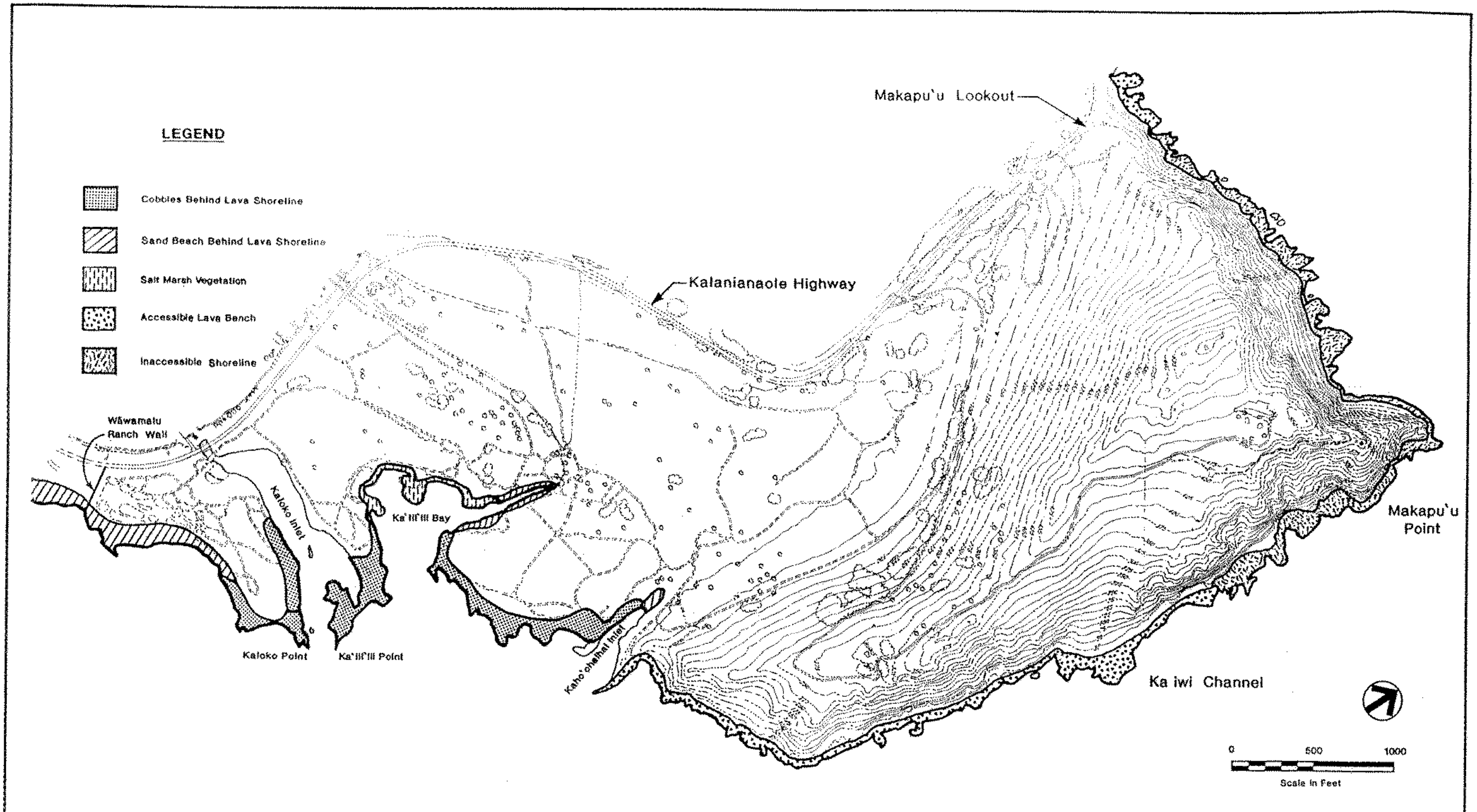


Fig. 3.2

Shoreline at the Proposed Golf Site

Fig. 3.3
Geologic Formations

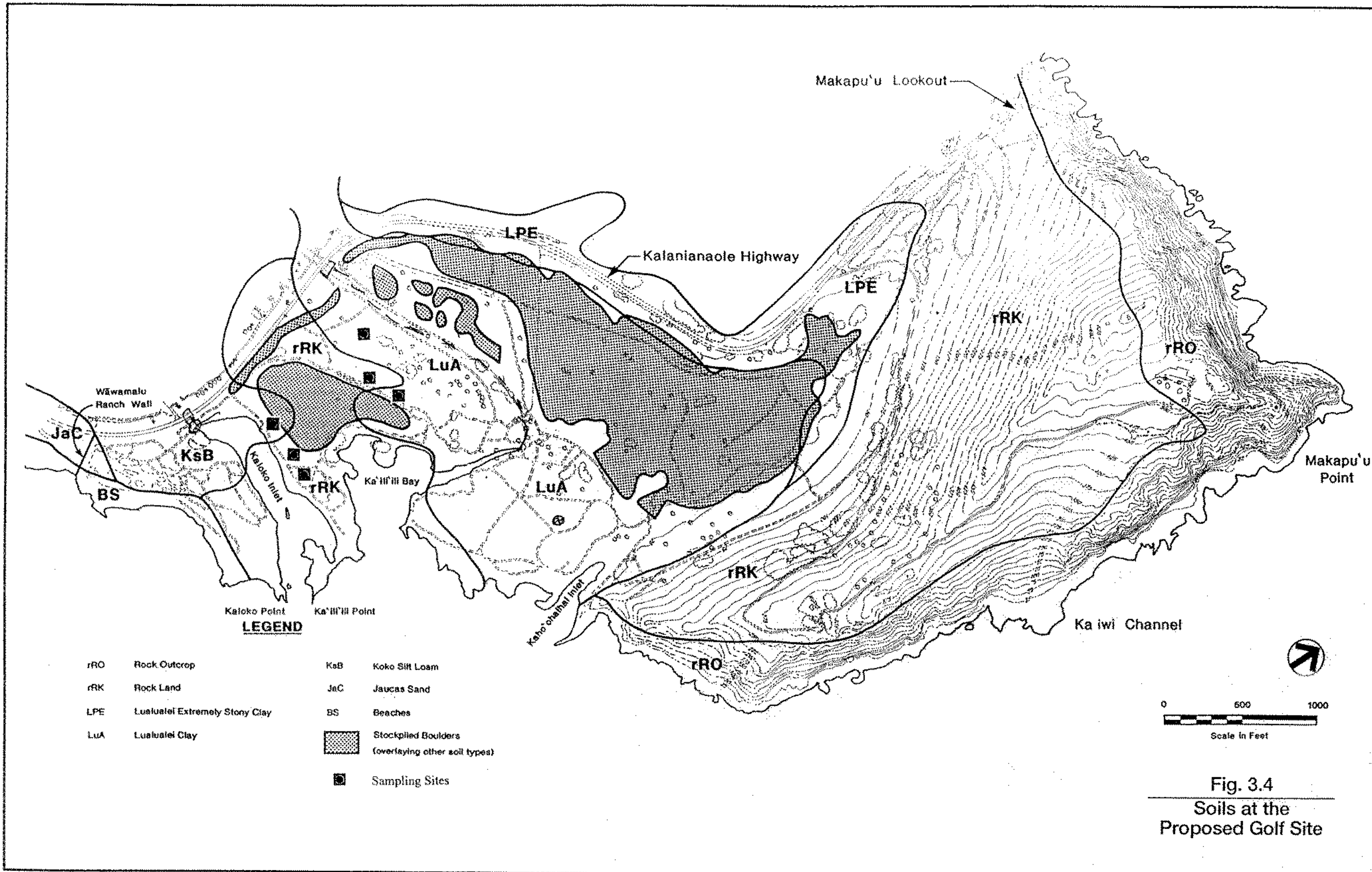


Fig. 3.4
Soils at the Proposed Golf Site

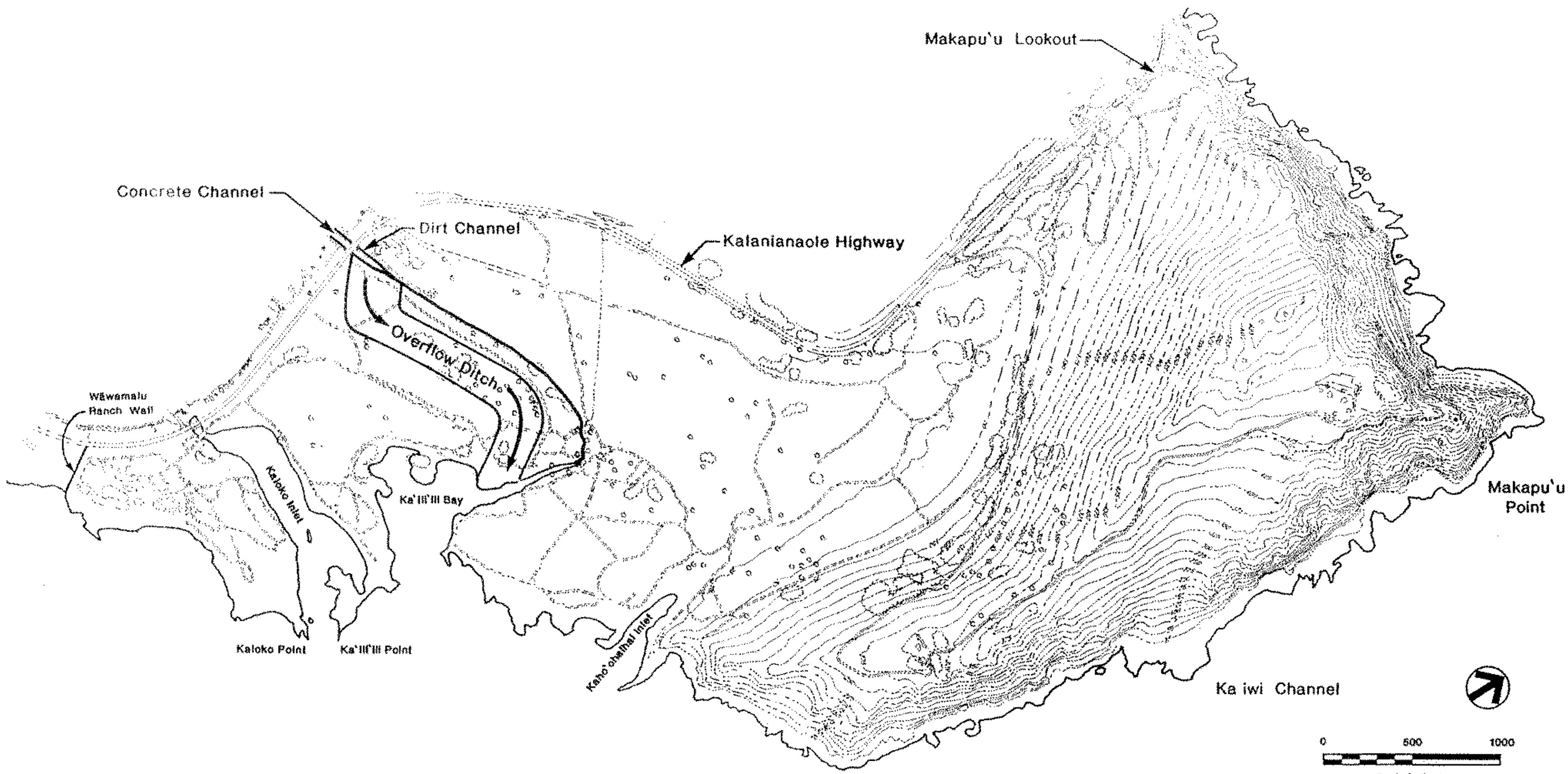


Fig. 3.5

Drainage at the Proposed Golf Site

Appendix

D

Botanical Survey

(Char & Associates)

BOTANICAL SURVEY
PROPOSED GOLF COURSE AT QUEEN'S BEACH
HONOLULU DISTRICT, ISLAND OF O'AHU

by

Winona P. Char

CHAR & ASSOCIATES
Botanical Consultants
Honolulu, Hawai'i

Prepared for: HELBER HASTERT & FEE

May 1995

Table of Contents

BOTANICAL SURVEY
PROPOSED GOLF COURSE AT QUEEN'S BEACH
HONOLULU DISTRICT, ISLAND OF O'AHU

INTRODUCTION

The project site consists of approximately 200 acres of Bishop Estate-owned land at Queen's Beach in East Honolulu, O'ahu. The property is leased by Kaiser Aluminum and Chemical Corporation. The proposed uses for the ±200-acre parcel include a golf course, recreation center, and public park and facilities.

The Queen's Beach site is bounded to the north by the Makapu'u Lookout, to the east by the steep, rocky slopes of Makapu'u Head, to the south by the ocean, and to the west by Kalaniana'ole Highway. Elevation on the site ranges from sea-level along the coast to about 175 ft. along the rocky slopes. Average annual rainfall is roughly 30 inches, with most of the precipitation occurring between October and April during Kona (winter) storms (Wilson Okamoto and Associates 1993). The more or less level coastal plain which occupies most of the project site has very sticky and very plastic, dark gray-colored Lualualei clay soils (Foote et al. 1972). Boulders, soil, and dredge material have also been stockpiled on the site.

The vegetation on the project site is composed of a mixture of introduced and native species, with the introduced plants such as koa-haole and buffel grass more abundant on those portions of the property which have been disturbed by past fires and bulldozing. Native plants are the dominant components in the coastal strand vegetation and the koa-haole/ma'o shrubland. A listed endangered species, Marsilea villosa or 'ihi'ihi-lau-akea -- an endemic water fern, is found in a few deep ruts along two 4-wheel drive roads which cross the koa-haole/ma'o shrubland.

Field studies to assess the botanical resources found on the ±200-acre Queen's Beach project site were conducted in March 1995; a team of three botanists was used to gather the technical data contained in this report. The primary objectives of the field studies were to: 1) provide a general description of the major vegetation types; 2) inventory the flora; 3) search for threatened and endangered species; and 4) identify areas of potential environmental problems or concerns and propose appropriate mitigation measures.

SURVEY METHODS

Prior to undertaking the field studies, a search was made of the pertinent literature to familiarize the principal investigator with other botanical studies conducted in the general area. Topographic maps and a very recent, colored aerial photograph were examined to determine vegetation cover patterns, terrain characteristics, access, boundaries, and reference points. The property is easily accessed from Kalaniana'ole Highway and there are a number of dirt roads which cross the site.

A walk-through survey method was used. Notes were made on plant associations and distribution, substrate types, topography, exposure, drainage, etc. Plant identifications were made in the field; plants which could not be positively identified were collected for later identification in the herbaria (University of Hawai'i, Manoa, HAW, and Bishop Museum, BISH), and for comparison with the most recent taxonomic literature.

The species recorded are indicative of the season ("rainy" vs. "dry") and the environmental conditions at the time of the field studies. A survey taken at a different time of the year and under varying environmental conditions would no doubt yield variations in the species list, especially of the weedy, annual plants. This survey was conducted during an optimal time of the year after several days of heavy rainfall had been recorded for the area and sufficient time had elapsed for the plants to establish themselves or produce new growth and flowers.

DESCRIPTION OF THE VEGETATION

There have been at least three botanical studies which described the vegetation on the project site. The first was part of a dissertation study examining nine dry-grass community types on O'ahu (Kartawinata and Mueller-Dombois 1972). Several transects were established on the coastal flats to moniter these dry-grass communities over a period of four years. A small population of the Marsilea villosa fern was found along transect 2, near the western end of the study site.

Two walk-through botanical studies were conducted of the Queen's Beach area by Funk in 1984, for the City and County of Honolulu's Department of Parks and Recreation, and in 1991, for the State's Department of Land and Natural Resources. The earlier study covered almost all of the present project site, while the later study also included the rocky Makapu'u headlands and the Coast Guard's Makapu'u Point Lighthouse facilities. During the 1991 study, a large population of the Marsilea fern was found in a line of deep, water-filled ruts made by off-road vehicles at the base of Kealakipapa Valley. Funk (1991) recognized four vegetation types on the Queen's Beach project site. These were the strand vegetation and wetlands, open grassland, widely scattered kiawe

with haole koa/cotton understory, and windsheared Prosopis/haole koa/panini scrub.

In the present study, six vegetation types are recognized on the ±200-acre Queen's Beach project site and are described in more detail below. The distribution of these vegetation types on the property is presented in Figure 1. An inventory of all the vascular plants found during the field studies is given in the checklist at the end of the report.

Coastal Strand Vegetation

The strand vegetation occurs as a narrow band along the exposed shoreline with the substrate varying from sandy dunes and beaches to jagged lava rocks to waterworn coral and basalt cobbles. In the area from the Wawamalu Ranch Wall to Kaloko Point, the substrate is beach and dune sand. This portion of the shoreline is known as Kaloko Beach. Along the seaward edge on the dunes, the vegetation consists almost exclusively of rounded patches of beach naupaka ((Scaevola sericea) with a few scattered taller tree heliotrope plants (Tourneforthia argentea). Unfortunately, off-road vehicles have mangled and run over many of the plants, leaving broken branches and a tangle of exposed roots. Inland of the dunes on Kaloko Point where the sand is packed harder and the topography more level, there is an interesting collection of native coastal species, mostly an 'ilima (Sida fallax), 'aki'aki (Sporobolus virginicus), and pa'u o Hi'iaka (Jaquemontia ovalifolia ssp. sandwicensis) community. Other native plants found here include nama (Nama sandwicensis), nohu (Tribulus cistoides), alena (Boerhavia repens), pohuehue or beach morning-glory (Ipomoea pes-caprae), Panicum faurei, 'akoko or beach spurge (Chamaesyce degeneri), and hinahina (Heliotropium anomalum var. argentea), which is locally abundant. The nama and Panicum are annual species which appear only during the wetter months. Again off-road vehicle tracks are everywhere. These coastal dry plant community types are considered rare and locally distributed with existing conditions making them vulnerable to extinction range-wide (Hawai'i Heritage Program 1994).

One smaller pocket of sandy beach is found at Kaho'ohaihai Inlet, but this small sand beach was artificially deposited at the mauka end of the inlet by the Hawaii Kai Development Company during the early 1960s (Wilson Okamoto & Associates 1993). There is very little coastal strand vegetation here, only a few milo (Thespesia populnea) and small kiawe (Prosopis pallida) trees.

Along the rest of the exposed shoreline, the substrate is lava rock interspersed with waterworn coral and basalt cobble beaches. On the rugged lava outcroppings, 'ohelo kai (Lycium sandwicense), a much-branched small woody shrub, forms low mats with attractive bright red, globose fruits. Also locally common in some areas are scattered pockets of 'akulikuli (Sesuvium portulacastrum) and Fimbristylis cymosa. Cobble beaches and smaller areas with very course sand and gravel support low clumps of beach naupaka, 3 ft. tall, and scattered mats of 'ilima, pa'u o Hi'iaka, alena, hina-hina, 'aki'aki, and 'ohelo kai.

Estuarine and Drainage Channel Vegetation

The estuarine vegetation is found along the protected areas of the shoreline in embayments or inlets which have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by fresh water (Cowardin et al. 1979). Kaloko Inlet and Ka'ili'ili Bay both have areas with estuarine vegetation.

Kaloko Inlet has been artificially extended to reach a small gulch under Kalaniana'ole Highway (Wilson Okamoto & Associates 1993). An old concrete bridge is also found in this area; this probably crossed the original Wawamalu Stream, which was realigned when the golf course was developed. This portion of the inlet is shallow with mud flats visible at low tide. Low mats of pickle-weed (Batis maritima) fringe this portion of the inlet and there are small stands of mangrove (Rhizophora mangle) and milo trees with scattered clumps of Indian pluchea shrubs (Pluchea indica). One Green Sea Turtle or Honu (Chelonia mydas agassizi), and several migratory shorebirds -- Ruddy Turnstone or 'Akekeke (Arenaria interpres), Kolea or Pacific Golden Plover (Pluvialis fulva), 'Ulili (Heteroscelus incanus) and one 'Auku'u (Nycticorax nycticorax hoactli) were observed in this inlet during the morning hours.

Along the mauka portions of Ka'ili'ili Bay, dense, almost impenetrable stands of mangrove occupy the mud flats. Low, yellow green-colored mats of pickleweed are abundant on muddy areas inland of the mangrove. A drainage channel or canal crosses the Queen's Beach property and enters the bay from the north, contributing silt to the mud flats in the bay's shallow water.

Where there is salt water intrusion (and probably some tidal influence), mangrove lines the drainage channel. Mangrove trees gradually thin out where there is more fresh water flow and plant species typical of fresh water wetlands appear. Plants found along this portion of the drainage channel include California grass (Brachiaria mutica), Indian pluchea, primrose willow (Ludwigia octovalvis), and Ruellia brittoniana. The drainage area had deep standing water at the time of the survey.

Koa-haole/Ma'o Shrubland

The koa-haole/ma'o shrubland covers the most area on the project site and is found on the coastal plain. Low piles of boulders which have been stockpiled on the site are common. Koa-haole (Leucaena leucocephala) forms an open shrubland, 3 to 6 ft. tall with 30 to 50% cover. Grassy open boulder-strewn areas between the clumps of koa-haole support large numbers of ma'o or Hawaiian cotton (Gossypium tomentosum). One particular location on the southeastern section of the project site (Figure 2) has a high concentration of ma'o plants of all sizes, including many young plants.

The most abundant grass in these open areas is buffel grass (Cenchrus ciliaris), although in areas with somewhat deeper soil Guinea grass (Panicum maximum) may be locally abundant. Other grasses observed occasionally in this vegetation type include swollen fingergrass (Chloris barbata), pitted beardgrass (Bothriochloa pertusa), and bristly foxtail (Setaria verticillata). Scattered through this area are a few small stands, or sometimes single trees, of kiawe (Prosopis pallida) and shrubs of naio (Myoporum sandwicense), pluchea (Pluchea symphytifolia), and wild basil (Ocimum gratissimum). Smaller shrubs and subshrubs are common to occasional. These include the nehe (Lipochaeta lobata) which is very noticeable during the wetter months when it produces large clusters of bright yellow flowers, the upright form of 'ilima (Sida fallax), 'ilihe'e (Plumbago zeylanica), Malvastrum americanum, hoary abutilon (Abutilon incanum), and virgate mimosa (Desmanthus virgatus).

In low lying areas where the sticky clay soils overlie dense and massive pahoehoe flows, water may collect during heavy rains and pond. Such areas support a number of species which prefer

a moister microhabitats; these include honohono (Commelina diffusa), jungle-rice (Echinochloa colona), cupgrass (Eriochloa punctata), and spikerush (Eleocharis obtusa). Along two overgrown dirt roads, in deep ruts made by off-road vehicles, the endangered 'ihi'ihi-lau-akea or 'ihi'ihi fern (Marsilea villosa) is found. These ruts fill with water during the rainy season, thus breaking the dormant (summer dry) stage of the fern and initiating new growth. A more detailed discussion of this species is presented in the "Endangered Plants" section of the report.

Koa-haole Shrubland

This vegetation type is found on the southwestern portion of the project site adjacent to Kalaniana'ole Highway. The koa-haole plants tend to be dense with shrub cover 80 to 100% in most places and 5 to 6 ft. tall. The ground cover is largely clumps of buffel grass, or Guinea grass where the soil is somewhat deeper. Scattered through this shrubland are a few kiawe trees. Locally common in a few places with small boulder piles are sprawling clumps of butterfly pea (Clitoria ternata). The koa-haole shrubland shares many of the same plant components found in the koa-haole/ma'o shrubland, but usually in lesser numbers as the dense cover of koa-haole shrubs and buffel grass tends to shade out most other smaller species.

The koa-haole shrubland behind Kaloko Beach occurs on stony Koko silt loam with a thin top layer of windblown sand. The koa-haole shrubs are more exposed to the wind and salt spray in this area and are shorter, up to 3 ft. tall. Much of the older growth has died back and the plants have sent out basal shoots. Because the shrub cover is more open and patchy, the buffel grass grows more vigorously and forms a dense mat, 1 to 3 ft. high, between the shrubs. Some elements of the coastal strand vegetation are found here and include beach naupaka, tree heliotrope, pa'u o Hi'iaka, alena, and 'ilima.

Grassland

The general physiognomy of this vegetation type is of low, open grassy cover, 1 to 3 ft. tall, with very scattered, small clumps of koa-haole. Two variants of the grassland are recognized on the Queen's Beach site. On the southern portion of the property on the more or less level areas along the coast, the grassland is composed almost exclusively of buffel grass, a native of Africa and tropical Asia, which forms wiry tussocks or mats 1 to 3 ft. tall. The buffel grass is very dense, almost monodominant, broken only by a few scattered clumps of koa-haole shrubs, 3 to 6 ft. tall. A few plants such as virgate mimosa, hoary abutilon, 'ilima, cheeseweed (*Malva parviflora*), and Guinea grass are found along the margins of this grassland, along dirt roads which cross through this vegetation type, or where the buffel grass has died back and thinned out.

The second variant of the grassland is composed of a mixture of grass species and various small shrubs and herbaceous plants. The mixed grassland occurs on the stonier portions of the project site on the northern half. The most abundant grass components are swollen fingergrass, pitted beardgrass, Australian bluestem (*Dichanthium sericeum*), and Guinea grass which tends to occur in swale areas with somewhat deeper soil. The mixed grassland located near the Makapu'u Lookout faces the prevailing tradewinds and is windswept and exposed to salt spray at times. The grasses thus tend to form low mats and the koa-haole shrubs are 6 inches to a foot tall. Other species commonly found here include 'ilima, pa'u o Hi'iaka, beach wiregrass (*Dactyloctenium aegyptium*), 'ihi (*Portulaca pilosa*), Chinese violet (*Asystasia gangetica*), virgate

mimosa, Australian saltbush (*Atriplex semibaccata*), and nehe.

The mixed grassland found just below the paved road to the Coast Guard Lighthouse is on more protected slopes and supports a number of weedy, mostly hebaceous species which include golden crownbead (*Verbesina encelioides*), milkweed (*Sonchus oleraceus*), virgate mimosa, pualele (*Emilia fosbergii*), bristly foxtail grass, hairy honohono (*Commelina benghalensis*), hairy merremia (*Merremia aegyptica*), Jimson weed (*Datura stramonium*), and common purslane or pigweed (*Portulaca oleracea*). There is evidence of a recent fire in this area.

Kiawe/Koa-haole Thicket

This vegetation type found on the eastern and northern portions of the project site occurs primarily on soils mapped as rock outcrop, "rRK" on the soil maps (Foote *et al*. 1972). Slopes on the eastern portion are 10 to 60%, while the slopes on the northern section, upper Kealakipapa Valley, are 5 to 10%. This vegetation type is composed of a closed- to open-canopied kiawe thicket with scattered patches of koa-haole shrubs under the trees. Rock outcrops and boulder piles are numerous.

On the more exposed northern section, the kiawe trees form low windswept or windsheared thickets, 10 to 12 ft. tall. The trees branch close to the ground and the tangle of thorny branches makes surveying difficult. Also locally common in this area are large, spiny clumps of panini or prickly pear cactus (*Opuntia ficus-indica*) and klu shrubs (*Acacia farnesiana*) with stipular spines, ½ inch to 1 inch long. Ground cover under the kiawe thicket consists primarily of Chinese violet and green panicgrass (*Panicum maximum* var. *trichoglume*), but rocky areas with few plants are also common. A number of old bulldozed roads are found here and can be seen on the aerial photos and identified on the topographic maps. These more open, disturbed sites support a mixture of grasses and herbs similar to those found in the mixed grassland. Among the most frequently observed species on these old roads are swollen fingergrass, 'ilima, virgate mimosa, sour grass (Digitaria insularis), and feather fingergrass (Chloris virgata).

On the eastern slopes of the project site, the kiawe/koa-haole thicket is more sheltered and the soil deeper. The kiawe trees are from 10 to 15 ft. tall with a somewhat dense koa-haole subcanopy layer, 6 to 10 ft. tall. Ground cover is rather dense, about 60 to 80%, with scattered rock outcroppings. The most abundant elements of the ground cover are green panicgrass and shrubs of wild basil. Where the woody cover is sparser and the substrate more eroded and stony, native species such as kakonakona (Panicum torridum), 'ilihe'e, 'ilima, hoary abutilon, 'uhaloa (Waltheria americana), and pili grass (Heteropogon contortus) are occasional to common. Introduced or alien species associated with these more open, sunnier areas include lantana (Lantana camara), false mallow (Malvastrum coromandelianum), comb hyptis (Hyptis pectinata), Natal redtop grass (Rhynchelytrum repens), West Indian beggar's tick (Bidens cynapiifolia), and pitted beardgrass.

ENDANGERED PLANTS

One endangered species, the 'ihi'ihi or 'ihi'ihi-lau-akea fern (Marsilea villosa) is found on the Queen's Beach project site. Marsilea villosa was listed as endangered by the U.S. Fish and Wildlife Service in June 1992. A listed species is protected by the Federal Endangered Species Act of 1973, as amended. Listing also implements the State regulations protecting endangered species. Hawai'i State Law (H.R.S. 195-D) protects all Federal and State listed plants (threatened and endangered) on all lands within the State.

Marsilea is an aquatic to semiaquatic fern with leaves that resemble a four-leaved clover. The four wedge-shaped leaves or segments which make up the leaf are found at the tip of the 2 to 10 inch tall stem. The leaves arise in pairs, and, when fertile produce small, hard sporocarps or spore cases. All parts of the plant including the spore cases may be covered by soft, short, rust-colored hairs (U.S. Fish and Wildlife Service 1992, Bruegmann 1989, St. John 1981). The plants grow in small shallow depressions on level or gently sloping terrain where there is periodic flooding or standing water to complete its life cycle. The spore cases normally are produced as the habitat begins to dry out and do not mature unless the plant is drought-stressed (U.S. Fish and Wildlife Service 1993, Bruegmann 1986). During the dry summer months, the leaves dry and drop off, leaving only the dried stems visible above ground. The rootstock or rhizome becomes dormant. In the rainy season when the shallow depressions are flooded, the rhizomes quickly send out new leaves and vegetatively produce young plants. The sporocarps also open to release male and female spores.

The fern has been recorded only from the islands of O'ahu, Moloka'i, and Ni'ihau. Marsilea was first collected in Nu'uanu Valley, O'ahu, in 1817. At that time it was apparently widespread on O'ahu, being commonly associated with taro fields, and, during the early to middle 1900's had been collected or observed at several sites including Barbers Point, 'Ewa, Kaimuki, Palolo Valley, and Makapu'u (U.S. Fish and Wildlife Service 1992, Bruegmann 1989). Degener (1936) noted that between 1925 and 1933 he had found the plants along a sandy road in Nanakuli, in a clay depression at Makapu'u, and in Lualualei Valley, Oa'hu. Today, only three populations of the fern are known from O'ahu. One at Koko Head on City and County of Honolulu land, one apparently planted at Queen's Beach, Makapu'u, and the third, on the Lualualei Naval Reservation (U.S. Fish and Wildlife Service 1993).

On Moloka'i, Marsilea was first collected in 1928 at Mokio and later at Mo'omomi and in the 'Ilio Point area. Surveys in these areas failed to find the plant. In 1989, a small population was found on privately owned lands at Kamaka'ipo, near La'au Point (Char 1990). Recently, a second small population was found (Bruegmann, pers. comm.). On Ni'ihau, one population was reported from Loe Lake in 1948, but because of limited access no recent collections have been made. It is unlikely that this population has survived as the area is heavily used for cattle grazing (U.S. Fish and Wildlife Service 1993).

On the Queen's Beach project site, a naturally occurring population of the fern was found by Kartawinata (Kartawinata and Mueller-Dombois 1972) during his studies of dry-grass community types on O'ahu. The plants were found along his transect 2, on the western end of the project site. Since Kartawinata's studies, a 15-foot wide drainage channel or ditch and a 200-foot wide overflow channel have been constructed in the area. Large boulders, dredge material, and soil have also been stockpiled on the site. In a search of the area around Kartawinata's transect 2, Funk (1984) did not find any Marsilea plants. During our studies an intensive search of the transect 2 area and adjoining transects was conducted. Low lying areas which pond during the heavy rains were observed in the transect 2 area. However, the site was so heavily disturbed by the construction of the drainage ditch and overflow channel that the fern has probably been extirpated from this particular area.

In the late 1980's, plants were taken from the Koko Head population and planted at Queen's Beach, Makapu'u (U.S. Fish and Wildlife Service 1993). These plants are found in the deep ruts and tracks made by off-road vehicles near the base of Kealakipapa Valley (Figures 1 and 2). The ruts fill with water during heavy rains.

DISCUSSION AND RECOMMENDATIONS

Most of the vegetation in the dry lowlands of the Hawaiian Islands has been extensively disturbed by humans and their introductions, and, thus are dominated by introduced or alien species, particularly shrubs and grasses (Cuddihy and Stone 1990). The Queen's Beach site was used for grazing cattle and was disturbed during the construction of the drainage ditch and overflow channel. A large portion of the site was also used to stockpile boulders and other material.

On the Queen's Beach property, the most abundant plants are introduced species such as koa-haole, buffelgrass, kiawe, and Guinea grass. These alien species are the dominant components in four of the six vegetation types recognized on the project site. Surprisingly, native species are abundant in the other two vegetation types. On the sandy beach and dune area from the Wawamalu Ranch Wall to Kaloko Point (Kaloko Beach), native species such as 'ilima, alena, nohu, nama, beach naupaka, etc., are important components of the coastal strand vegetation. In other places along the exposed shoreline, the substrate is lava rock interspersed with waterworn coral and basalt cobble. Here native coastal species such as 'ohelo kai, 'akulikuli, and Fimbristylis cymosa are abundant. In the koa-haole/ma'o shrubland, ma'o or the Hawaiian cotton is codominant with koa-haole. This shrubland also supports other native species such as naio, 'ilihe'e, 'ilima, and the endangered 'ihi'ihi or Marsilea fern.

The golf course and ancillary facilities proposed for the site will have a significant impact on the vegetation, especially of the native components. Areas which support high concentrations of native species will need to be preserved and managed.

The following recommendations are proposed to mitigate the impacts of the project on the botanical resources:

1. Preservation of Marsilea and preparation of a management plan.

The two areas which contain the *Marsilea* fern should be managed as a santuary or preserve. Currently, Char & Associates has been retained to provide a management plan for the *Marsilea*. The plan will be based primarily on the U.S. Fish and Wildlife Service Recovery Plan (1993) drafted for the *Marsilea*. The plan will be reviewed by the Service as well as the State's Division of Forestry and Wildlife. Alien species control will be addressed in the management plan.

2. Management of the coastal strand vegetation.

Active management of the area occupied by this vegetation type is needed, especially if public use is allowed. Off-road vehicles should not be allowed on Kaloko Beach. The present strand vegetation on the dunes, composed largely of beach naupaka, is already damaged and there is severe sand erosion in places. A boardwalk or someting similar to control pedestrian traffic should be established in the areas which support the more delicate annual species such as nama and *Panicum faurei*.

There are other agencies which have handled management of strand vegetation and could provide assistance. These are the State's Natural Areas Reserve System (NAR) which manages the Ka'ena NAR and The Nature Conservancy of Hawai'i which manages the Mo'omomi Preserve on Moloka'i.

3. Preservation of the area with high ma'o density.

There are few sites left in the Hawaiian Islands which support

such large numbers of Hawaiian cotton or ma'o. All or a large portion of the site identified in Figure 2 with a high density of ma'o should be left intact. Two endemic insects, the Oliarus wild cotton planthopper (*Oliarus discrepans*) and a Hawaiian snout beetle (*Rhyncogonus simplex*) have been collected from the ma'o in the Makapu'u area (Wilson Okamoto & Associates 1990). Both are category 2 candidate endangered species.

4. Use of native plants in landscaping.

Incorporating native plants into the landscape design is strongly recommended. Native plants already found on the project site are well-adapted to the local climatic and soil conditions, and could be defined as low-maintenance. This plant material should be collected and propagated before portions of the site are cleared. Many are of more-than-passing ornamental value and are recommended for landscaping the golf course and facilities. These include the nehe, naio, ma'o, naupaka, wiliwili, pa'u o Hi'iaka, hinahina, and 'ilihe'e.

LITERATURE CITED

Bruegmann, M.M. 1986. The phenology, tissue water relations and taxonomy of Marsilea villosa. M.S. thesis, Botany Department, University of Hawai'i, Manoa. Unpublished.

__________. 1989. Unpublished status report on Marsilea villosa. U.S. Fish and Wildlife Service, Honolulu office.

Char, W.P. 1990. Botanical reconnaissance survey, Hotel Alpha West Moloka'i property, West Moloka'i, Maui County, Hawai'i. Prepared for Belt Collins & Associates. January 1990.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Prepared for U.S. Fish and Wildlife Service. FWS/OBS-79/31. December 1979.

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: Effects of humans, their activities and introductions. Cooperative National Park Resources Studies Unit, University of Hawai'i, Manoa.

Degener, O. 1936. Flora Hawaiiensis, family 8. Marsileaceae: Marsilea villosa. Privately published.

Foote, D.E., E.L. Hill, S. Nakamura, and F. Stephens. 1972. Soil survey of the islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

Funk, E.J. 1984. Queen's Beach Park Feasibility Study, Botanical survey. Prepared for the Department of Parks and Recreation, City and County of Honolulu. July 1984.

Funk, E.J. 1991. Botanical reconnaissance survey of Ka Iwi. Prepared for Department of Land and Natural Resources. October 1991.

Hawai'i Heritage Program, The Nature Conservancy of Hawai'i. 1994. Summary listing of Hawaiian natural communities. Memorandum. February 1994.

Kuswata, K. and D. Mueller-Dombois. 1972. Phytosociology and ecology of the natural dry-grass communities on Oahu, Hawaii. Reinwardtia 8(3): 369-494.

Lamoureux, C.H. 1988. Draft checklist of Hawaiian pteridophytes, "Kupukupu O Hawai'i Ne'i". Lyon Arboretum, University of Hawai'i, Manoa.

St. John, H. (C.A. Corn, ed.). 1981. Rare endemic plants of the Hawaiian Islands. Department of Land and Natural Resources, State of Hawai'i, Honolulu.

U.S. Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants; Determination of endangered status for Marsilea villosa ('Ihi'ihi). Federal Register 57(120): 27863-27867. 22 July 1992.

__________. 1993. Marsilea villosa recovery plan. U.S. Fish and Wildlife Service, Portland, Oregon.

Wagner, W.L., D.R. Herbst, and S.H. Sohmer. 1990. Manual of the flowering plants of Hawai'i. 2 vols. University of Hawai'i Press and B.P. Bishop Museum Press, Honolulu. B.P. Museum Special Publication 83.

Wilson Okamoto & Associates, Inc. 1993. Ka Iwi Master Plan (Preliminary draft). Prepared for State Department of Land and Natural Resources, Division of Parks. May 1993.

PLANT SPECIES LIST -- Queen's Beach, Makapu'u, O'ahu

A checklist of all those vascular plant species inventoried on the project site during the field studies is presented below. The species are arranged alphabetically by families within each of three groups: Ferns, Monocots, and Dicots. The taxonomy and nomenclature of the Ferns follow Lamoureux (1988), while the flowering plants, Monocots and Dicots, are in accordance with Wagner et al. (1990), for the most part.

For each species, the following information is provided:

1. Scientific name with author citation.
2. Common English and/or Hawaiian name(s), when known.
3. Biogeographic status. The following symbols are used:
   - E = endemic = native only to the Hawaiian Islands.
   - I = indigenous = native to the Hawaiian Islands and also elsewhere throughout the Pacific and tropics.
   - P = Polynesian introduction = all those plants brought to the Hawaiian Islands by the Polynesians, intentionally or accidentally, prior to Western contact (Cook's discovery of the islands in 1778).
   - X = introduced or alien = all those plants brought to the Hawaiian Islands by humans, intentionally or accidentally, after Western contact.
   - I? = questionably indigenous = dates of introduction or other information unclear, but the weight of evidence suggests probably indigenous.
   - P? = questionably a Polynesian introduction = maybe Polynesian introduction or possibly introduced after early Western contact.
   - X? = questionably introduced or alien = dates of introduction are very early, and the weight of evidence suggests probably introduced.

4. Presence (+) or absence (-) of a particular species within each of six vegetation types recognized on the project site (see text for discussion):
c = Coastal Strand Vegetation
e = Estuarine and Drainage Channel Vegetation
m = Koa-haole/Ma'o Shrubland
k = Koa-haole Shrubland
g = Grassland
t = Kiawe/Koa-haole Thicket

Scientific name	Common name	Status	Vegetation types c	e	m	k	g	t
FERNS								
MARSILEACEAE (Water Clover Family)								
Marsilea villosa Kaulf.	'ihi'ihi-lau-akea	E	-	-	+	-	-	-
MONOCOTS								
AGAVACEAE (Sisal Family)								
Agave sisalana Perrine	sisal, malina	X	-	-	+	+	-	-
Sansevieria trifasciata Prain	snake plant, mother-in-law's tongue	X	-	-	+	+	-	-
COMMELINACEAE (Spiderwort Family)								
Commelina benghalensis L.	hairy honohono	X	-	-	+	-	+	+
Commelina diffusa N.L. Burm.	honohono	X	-	-	-	-	+	-
CYPERACEAE (Sedge Family)								
Cyperus rotundus L.	nutgrass, nut sedge	X	+	-	+	-	+	-
Eleocharis obtusa (Willd.) Schult.	spikerush, kohekohe, pipi wai	I	-	-	+	-	-	-
Fimbristylis cymosa R. Br.		I	+	-	-	-	-	-
LILIACEAE (Lily Family)								
Aloe vera L.	aloe	X	-	-	+	-	-	-
POACEAE (Grass Family)								
Bothriochloa pertusa (L.) A. Camus	pitted beardgrass	X	-	-	+	-	+	+
Brachiaria mutica (Forssk.) Stapf	California grass	X	-	+	-	-	-	-
Cenchrus ciliaris L.	buffelgrass	X	+	-	+	+	+	+
Cenchrus echinatus L.	common sandbur, 'ume'alu	X	+	-	-	-	-	-
Chloris barbata (L.) Sw.	swollen fingergrass, mau'ulei	X	-	-	+	-	+	+
Chloris radiata (L.) Sw.	radiate fingergrass	X	-	-	-	-	-	+
Chloris virgata Sw.	feather fingergrass	X	-	-	-	-	-	+
Coix lachryma-jobi L.	Job's tears	X	-	+	-	-	-	-

Scientific name	Common name	Status	c	e	m	k	g	t
Cynodon dactylon (L.) Pers.	Bermuda grass, manienie	X	+	-	+	+	-	-
Dactyloctenium aegyptium (L.) Willd.	beach wiregrass	X	+	-	-	+	+	+
Dichanthium sericeum (R. Br.) A. Camus	Australian bluestem	X	-	-	+	-	+	-
Digitaria insularis (L.) Mez ex Ekman	sourgrass	X	-	-	-	-	+	+
Digitaria setigera Roth		I	-	-	-	-	+	
Echinochloa colona (L.) Link	jungle-rice	X	-	-	+	-	+	-
Echinochloa crus-galli (L.) P. Beauv.	barnyard rice	X	-	+	-	-	-	-
Eleusine indica (L.) Gaertn.	wire grass, goosegrass	X	-	-	-	+	-	+
Eragrostis af. pilosa (L.) P. Beauv.		X	-	-	+	-	-	-
Eriochloa punctata (L.) Desv. ex W. Ham.	cupgrass	X	-	-	+	-	-	-
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	pili, pili grass	I	-	-	-	-	-	+
Melinis minutiflora P. Beauv.	molasses grass	X	-	-	+	-	-	-
Panicum fauriei Hitchc.		E	+	-	-	-	-	-
Panicum maximum Jacq.	Guinea grass	X	-	+	+	+	+	+
Panicum maximum var. trichoglume Eyles ex Robyns	green panicgrass	X	-	-	-	-	-	+
Panicum miliaceum L.	Proso millet, broomcorn millet	X	-	-	+	-	-	-
Panicum torridum Gaud.	kakonakona	E	-	-	-	-	-	+
Rhynchelytrum repens (Willd.) Hubb.	Natal redtop grass	X	-	-	-	-	-	+
Setaria verticillata (L.) P. Beauv.	bristly foxtail	X	-	-	+	-	+	-
Sporobolus virginicus (L.) Kunth	beach dropseed, 'aki'aki	I	+	-	-	-	-	-

DICOTS

Scientific name	Common name	Status	c	e	m	k	g	t
ACANTHACEAE (Acanthus Family)								
Asystasia gengetica (L.) T. Anderson	Chinese violet, asystasia	X	-	-	+	-	+	+
Ruellia brittoniana E. Leonard		X	-	+	+	-	-	-
Ruellia prostrata Poir		X	-	-	+	-	+	+
AIZOACEAE (Fir-marigold Family)								
Sesuvium portulacastrum (L.) L.	'akulikuli	I	+	+	-	-	-	-
Tetragonia tetragonioides (Pall.) Kuntze	New Zealand spinach	X	+	-	-	-	-	-
Trianthema portulacastrum L.		X	-	-	+	-	+	-

Scientific name	Common name	Status	c	e	m	k	g	t
AMARANTHACEAE (Amaranth Family)								
Alternanthera pungens Kunth	khaki weed	X	-	-	-	+	-	-
Amaranthus spinosus L.	spiny amaranth, pakai kuku	X	-	-	+	-	-	-
Amaranthus viridus L.	slender amaranth, pakai	X	-	-	-	-	+	-
ANACARDIACEAE (Mango Family)								
Schinus terebinthifolius Raddi	Christmas berry	X	-	-	+	-	-	-
ASCLEPIADACEAE (Milkweed Family)								
Stapelia gigantea N.E. Brown	carrion flower	X	-	-	+	-	+	-
ASTERACEAE (Daisy Family)								
Ageratum conyzoides L.	maile hohono	X	-	-	+	-	-	+
Bidens cynapiifolia Kunth	West Indian beggar's tick	X	-	-	+	-	-	+
Bidens pilosa L.	Spanish needle, beggar's tick, ki	X	-	-	+	-	+	-
Calyptocarpus vialis Less.	hierba del cabello	X	-	-	-	-	+	-
Emilia fosbergii Nicolson	pualele	X	-	-	-	-	+	-
Hypochoeris glabra L.	smooth cat's ear	X	-	-	-	-	-	+
Lipochaeta lobata (Gaud.) DC.	nehe	E	-	-	+	+	+	+
Pluchea indica (L.) Less.	Indian pluchea, Indian fleabane	X	+	+	-	-	-	-
Pluchea symphytifolia (Mill.) Gillis	pluchea, sourbush	X	-	-	+	-	-	-
Reichardia tingitana (L.) Roth		X	+	-	-	-	-	-
Sonchus oleraceus L.	sowthistle, pua-lele	X	-	-	+	+	+	+
Synedrella nodiflora (L.) Gaertn.	nodeweed	X	-	-	-	-	-	+
Tridax procumbens L.	coatbuttons	X	-	-	+	+	-	-
Verbesina encelioides (Cav.) Benth. & Hook.	golden crown-beard	X	-	-	-	-	+	-
Xanthium strumarium var. canadense (Mill.) Torr. & A. Gray	cocklebur, kikania	X	-	-	+	-	-	-
BATIDACEAE (Saltwort Family)								
Batis maritima L.	pickleweed	X	-	+	-	-	-	-

Scientific name	Common name	Status	Vegetation types c	e	m	k	g	t
BORAGINACEAE (Heliotrope Family)								
Heliotropium anomalum var. argenteum A. Gray	hinahina, hinahina ku kahakai	E	+	-	-	-	-	-
Heliotropium curassavicum L.	kipukai, nena	I	-	+	-	-	-	-
Heliotropium procumbens var. depressum (Cham.) Fosb.		X	-	-	+	-	-	-
Tournefortia argentea L. f.	tree heliotrope	X	+	-	-	+	-	-
CACTACEAE (Cactus Family)								
Opuntia ficus-indica (L.) Mill.	prickly pear, panini	X	-	-	+	-	-	+
CARYOPHYLLACEAE (Pink Family)								
Spergularia marina (L.) Griseb.	saltmarsh sand spurry	X	-	+	-	-	-	-
CASUARINACEAE (Ironwood Family)								
Casuarina equisetifolia L.	ironwood, paina	X	+	-	-	+	-	-
CHENOPODIACEAE (Goosefoot Family)								
Atriplex semibaccata R. Br.	Australian saltbush	X	+	-	-	-	+	-
Chenopodium murale L.	'aheahea	X	-	-	-	+	-	-
COMBRETACEAE (Terminalia Family)								
Conocarpus erectus L.	buttonwood	X	-	+	-	-	-	-
CONVOLVULACEAE (Morning-glory Family)								
Ipomoea cairica (L.) Sweet	koali	X?	-	-	+	+	-	+
Ipomoea obscura (L.) Ker-Gawl.	field bindweed	X	-	-	+	-	-	-
Ipomoea pes-caprae ssp. brasiliensis (L.) Ooststr.	beach morning-glory, pohuehue	I	+	-	-	-	-	-
Ipomoea triloba L.	little bell, pink bindweed	X	-	-	+	-	-	-
Jacquemontia ovalifolia ssp. sandwicensis (A. Gray) K. Robertson	pa'u o Hi'i'aka	E	+	-	+	+	+	-
Merremia aegyptia (L.) Urb.	hairy merremia, koali kua hulu	X?	+	-	+	+	+	+

Scientific name	Common name	Status	Vegetation types c	e	m	k	g	t
CRASSULACEAE (Orpine Family)								
Kalanchoe pinnata (Lam.) Pers.	air plant	X	-	-	+	-	-	-
Kalanchoe tubiflora (Harv.) Raym.-Hamet	chandelier plant	X	-	-	+	-	-	-
CUCURBITACEAE (Squash Family)								
Coccinia grandis (L.) Voigt	coccinia, ivy gourd	X	-	-	+	-	+	-
Momordica charantia L.	wild bittermelon, balsam pear	X	-	-	+	-	-	-
EUPHORBIACEAE (Spurge Family)								
Chamaesyce degeneri (Sherff) Croizot & Degener	beach spurge, 'akoko	E	+	-	-	-	-	-
Chamaesyce hirta (L.) Millsp.	hairy spurge, garden spurge	X	-	-	-	+	+	-
Chamaesyce hypericifolia (L.) Millsp.	graceful spurge	X	-	-	+	-	+	-
Chamaesyce prostrata (Aiton) Small	prostrate spurge	X	-	-	-	+	+	-
Euphorbia heterophylla L.	kaliko	X	-	-	+	-	-	-
Euphorbia tirucalli L.	pencil plant, milk hedge	X	-	-	+	-	-	-
Phyllanthus debilis Klein ex Willd.	niruri	X	-	+	+	-	-	+
Ricinus communis L.	castor bean, koli	X	-	+	-	-	-	-
FABACEAE (Pea Family)								
Acacia farnesiana (L.) Willd.	klu	X	-	-	+	-	+	+
Chamaecrista nictitans (L.) Moench	partridge pea, lauki	X	-	-	-	-	-	+
Clitoria ternata L.	butterfly pea	X	-	-	+	+	-	-
Crotalaria incana L.	fuzzy rattlepod, kukaehoki	X	-	-	+	-	-	-
Desmanthus virgatus (L.) Willd.	slender mimosa, virgate mimosa	X	-	-	+	+	+	+
Erythrina crista-galli L.	coral tree	X	-	-	+	-	-	-
Erythrina sandwicensis Degener	wiliwili	E	-	-	+	-	-	-
Indigofera suffruticosa Mill.	indigo, 'iniko	X	-	-	+	-	-	-
Leucaena leucocephala (Lam.) de Wit	koa-haole	X	-	+	+	+	+	+
Macroptilium lathyroides (L.) Urb.	wild bushbean, cow pea	X	-	-	+	-	+	-
Medicago sativa L.	alfalfa, lucerne, 'alapapa	X	-	-	+	-	-	-
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth	kiawe	X	+	-	+	+	+	+

Scientific name	Common name	Status	c	e	m	k	g	t
GOODENIACEAE (Goodenia Family)								
Scaevola sericea Vahl	naupaka, naupaka kahakai	I	+	-	-	+	-	-
HYDROPHYLLACEAE (Waterleaf Family)								
Nama sandwicensis A. Gray	nama	E	+	-	-	-	-	-
LAMIACEAE (Mint Family)								
Hyptis pectinata (L.) Poit.	comb hyptis	X	-	-	-	-	-	+
Ocimum gratissimum L.	wild basil	X	-	-	+	+	+	+
Plectranthus sp. (ornamental)		X	-	-	+	-	-	-
MALVACEAE (Mallow Family)								
Abutilon incanum (Link) Sweet	hoary abutilon	I?	-	-	+	-	+	+
Gossypium tomentosum Nutt. ex Seem.	ma'o, huluhulu	E	-	-	+	-	+	-
Malva parviflora L.	cheese weed	X	-	-	+	-	+	-
Malvastrum americanum (L.) Torr.		X	-	-	+	-	-	+
Malvastrum coromandelianum (L.) Garcke	false mallow, hauuoi	X	-	-	+	-	+	+
Sida fallax Walp.	'ilima	I	+	-	+	+	+	+
Sida rhombifolia L.	Cuba jute	X	-	-	+	-	-	-
Sida sp.		X	-	-	-	+	-	-
Thespesia populnea (L.) Sol. ex Correa	milo	I?	+	+	-	+	-	-
MYOPORACEAE (Myoporum Family)								
Myoporum sandwicense A. Gray	naio	I	+	-	+	+	-	-
NYCTAGINACEAE (Four-o'clock Family)								
Boerhavia coccinea Mill.	red-flowered boerhavia	X	-	-	-	+	-	-
Boerhavia glabrata Blume	alena, nena	I	-	-	+	-	+	+
Boerhavia repens L.	alena	I	-	-	-	-	-	-
ONAGRACEAE (Evening Primrose Family)								
Ludwigia octovalvis (Jacq.) Raven	primrose willow, kamole	P?	-	+	-	-	-	-
PASSIFLORACEAE (Passion Flower Family)								
Passiflora foetida L.	scarlet-fruited passion flower, pohapoha	X	-	-	+	-	-	-

Scientific name	Common name	Status	c	e	m	k	g	t
PLUMBAGINACEAE (Leadwort Family)								
Plumbago zeylanica L.	'ilie'e, hilie'e	I	-	-	+	-	-	+
POLYGONACEAE (Buckwheat Family)								
Antigonon leptopus Hook. & Arnott	Mexican creeper, chain-of-hearts	X	-	-	+	-	-	-
Coccoloba uvifera (L.) L.	sea grape	X	+	-	-	+	-	-
PORTULACACEAE (Purslane Family)								
Portulaca grandiflora Hook.	portulaca	X	-	-	+	-	-	-
Portulaca oleracea L.	common purslane, pigweed, 'ihi	X	+	-	-	-	+	+
Portulaca pilosa L.	'ihi	X	+	-	-	-	+	-
RHIZOPHORACEAE (Mangrove Family)								
Rhizophora mangle L.	American mangrove, red mangrove	X	-	+	-	-	-	-
SOLANACEAE (Nightshade Family)								
Datura stramonium L.	Jimson weed, la'au hano	X	-	-	-	-	+	-
Lycium sandwicense A. Gray	'ohelo kai, 'ae'ae	I	+	-	-	-	-	-
Lycopersicon pimpinellifolium (Jusl.) Mill.	currant tomato, wild tomato	X	-	-	+	-	-	-
Solanum americanum Mill.	popolo	I?	+	-	-	-	-	+
STERCULIACEAE (Cacao Family)								
Waltheria indica L.	'uhaloa, hi'aloa, kanakaloa	I?	+	-	+	-	+	+
VERBENACEAE (Verbena Family)								
Lantana camara L.	lantana, lakana	X	-	-	-	-	-	+
ZYGOPHYLLACEAE (Caltrop Family)								
Tribulus cistoides L.	nohu	I	+	-	-	-	-	-

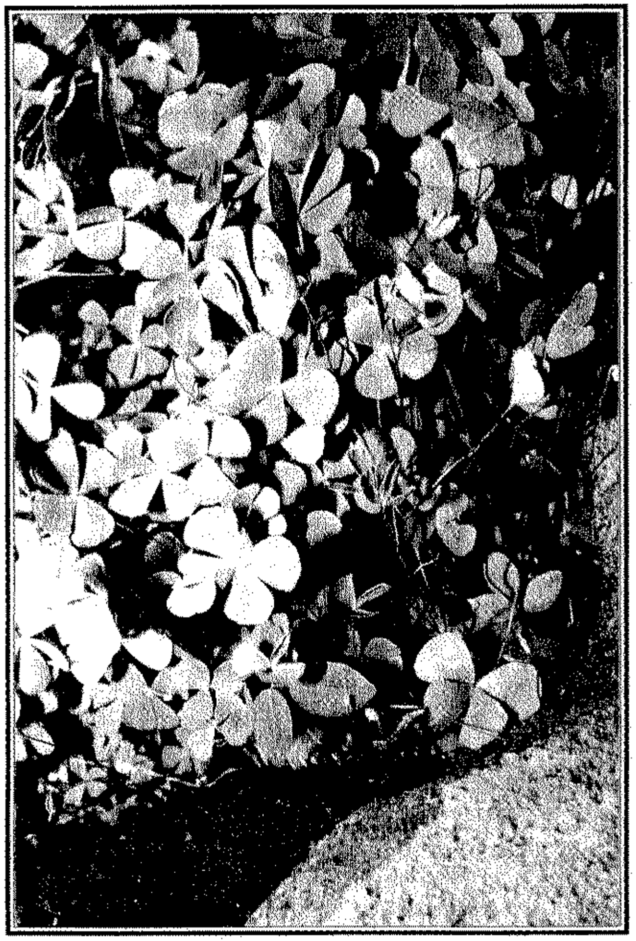


Figure 3. Marsilea villosa or ʻihi ʻihi fern, Queen's Beach, Makapuʻu, Oʻahu.

On the project site, the ferns are found in deep ruts made by off-road vehicles which fill with water during the rainy season. The leaves resemble a four-leaved clover and occur in pairs. The plants become dormant during the dry summer months and become difficult to find.

Photo by T.J. Motley

Figure 4. Gossypium tomentosum or maʻo.

The native cotton or maʻo occurs in leeward lowland areas on all the main islands except Hawaiʻi. This attractive shrub has large lemon-yellow flowers and silver-gray leaves. Fruits split open to reveal several seeds covered by reddish-brown hairs. The plants are abundant on some parts of the Queen's Beach project site.

Photo by T.J. Motley

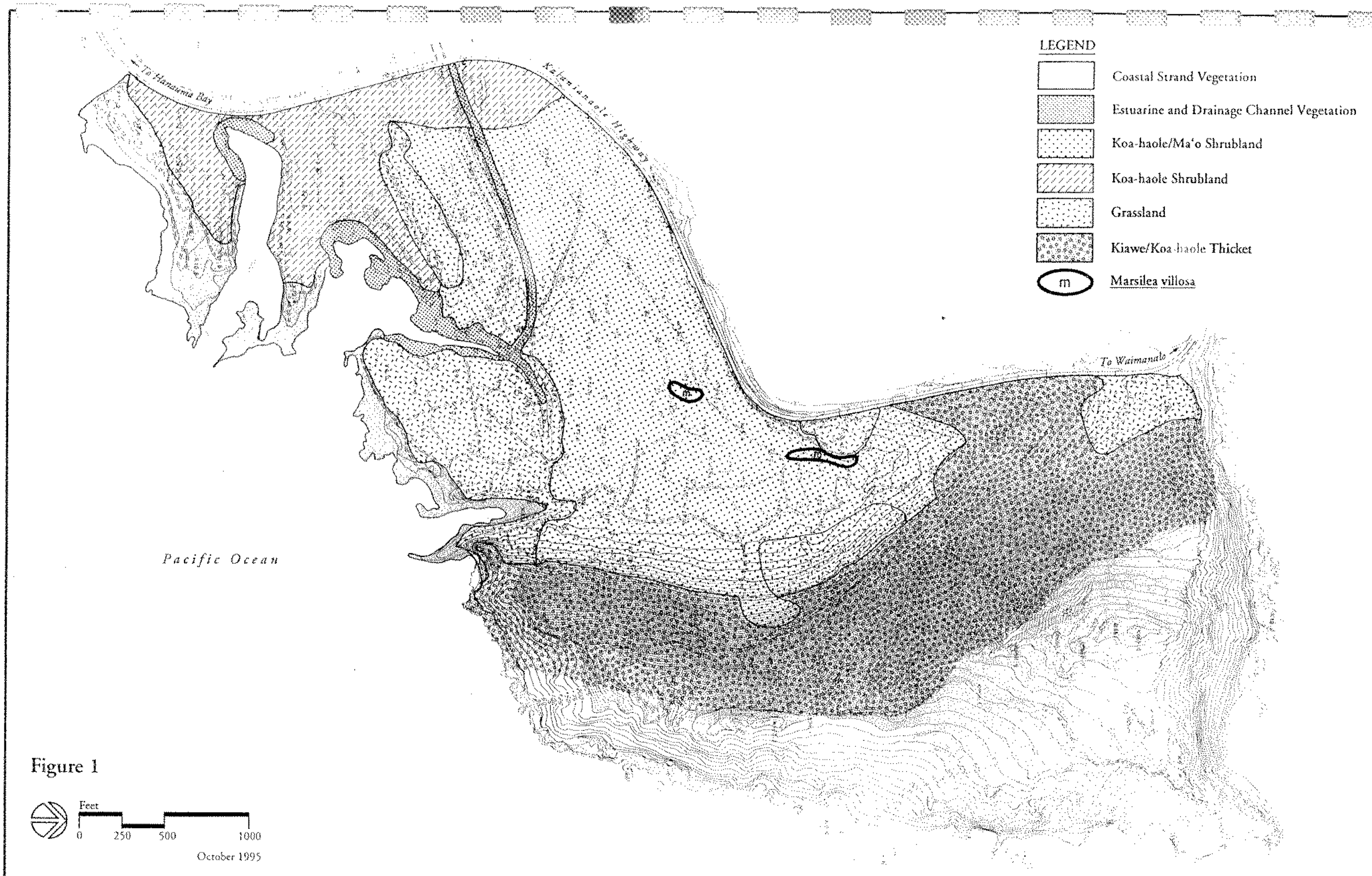
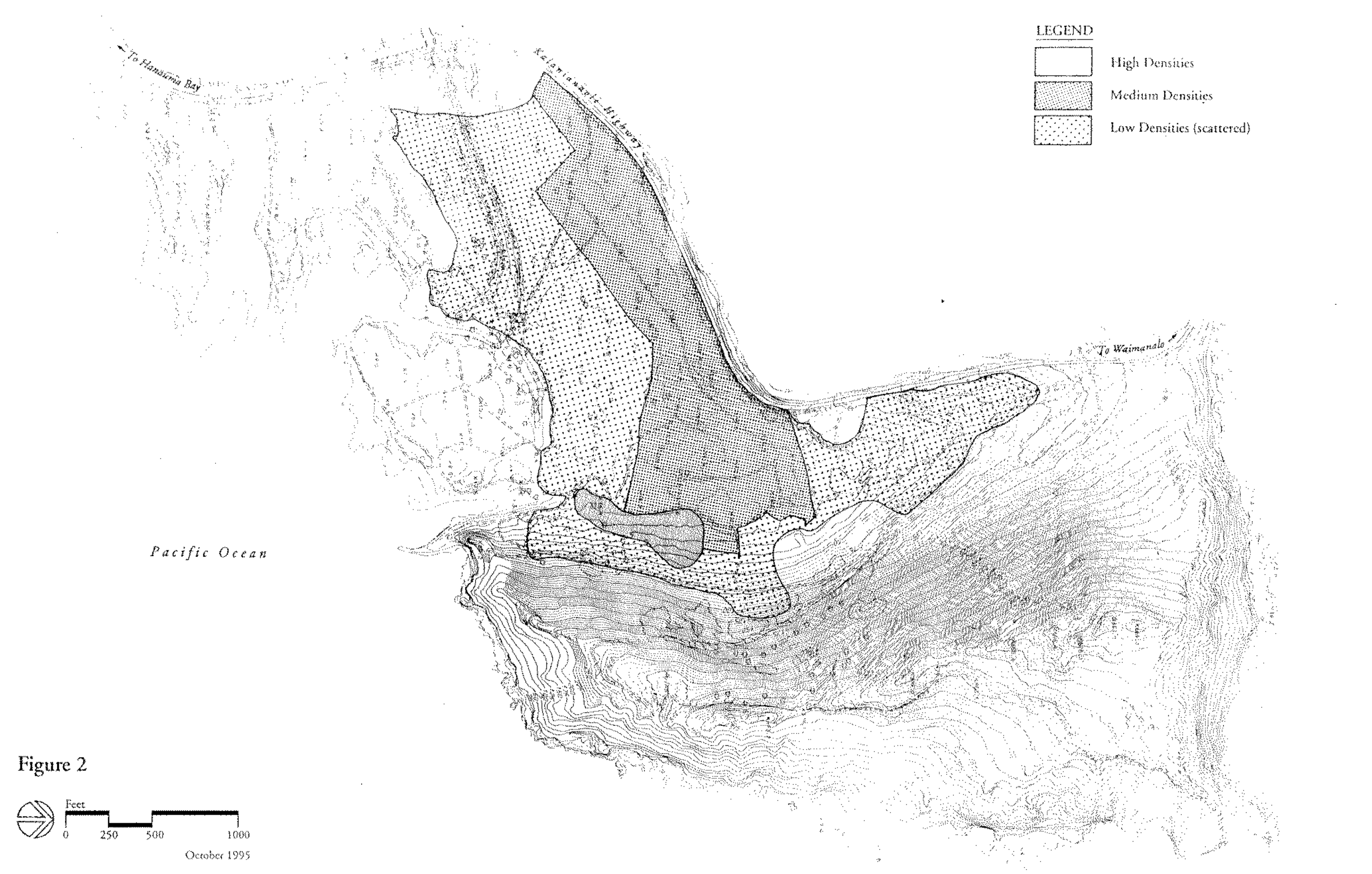

LEGEND
Coastal Strand Vegetation
Estuarine and Drainage Channel Vegetation
Koa-haole/Ma'o Shrubland
Koa-haole Shrubland
Grassland
Kiawe/Koa-haole Thicket
m
Marsilea villosa
To Hanauma Bay
Kalanianaole Highway
To Waimanalo
Pacific Ocean
Feet
0
250
500
1000
October 1995

Figure 1



LEGEND
High Densities
Medium Densities
Low Densities (scattered)
To Hanauma Bay
Kalanianaole Highway
To Waimanalo
Pacific Ocean
Feet
0
250
500
1000
October 1995

Figure 2

QUEEN'S BEACH GOLF COURSE

Appendix

E

Wetlands Survey

(Char & Associates)

and Letter from U.S. Army Corps of Engineers

April 17, 1996

Ms. Kathleen A. Dadey, Ph.D.
Environmental Engineer
Operations Division
U.S. Army Corps of Engineers
Pacific Ocean Division
Building 230
Ft. Shafter, HI 96858-5440

Dear Dr. Dadey:

Request for Wetlands Determination
Kealakipapa Valley, Queen's Beach
Makapu'u, O'ahu
Tax Map Key: 1-3-9-11:3

Over the course of the last several months, information was presented in a Draft Environmental Impact Statement prepared for the State of Hawaii Department of Land and Natural Resources which suggested the presence of wetlands on the above property. On behalf of the current lessee of the property (Kaiser Aluminum and Chemical Corporation), and with the cooperation of the landowner (Kamehameha Schools Bernice Pauahi Bishop Estate) we engaged the services of Char & Associates to conduct a study to assist in the determination of the presence/absence of wetlands on the subject property.

In March of 1996, Char & Associates, with the assistance of Edwin Murabayashi, surveyed three sites to determine presence/absence of wetland conditions (see attached location map). Their findings are attached. In summary, none of the three sites exhibited all necessary conditions to be considered wetlands. Specifically, no hydric soils were present.

We have also attached representative photos of Site #1, which exhibited the most abundant number of *Marsilea villosa*, the endangered water fern. While we believe none of the sites should be considered wetlands, we do recognize the need to protect the three colonies of *Marsilea*, and will work closely with the U.S. Fish and Wildlife Service to develop appropriate mitigation measures as we continue with our own environmental impact statement (EIS) process for a proposed golf course at Queen's Beach.

The golf course is the subject of a recent EIS Preparation Notice (March 1996) that has been forwarded to your office for review and comment. At this time we ask for your

Helber Hastert & Fee
Grosvenor Center, Makai Tower
733 Bishop Street, Suite 2590
Honolulu, Hawaii 96813
Telephone 808 545-2055
Facsimile 808 545-2050

concurrence with the findings of Char & Associates, and are hopeful we can include your determination in the upcoming draft EIS for the proposed golf course.

If you have any questions, or need additional information, please call me.

Sincerely,

HELBER HASTERT & FEE, Planners

Scott Ezer
Senior Associate

Enclosures

CHAR & ASSOCIATES
Botanical/Environmental Consultants
4471 Puu Panini Ave.
Honolulu, Hawaii 96816
(808) 734-7828

March 1996

Summary of Findings
Wetlands Study at Queen's Beach
Makapu'u, O'ahu

On 02 March 1996, a study was made of the suspected wetland areas which support the three *Marsilea villosa* colonies. Site #1 is located within the most northern *Marsilea* colony, which lies in an overgrown tire rut adjacent to a natural drainage area from a small gully. Site #2 is located within the *Marsilea* colony along the powerline road, slightly south of Site #1. Site #3 is found within the *Marsilea* colony located on a side road off of the powerline road. This colony is located about 600 ft. south of the other two colonies. The surrounding vegetation consists of koa-haole (*Leucaena leucocephala*) shrubland with scattered trees of kiawe (*Prosopis pallida*). Guinea grass (*Panicum maximum*) forms dense clumps between the koa-haole shrubs.

Data forms for wetland determination of each of the three sites are attached.

Wetland indicator species were only associated with the road areas where the soil had been disturbed and compacted by vehicular traffic. The surrounding lands had no standing water and supported nonwetland and facultative upland species such as koa-haole, kiawe, Guinea grass, 'ilima (*Sida fallax*), swollen fingergrass (*Chloris barbata*), asystasia (*Asystasia gangetica*), etc. All the standing water in the tire ruts along the road were from surface runoff. There is no water table close to the surface in this area.

Although these depressions do support wetland indicator species and appear to pond for some duration during some years with higher rainfall, the water does not stand long enough and/or occur frequently enough to cause changes in soil chemistry and the formation of hydric soils.

We did not observe any mottling or anaerobic conditions in the soil test pits excavated at the three sites. The Lualualei soil series found within the study area have a high clay content which when compacted by vehicular traffic tends to drain slowly, encouraging surface ponding (see soils report attached).

Because of the lack of hydric soils, these areas are not considered to be wetlands. They are the result of soil compaction due to vehicular traffic. If vehicular traffic were excluded from these areas, the compacted soil loosened, and the runoff water diverted and spread out onto the surrounding koa-haole shrubland, there would be no ponded areas.

EDWIN T. MURABAYASHI
1013 Liku Street
Kailua, Hawaii 96734

March 8, 1996

Soils Report for Makapuu Depressions, Oahu

The Soil Conservation soils map* of the area investigated shows Lualualei as the soil series, with two mapping units differentiated by slope variations: *LuA* Lualualei clay, 0 to 2 percent slopes, and *LuB* Lualualei clay, 2 to 6 percent slopes. This study concurs that the soil characteristics observed in the field on March 2, 1996 are consistent with the Lualualei Series description.

The Lualualei Series has two major distinguishing features:
(a) a dark surface soil typically very dark grayish brown to almost black, which is readily noticeable even by casual observation. This dark surface soil generally extends to a depth of about 20 inches, then grading to a grayer color in the subsoil. The dark color in this soil is not attributable to an unusually high organic matter content. Also, there was no mottling, indicative of prolonged reducing conditions, observed in the field profiles taken from within the water-logged depressions themselves. This is consistent with the description of the well-drained Lualualei in the soil survey report. (b) exhibits characteristics commonly associated with high clay content. This is attributable to high smectite (formerly called montmorilomite) clay content in this soil. There is only one soil type, Lualualei clay and it strongly exhibits the characteristics commonly associated with a high clay soil: very sticky and plastic; considerable expansion and contraction on wetting and drying which is particularly noticeable with the appearance of wide vertical cracks as the soil dries; slow water movement through the profile due to high swelling on wetting.

From these characteristics, it appears likely that the combination of high clay content and vehicular traffic has contributed to the ponding situation. The vehicular traffic caused compaction, resulting in depressed tire ruts which became water containers when it rained. Runoff from adjacent areas accumulated in the depression, providing moisture for clay expansion. This tended to further reduce internal drainage and, by elimination, encourage surface ponding. It was observed that ponding was apparent only in the depressed tire ruts and not in adjacent undisturbed areas. The tire compaction also reduced water infiltration and percolation by destroying inherent soil structure, which under undisturbed conditions enhances internal water movement. The next effect of this is the reduction of infiltration and percolation within the compacted layer and results in accumulation of water at the surface in the ruts.

*U.S. Department of Agriculture, Soil Conservation Service, *Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii*, August 1972.

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Queen's Beach, Makapu'u, O'ahu	Date: 02 March 1996
Applicant/Owner:	County: Honolulu
Investigator: CHAR & ASSOCIATES	State: Hawai'i
Do Normal Circumstances exist on the site? (Yes) No	Community ID:
Is the site significantly disturbed (Atypical Situation)? Yes (No)	Transect ID:
Is the area a potential Problem Area? Yes No	Plot ID: Site #1
(If needed, explain on reverse.)	(Marsilea colony in overgrown tire rut by gully -- natural drainage)

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Marsilea villosa	herb/fern	OBL	9.		
2.			10.		
3.			11.		
4.			12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). ± 90%

Remarks: Marsilea restricted to tire rut area, not in surrounding Koa-haole shrubland.

HYDROLOGY

___ Recorded Data (Describe in Remarks): ___ Stream, Lake, or Tide Gauge ___ Aerial Photographs ___ Other ✓ No Recorded Data Available	Wetland Hydrology Indicators: Primary Indicators: ✓ Inundated ___ Saturated in Upper 12 Inches ___ Water Marks ___ Drift Lines ___ Sediment Deposits ___ Drainage Patterns in Wetlands Secondary Indicators (2 or more required): ___ Oxidized Root Channels in Upper 12 Inches ___ Water-Stained Leaves ___ Local Soil Survey Data ___ FAC-Neutral Test ___ Other (Explain in Remarks)
Field Observations: Depth of Surface Water: 10 (in.) (at deep end) Depth to Free Water in Pit: ___ (in.) Depth to Saturated Soil: ___ (in.)	

Remarks: Filamentous green algae mats present. At least two aquatic insect species observed, water boatmen (family: Corixidae) and dragonfly nymphs (family: Aeshnidae ?).

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Queen's Beach, Makapu'u, O'ahu	Date: 02 March 1996
Applicant/Owner:	County: Honolulu
Investigator: CHAR & ASSOCIATES	State: Hawai'i
Do Normal Circumstances exist on the site? (Yes) No	Community ID:
Is the site significantly disturbed (Atypical Situation)? Yes (No)	Transect ID:
Is the area a potential Problem Area? Yes No (If needed, explain on reverse.)	Plot ID: Site #2 (Marsilea colony in powerline road)

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Marsilea villosa	herb/fern	OBL	9.		
2. Echinochloa colona	herb/grass	FACW	10.		
3. Dichanthium aristatum	herb/grass	NL*	11.		
4.			12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 85%

Remarks: Wetland indicator species restricted to tire rut area, not extending into adjacent Koa-haole shrubland.

*NL = not listed in Reed (1988). National list of plant species that occur in wetlands: Hawaii (Region H). U.S. Fish and Wildlife Service Biological Report 88(26.13).

HYDROLOGY

___ Recorded Data (Describe in Remarks):
- ___ Stream, Lake, or Tide Gauge
- ___ Aerial Photographs
- ___ Other

✓ No Recorded Data Available

Field Observations:

Depth of Surface Water: 2 in. at test pit to 4 in. at deepest end (in.)

Depth to Free Water in Pit: ______ (in.)

Depth to Saturated Soil: ______ (in.)

Wetland Hydrology Indicators:

Primary Indicators:
- ✓ Inundated
- ___ Saturated in Upper 12 Inches
- ___ Water Marks
- ___ Drift Lines
- ___ Sediment Deposits
- ___ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
- ___ Oxidized Root Channels in Upper 12 Inches
- ___ Water-Stained Leaves
- ___ Local Soil Survey Data
- ___ FAC-Neutral Test
- ___ Other (Explain in Remarks)

Remarks: Filamentous green algae common; leaving a thin, dried mat where the water has evaporated. Water boatmen and dragonfly nymphs observed.

SOILS (See attached soils report)

Map Unit Name (Series and Phase): ______

Drainage Class: ______

Field Observations Confirm Mapped Type? Yes No

Taxonomy (Subgroup): ______

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators:
- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	(Yes) No	(Circle)
Wetland Hydrology Present?	(Yes) No	
Hydric Soils Present?	Yes (No)	

Is this Sampling Point Within a Wetland? (Circle) Yes (No)

Remarks: Does not meet hydric soils criterion for a wetland.

Approved by HQUSACE 3/92

DAT[illegible]M
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Queen's Beach, Makapu'u, O'ahu	Date: 02 March 1996
Applicant/Owner:	County: Honolulu
Investigator: CHAR & ASSOCIATES	State: Hawai'i
Do Normal Circumstances exist on the site? (Yes) No	Community ID:
Is the site significantly disturbed (Atypical Situation)? Yes (No)	Transect ID:
Is the area a potential Problem Area? Yes No	Plot ID: Site #3
(If needed, explain on reverse.)	(Marsilea colony in overgrown side road off of powerline road)

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Marsilea villosa	herb/fern	OBL	9.		
2. Echinochloa colona	herb/grass	FACW	10.		
3. Panicum maximum	herb/grass	FACU	11.		
4. Chloris barbata	herb/grass	FACU	12.		
5. Xanthium strumarium	herb	FACU	13.		
6. Dichanthium aristatum	herb/grass	NL	14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-): > 50%

Remarks: Of the 3 sites with Marsilea, this one dries out the fastest -- tire rut is shallow, and is overgrown with many nonwetland indicator species.

HYDROLOGY

___ Recorded Data (Describe in Remarks):
- ___ Stream, Lake, or Tide Gauge
- ___ Aerial Photographs
- ___ Other

✓ No Recorded Data Available

Field Observations:

Depth of Surface Water: ______ (in.)

Depth to Free Water in Pit: ______ (in.)

Depth to Saturated Soil: at surface (in.)

Wetland Hydrology Indicators:

Primary Indicators:
- ___ Inundated
- ✓ Saturated in Upper 12 Inches
- ___ Water Marks
- ___ Drift Lines
- ___ Sediment Deposits
- ___ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
- ___ Oxidized Root Channels in Upper 12 Inches
- ✓ Water-Stained Leaves
- ___ Local Soil Survey Data
- ___ FAC-Neutral Test
- ✓ Other (Explain in Remarks)

Remarks: No standing water, but dead dragonfly nymph found on wet soil.

SOILS (See soils report attached)

Map Unit Name (Series and Phase): ______ Drainage Class: ______

Field Observations Confirm Mapped Type? Yes No

Taxonomy (Subgroup): ______

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators:
- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present? (Yes) No (Circle)

Wetland Hydrology Present? (Yes) No

Hydric Soils Present? Yes (No)

Is this Sampling Point Within a Wetland? (Circle) Yes (No)

Remarks: Does not meet all three criteria for a wetland.

SOILS (See attached soils report)

Map Unit Name (Series and Phase): ____ Drainage Class: ____
Field Observations Confirm Mapped Type? Yes No

Taxonomy (Subgroup): ____

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators:

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks:

WETLAND DETERMINATION

Hydrophytic Vegetation Present? (Yes) No (Circle)
Wetland Hydrology Present? ~~Yes~~ (No)?
Hydric Soils Present? Yes (No)

Is this Sampling Point Within a Wetland? Yes (No) (Circle)

Remarks: Wetland hydrology is questionable as it appear to dry out quickly - less than 1 or 2 weeks.
Hydric soils not present.

Approved by HQUSACE 3/92

SOILS #1 SITE, MAKAPUU DEPRESSION, OAHU

Map Unit Name (Series and Phase): L'UALUALEI CLAY 2-6% SLOPE Drainage Class: WELL-DRAINED
Field Observations Confirm Mapped Type? (Yes) No

Taxonomy (Subgroup): TYPIC CHROMUSTERTS ORDER VERTISOLS

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-19"+	A1	10 YR 2/2 V. DK. BRN	NONE	NONE	VERY STICKY CLAY VERY PLASTIC
	STONY LAYER AT 19 IN.				

FIELD WORK 3/2/96

Hydric Soil Indicators:

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- X Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks: (1) SITE OCCURS IN TIRE-RUT DEPRESSION 5FT X 10 FT. (2) 10 INCHES STANDING WATER OVER PROFILE. (3) HORIZON IS SATURATED BUT NO EVIDENCE OF MOTTLING OR GLEYING. (4) NO ODOR OF REDUCING ANAEROBIC CONDITIONS. (5) GENERAL LAND SLOPE 2% (6) SOME GRASS ROOTS

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes No (Circle)
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No

Is this Sampling Point Within a Wetland? Yes No (Circle)

Remarks:

Approved by HQUSACE 3/92

SOILS #2 SITE, MAKAPUU DEPRESSIONS, OAHU

Map Unit Name (Series and Phase): LUALUALEI CLAY, 0-2% SLOPE
Drainage Class: WELL-DRAINED
Field Observations
Confirm Mapped Type? (Yes) No
Taxonomy (Subgroup): TYPIC CHROMUSTERTS ORDER VERTISOLS

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-21"	A1	10 YR 2/2 V. DK. BRN	NONE	NONE	CLAY VERY STICKY VERY PLASTIC
	STONY LAYER AT 21 IN.				

Hydric Soil Indicators: FIELD WORK 3/2/96

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- X Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks: (1) SITE OCCURS IN TIRE-RUT DEPRESSION 35FT. X 6FT. (2) 2 INCHES STANDING WATER OVER PROFILE. (3) HORIZON IS SATURATED BUT NO EVIDENCE OF MOTTLING OR GLEYING (4) NO EVIDENCE OF REDUCING ANAEROBIC CONDITIONS. (5) GENERAL LAND SLOPE 1-0% (6) SOME GRASS ROOTS.

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes No (Circle)
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No

Is this Sampling Point Within a Wetland? (Circle) Yes No

Remarks:

Approved by HQUSACE 3/92

SOILS #3 SITE, MAKAPUU DEPRESSIONS, OAHU

Map Unit Name (Series and Phase): LUALUALEI CLAY 0-2% SLOPE
Drainage Class: WELL-DRAINED
Field Observations
Confirm Mapped Type? (Yes) No
Taxonomy (Subgroup): TYPIC CHROMUSTERTS ORDER VERTISOLS

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-18"+	A1	10 YR 2/2 V. DK. BRN.	NONE	NONE	CLAY VERY STICKY VERY PLASTIC

Hydric Soil Indicators: FIELD WORK 3/2/96

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- X Aquic Moisture Regime
- ___ Reducing Conditions
- ___ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ___ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks: (1) SITE OCCURS IN TIRE-RUT DEPRESSION 40IN. X 5 FT. (2) NO STANDING WATER OVER PROFILE (3) PROFILE WET, BUT SOIL SURFACE STARTING CONTRACTION CRACKS 1 IN. DEEP X 1 IN. WIDE. (4) NO MOTTLING OR GLEYING (5) NO ODOR OF REDUCING ANAEROBIC CONDITIONS. (6) ABUNDANT ROOTS (7) GENERAL LAND SLOPE 0-1%.

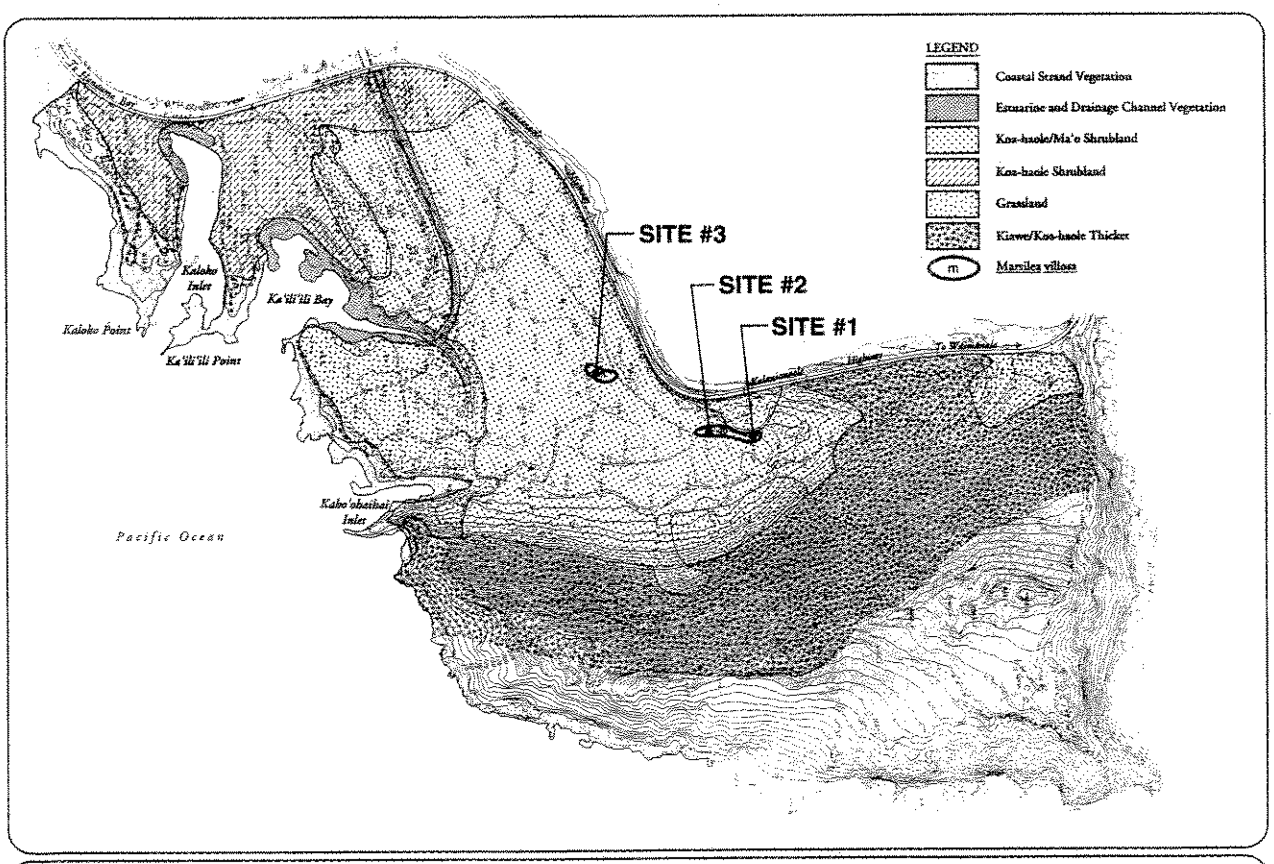
WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes No (Circle)
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No

Is this Sampling Point Within a Wetland? (Circle) Yes No

Remarks:

Approved by HQUSACE 3/92



Marsilea Villosa Colony Sites

PROPOSED GOLF COURSE

Queen's Beach, Hawaii Kai, Oahu
Kaiser Aluminum & Chemical Corporation

Feet
0 400 800 1600

Prepared By: Helber Hastert & Fee, Planners

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
FT. SHAFTER, HAWAII 96858-5440

REPLY TO
ATTENTION OF

Operations Branch

June 5, 1996

JUN - 6

Mr. Scott Ezer
Senior Associate
Helber Hastert and Fee
733 Bishop Street, Suite 2590
Honolulu, HI 96813

Dear Mr. Ezer:

This responds to your request of April 17, 1996 for a delineation of possible wetlands at TMK 1-3-9-11:3, Kealakipapa Valley, Makapuu, Oahu, Hawaii.

A visit to the site was performed by myself and members of the U.S. Fish and Wildlife Service on May 24, 1996. Both you and your client's consultant, Winona Char were in attendance.

As you are aware, we examined three areas that support transplanted populations of Ihi'ihilauakea (*Marsilea villosa*), a federally endangered plant species. Marsilea is an obligate wetland plant; these areas clearly meet the Corps' wetland vegetation characteristic. As part of our investigation, we dug four holes to determine if the areas meet the other characteristics required for the area(s) to be delineated as jurisdictional wetlands, i.e., hydrology and hydric soils. At the time of our visit, no hydrology or hydric soils field indicators were observed. As a result, the areas are not jurisdictional waters of the U.S. and are not subject to regulation by the Corps of Engineers.

File Number 950010102 has been assigned to this project. Please refer to this number in any future correspondence. If you have further questions regarding this matter, please feel free to call me at 438-9258, extension 15.

Sincerely,

Kathleen A. Dadey
Environmental Engineer

Copy Furnished:

U.S. Fish and Wildlife Service, Honolulu, HI
State of Hawaii Department of the Attorney General, Honolulu, HI
Clean Water Branch, Department of Health, Honolulu, HI
Office of State Planning, Coastal Zone Management Program Office, Honolulu, HI
Department of Land and Natural Resources, Honolulu, HI
Department of Land Utilization, Honolulu, HI

Appendix

F

Entomological Resources

(Steven Montgomery, Ph.d.)

Native Arthropod Resources of Queen's Beach and its Coastal Flats on East O'ahu

February 25, 1996

By Steven Lee Montgomery, Ph. D.
Consulting Biologist
94-610 Palai Street, Waipahu, HI 96797-4535
(808) 676-4974 Phone (808) 677-3721 Fax

SCOPE OF WORK

The scope is to review literature and conduct an entomological survey of the Queen's Beach coastal plain and lower Kealakīpapa Valley project site, with emphasis on the snout beetle, *Rhyncogonus simplex*, and its prime host plant ma'o (*Gossypium sandwicense*) plus two other insects, *Ithamar hawaiiensis* and *Oliarus discrepans*.

BACKGROUND

The health of native Hawaiian invertebrate populations depends on host plant availability and absence or low levels of continental predators. Recent surveys found a few native plants, such as naio, ma'o, ilima, nehe, a small grass, and beach flora. Swezey (1935) found 49 insect species on ma'o, but only 6 were Hawaiian endemic species.

In his comprehensive 1948 introduction to *Insects of Hawaii*, Elwood C. Zimmerman made this summary statement on the 34 species of *Rhyncogonus* in Hawai'i:

> "Indeed, they are among the largest, most conspicuous and most sought of all the Hawaiian beetles. They are such prizes that collectors never pass them by; even snail collectors and botanists bring them in for the entomologists. There are few Hawaiian genera which have received such careful attention as has *Rhyncogonus*. Only one new Hawaiian species has been collected in the past 20 years. Dr. Otto Swezey has given the genus special study, and has plotted the distribution of the 13 species found on O'ahu. Most species have been taken at altitudes between 1000 and 2000 feet. Each species occupies a discrete locality, and no two species are known to overlap."

He states that *Rhyncogonus*, belongs to the western Pacific weevil tribe Celeuthetini expanded into the Cook, Austral, Society, Marquesas, Tuamotu, Line and Hawaiian chains. The eggs are glued to leaves, from which the young grubs drop to the ground, where they burrow to the roots and feed. By day the adult weevils usually hide in leaf litter. Egg-bearing leaves, when blown to a new site, provide the probable dispersal means.

The statement in the "Ka Iwi Master Plan", Ch. 9, p. 30, that all other species are "limited to the Island of Moloka'i" is erroneous, since most islands have these beetles (Anon. 1993). *R. welchi* lives near soapberry trees in Lualualei Valley at 1600', while *R. extraneus* eats *Portulaca* and *Amaranthus* foliage by Kunia cane fields.

The only examples of recent lowland collections are:

- an undescribed species of *Rhyncogonus* found on two mallows, *Sida* and *Gossypium* , at Mānele Bay, Lāna'i, in 1988 and 1993 by Gustav Paulay and S. L. Montgomery;
- eight weevils collected by Montgomery on *Ipomoea imperati* on Kaho'olawe at 200' in 1994 are a *Rhyncogonus*, species undetermined.

A native thrush on Kauai hunted *Rhyncogonus*, and is the only forest bird known to feed on such large weevils (Perkins 1913). Plovers are known to feed on the hunting billbug, a lawn weevil (*Sphenophorus)* of similar size.

METHODS

I conducted a survey of the subject site, reviewed the literature regarding the species of focus, and visited major collections at the B. P. Bishop Museum and the Hawaii State Department of Agriculture [Table 2]. I also spoke with Robin C. A. Rice and William Perreira regarding their extensive observations and collections of *Rhyncogonus* In 1995, on April 8 and 27 [at night] and May 26 [in daylight], I searched 250 cotton plants for any signs of feeding by Hawaiian foliage weevils. In early 1996, heavy rains greened the leeward landscapes. On February 8, 10, and 11, 1996, I renewed searching for the weevil, plus two other very rare, lowland insects - *Oliarus discrepans* Giffard, a cixiid planthopper, and *Ithamar hawaiiensis* Kirkaldy, of the squash bug family, Coreidae. February searches were conducted during the day with a sweep net and at night with a 150 watt, MV electric light.

Table 1 lists all native insects and some prominent aliens associated with cotton, with pertinent comments from the literature.

RESULTS

Rhyncogonus simplex The simple mallow robust weevil:
Rhyncogonus simplex, leaves a characteristic large leaf notch whenever it feeds, making the mapping of its presence a matter of mapping those plants it climbs. Only 8 of these notches were seen on February 11, 1996. Two shell-like wing remnants of two *R. simplex* were found near the base of one plant, and being silt-filled and deep in the litter, they could be 10 or 20 years in age. By day these weevils usually hide in leaf litter at the base of host plants, in this case malvaceous plants. Consequently, they are best collected or directly observed at night with a light, but R. Rice, the most recent collector, said his captures were diurnal.

Ithamar hawaiiensis a coreid plant sap-sucking bug:
not observed at the study site. Once abundant on cotton, *Sida* , and 3 other families of plants when R. C. L. Perkins wrote his "Introduction" to *Fauna Hawaiiensis* , but rarely collected by 1948, when E. C. Zimmerman referred to it in *Insects of Hawaii*. Bishop Museum collections' most recent O'ahu specimen is from Kaena Pt. in 1914; from Haleakala, Maui at 7000' it was taken in 1985, indicating a relict population only in higher mountain shrub lands.

Oliarus discrepans Giffard, a cixiid planthopper:
not observed at the study site. O. H. Swezey collected a series on native cotton, including nymphs under stones (where they probably sucked sap from its roots). Of the four specimens in Museum collections, the most recent is from 1925, with Manoa Valley floor as the locality for two. E. C. Zimmerman referred to it in *Insects of Hawaii* as a species especially distinct from others found in the genus.

Compared to J. C. Bridwell's 1920 finds at Ewa, East Oahu now has few native invertebrates, perhaps because it lacks *Euphorbia multiformis*, (an akoko) host of much of this fauna. The presence of four dominant predatory species of ant is also a factor in low numbers of native Hawaiian invertebrates.

CONCLUSIONS

Native insects were very scarce at the flats by Queen's Beach in winter 1994-1995, and early 1996. Many Hawaiian insects that live in dry habitats time their emergence and breeding to follow wet periods. No *Rhyncogonus simplex* were seen and no examples of *Ithamar hawaiiensis* or *Oliarus discrepans* were observed, during any of the searches. A few of the telltale leaf feeding notches were observed and shell-like wing remnants of two *R. simplex* were found. The large, characteristic leaf notches probably indicate the presence of the insect, but at very low levels.

MITIGATION

Since these insects are quite dependent upon native flora, grazing mammals should be excluded and off road vehicles restricted from the habitat. Patches of ma'o plants, especially in the eastern boulder fields, should be preserved in place (no disturbance of the soil) for the benefit of any relict [remnant survivor] native invertebrate populations. During any earth moving work in the area, a buffer zone should be set up to ensure no disturbance of the root zone of ma'o plants. The buffer should be maintained if any fertilizer or pesticide applications are planned adjacent to the plants.

REFERENCE LIST

Bridwell, J. C. , 1920, "Ewa Dryland Insects," *Proceedings of the Hawaiian Entomological Society*, 10: 479.

Funk, Evangeline, 1985, "A Survey of Queen's Beach, O'ahu, Hawai'i," *Newsletter of the Hawaiian Botanical Society*, 24:4-5.

Perkins, R. C. L. , 1899-1913, *Fauna Hawaiiensis*, University of Cambridge Press, and Bishop Museum Special Publication 6.

Swezey, O. H., 1935, "Winter Revival of Insect Life in the Arid Region at Koko Head, O'ahu, " *Proceedings of the Hawaiian Entomological Society*, 9: 95- 96.

Swezey, O. H., 1935, "Insect Fauna of *Gossypium tomentosum*," *Proceedings of the Hawaiian Entomological Society*, 9: 96-98.

TABLE 1: NATIVE AND COMMON INSECTS OF *GOSSYPIUM* (MA'O) AT EAST O'AHU
* = ENDEMIC

HETEROPTERA

Rhopalidae [scentless plant bug family]

- **Ithamar hawaiiensis* Kirkaldy [a sap feeding bug]
  An unusual endemic genus with no known close relative; not seen recently on Oahu; at 6000', Kahikinui, Maui, in 1976, found on *Styphelia* by Montgomery, with a photo in Howarth & Mull, 1992, page 94 ; high elevations are its main refuge

- *Liorhyssus hyalinus* (Fab.) [hyaline grass bug]
  common on *Sida* flower buds

Lygaeidae

- **Nysius delectus* White [seed bug]
  from sedge

- **Nysius coenosulus* Stal. [seed bug]

Miridae

- **Trigonotylus (=Oronomiris) hawaiiensis* Kirkaldy [Hawaiian grass leaf bug]
  a few seen in 1996; seen by Swezey in abundance; lives on Bermuda grass

Nabidae

- *Nabis capsiformis* (Germ.) [pale damsel bug]

Reduviidae

- *Zelus renardii* Kol. [Leafhopper assassin bug]

HOMOPTERA

- **Oliarus discrepans* Giffard [sap feeding planthopper]
  found with nymphs under stones and bark in 1934; few records and none recent.

TABLE 1: NATIVE AND COMMON INSECTS OF *GOSSYPIUM* (MA'O) AT EAST O'AHU
* = ENDEMIC

COLEOPTERA

Curculionidae

- **Rhyncogonus simplex* Perkins [simple robust mallow leaf weevil]
  On U. S. Fish and Wildlife list as a "**species of concern**"; no action currently planned.
  From mid-western Moloka'i. Many dimorphic pairs; most variable, broadest ranged robust weevil; all specimens are in British Museum. On Oahu: 3 discovered Jan. 11, 1928, by Fred Hadden; 18 recollected Nov. 27, 1930, on *Malvastrum* ; Feb. 22, 1933, on ground by Swezey, who found them over an area of 100 yards in extent. Eggs laid between folded edges of leaves and larvae fall to soil to eat roots. Unseen since R. Rice's 1975 daylight collections on cotton in patches near the boulders on subject property. No collections from careful O'ahu search during last 10 years by W. Perreira.

- *Pantomorus godmani* [Fuller's rose weevil]
  eats small 5 mm notches on leaf edges of many plants

Aglycyderidae

- *Proterhinus deceptor* Perkins
  5 found in dead ma'o twigs in 1934, not seen recently

Scolytidae

- *Hypothenemus eruditus* Westwood [shot hole borer]

- *Hypothenemus maculicollis* [shot hole borer]
  in dead ma'o twigs in 1934

ORTHOPTERA

Gryllidae

- **Caconemobius* species [Hawaiian splash zone cricket]
  widespread in littoral zone

TABLE 1: NATIVE AND COMMON INSECTS OF *GOSSYPIUM* (MA'O) AT EAST O'AHU
* = ENDEMIC

Formicidae (cont.)
- *Pheidole megacephala* (Fab.) [big-headed ant]

- *Plagiolepsis allaudi* Emery [little yellow ant]

- *Solenopsis geminata rufa* (Jerdon) [fire ant]

HYMENOPTERA
Prosopidae
- **Nesoprosopis* species
  Yellow-faced bee seen by J. W. Beardsley as pupa in *Messerschmidtia* stem (pers. comm.)

LEPIDOPTERA
Buccutrigidae
- *Bucculatrix thurberiella* Busck 1914 [cotton leaf perforator]
  immigrant from southwest USA in 1971; on Oahu as ma'o leaf feeder; serious pest on cotton crops in CA

Gelechiidae
- *Pectinophora gossypiella* Saunders [pink bollworm]
  established by 1900; heavy damage to seeds and fibers of crop and native cottons (*Hibiscus brackenridgei* and *Hibiscadelphus hualalaiensis*); 50-99% infestation is prime reason cotton growing was abandoned in Hawaii

- *P. scutigera* Holdaway [Queensland pink bollworm]
  on cotton and other mallows (hau & milo) since 1918; described from larvae similar to *P. gossypiella*

Noctuidae
- *Heliothis hawaiiensis* Quaintance and Brues
  immigrant pre-1880; polyphagous on many plants; larvae often lie exposed on *Sida* flowers after rains beget lush growth

Queen's Beach Arthropods / Montgomery February 25, 1996

TABLE 1: NATIVE AND COMMON INSECTS OF *GOSSYPIUM* (MA'O) AT EAST O'AHU
* = ENDEMIC

LEPIDOPTERA
Sphingidae
- *Hyles lineata* (Fab.) [Whitelined sphinx]
  on vines of morning glory

Hyposmocomidae
- **Hyposmocoma empedota* Meyr. [Hawaiian casebearer moth]

COLEOPTERA
Cerambycidae
- *Sybra alternans* Wied. [Longhorned woodborer]
  swept from basil

Tenebrionidae
- *Gonocephalum seriatum* Boisd. [Darkling beetle]
  in litter layer

HYMENOPTERA
Bethyliidae
- *Nesepyris ewa* [beetle parasite]

Eupelmidae
- **Eupelmus niger* Ash.
  small wasp with parasitic habits

- **Lepideupelmus setiger* Perkins

Formicidae
- *Paratrechina longicornis* (Lat.) [crazy ant]
  enormously abundant under stones and cow dung in Feb. 1934, scarce in 1996

TABLE 2: COLLECTION RECORDS OF R. SIMPLEX

DATE	COLLECTOR	NO. COLL'D	PLACE COLLECTED [1]
Jan. 1902	R. C. L. Perkins	29	Moloka'i, 800' [2]
Jan. 11, 1928	F. C. Hadden	3	Kokohead, O'ahu, on *Bidens*
Feb. 27, 1930	O. H. Swezey	7	Kokohead, O'ahu
Nov.27, 1930	O. H. Swezey	"several"	Makapu'u Flats, O'ahu, in *Malvastrum* and *Gossypium*
Jan. 23, 1932	E. B. Ford	11	Kokohead, O'ahu, on *Sida*
Feb. 11, 1934	O. H. Swezey	53	Kokohead, O'ahu, on *Gossypium*
Feb. 21, 1934	N. L. H. Krauss	31	Kokohead, O'ahu
Dec. 30, 1934	O. H. Swezey	6	Kokohead, O'ahu, on flats
Dec. 31, 1934	[not on label]	7	Wai'anae Plantation, O'ahu [3], on *Sida* and *Malva*
Jan. 27, 1935	E. C. Zimmerman	21	Kokohead, O'ahu
Jan. 23, 1952	E. B. Ford	4	Kokohead, O'ahu
1975	R. C. A. Rice	"several" [4]	Makapu'u Flats, O'ahu, on *Gossypium*
Feb. 11, 1996	S. L. Montgomery	2 pairs elytra	Makapu'u Flats, O'ahu, in soil litter under *Gossypium*

1 Location information is as given on specimen label.

2 Since Perkins' 1910 published description, no Moloka'i *R. simplex* are known, even with my 1990 search of many ma'o on the coastal trail to 'Ilio Point.

3 It is puzzling that Swezey does not include the Wai'anae locale on his 1934 map.

4 Information based on oral communication to Montgomery, May 1995.

TABLE 1: NATIVE AND COMMON INSECTS OF *GOSSYPIUM* (MA'O) AT EAST O'AHU
* = ENDEMIC

Tortricidae
- *Amorbia emigratella* Busck [Mexican leaf-roller]
  immigrant from Mexico in 1902; feeds on 20 hosts plus *Gossypium*

QUEEN'S BEACH GOLF COURSE

Appendix

G

Avifaunal and Feral Mammal Survey

(Phil Bruner)

AVIFAUNAL AND FERAL MAMMAL SURVEY OF QUEEN'S BEACH, OAHU, HAWAII

Prepared for

Helber Hastert and Fee

by

Phillip L. Bruner
Assistant Professor of Biology
Director, Museum of Natural History
BYU-Hawaii
Environmental Consultant - Faunal (Bird & Mammal) Surveys

9 November 1994
Revised (26 December 1994)

INTRODUCTION

The purpose of this report is to summarize the findings of a two day (22, 23 October 1994) bird and mammal field survey of Queen's Beach, Oahu, Hawaii (Fig. 1). Also included are references to pertinent literature and observations based on personal field experience in this region from 1970 to 1994.

The objectives of this field survey were to:

1- Document what bird and mammal species occur on and near the property.

2- Note the presence or likely occurrence of any native fauna, particularly any that are considered "Endangered" or "Threatened".

3- Locate those sites most important to native wildlife.

GENERAL SITE DESCRIPTION

Figure One shows the area examined by this faunal survey. Habitats on the property include: rocky shoreline; coastal estuaries (mangroves); drainage ditches with standing water following heavy rains; and dry scrubland. The topography is relatively flat except along the hillsides towards Makapuu. The plant communities are largely introduced species. The overall appearance of the habitat is dry and windswept. Numerous roads bisect the property. Off-road vehicles were present during the survey. Figure Two indicates important waterbird and migratory shorebird foraging and resting habitat.

Weather was clear with easterly winds of 10-15 mph. on both days of the survey.

STUDY METHODS

The property was surveyed by walking the numerous roads and trails that crisscross the site. Field observations were made with binoculars and by listening for vocalizations. At various locations in all habitats eight minute census counts were made of all birds seen or heard (Fig. 1, Table 1). Published and unpublished data of birds known from similar habitats were reviewed in order to acquire a more complete picture of the possible species that might be expected in this region (Bruner 1988, 1989; Pratt et al. 1987; Hawaii Audubon Society 1993; Tanino 1994). Personal observations from field notes accumulated during previous visits to this area were also consulted. Data on feral mammals were limited to visual observations. No trapping was attempted.

Scientific names used in this report follow those given in Hawaii's Birds (Hawaii Audubon Society 1987); Field guide to the bird of Hawaii and the Tropical Pacific (Pratt et al. 1987); Thirtyninth supplement to the American Ornithologists' Union Checklist of North American Birds (American Ornithologists' Union 1993) and Mammal Species of the World (Honacki et al. 1982).

RESULTS

Resident Endemic (Native) Land Birds:

No native, resident land birds were observed on the survey. One species which is known from this area is the Short-eared Owl or Pueo (*Asio flammeus sandwichensis*). The Pueo is listed as an endangered species on Oahu by the State of Hawaii Division of Forestry and Wildlife. They forage over open fields and forest habitat. This species is active at dawn and dusk. The introduced Common Barn Owl (*Tyto alba*) is nocturnal and is often mistakenly reported as Pueo by those unfamiliar with identification marks that distinguish these two species of owls. I have seen Pueo twice at Bellows AFS, once in 1980 and again in 1983. Both sightings were of single birds foraging near the firebreak road at the base of Keola Hills. I have also seen Pueo on the slope of Koko Crater in the 1970 No other native resident land birds would be expected at this elevation and locality.

Resident Waterbirds:

One Black-crowned Night Heron (Auku'u) (*Nycticorax nycticorax*) was tallied on the survey. The bird was seen in the mangrove wetland. This is the only native waterbird in Hawaii that is not listed as endangered. I have observed Black-crowned Night Heron on many occasions along this stretch of the coast. The estuary provides foraging habitat and the mangroves are utilized for resting. I have also seen the endangered Black-necked Stilt (Himantopus mexicanus knudseni) and the endangered Hawaiian Coot (Fulica alai) in the estuaries and around the patches of mangrove at this site. Stilt are opportunistic foragers and will utilize a variety of permanent and temporary wetlands. They wade in shallow water searching for aquatic invertebrates and small fish. Coot prefer open water and will dive as well as wade when foraging. Based on my experience Black-crowned Night Heron are more common in these coastal wetlands than either stilt or coot although all three species can and do occur on this property.

Seabirds:

Several species of seabirds can be seen offshore and flying over the property. During the survey Red-footed Booby (Sula sula) and Great Frigatebird (Fregata minor) were observed. Sooty Tern (Sterna fuscata) and Brown Noddy (Anous stolidus) are two other common seabirds seen in this area. Red-tailed Tropicbird (Phaethon rubricauda) have nested on the sea cliffs near Makapuu Lighthouse (personal observations from 1990's). The flat lands on the site are accessible to predators and no seabirds would be expected to nest in these areas. On one occasion I saw Laysan Albatross (Diomedea immutabilis) resting on a bare patch of ground near the Sandy Beach end of the property. At the time I was with a class

from Waikiki Aquarium studying coastal plants. The albatross was photographed by several people in the class. This species has recently begun to reoccupy the main Hawaiian Islands. Some nesting attempts have been successful but most have been disrupted by dogs and human disturbance. Presently there is a project, partially funded by the State of Hawaii, designed to attract Laysan Albatross to nest on a small offshore islet between Sea Life Park and Manana Island. Some albatross have landed on the island and have even courted the decoys. No nesting has occurred but ongoing attempts to attract albatross may eventually prove successful in establishing a breeding colony at that site.

Migratory Birds:

Migratory ducks and shorebirds regularly visit Hawaii each year. No migratory ducks were accounted for on this field survey. However, Northern Shoveler (Anas clypeata) and Northern Pintail (Anas acuta) could occur in the mangrove estuaries on this property.

Three species of common migratory shorebirds were seen on the survey. Three Wandering Tattler (Heteroscelus incanus) were seen foraging along the rocky shoreline. A total of eight Ruddy Turnstones (Arenaria interpres) were recorded in and around the estuaries. Twenty eight Pacific Golden Plovers (Pluvialis fulva) were tallied over the course of the survey. This species is the most abundant migrant in Hawaii. Plover prefer open habitats such as lawns, mudflats, fields and shorelines. Our studies have learned much about the life history of this bird (Johnson et al. 1981, 1989, 1993; Johnson and Johnson 1983; Bruner 1993). The Sanderling (Calidris alba) is the other common migrant that may be expected at this site. None, however, were observed during the survey.

Exotic (Introduced) Birds:

A total of 17 species of exotic birds were recorded during the field survey (Table 1). Pratt et al. (1987); Hawaii Audubon Society (1993) and Tanino (1994) confirm that this array of introduced birds would be expected for this locality. In addition, other species which could occur in this region include: Barn Owl (Tyto alba); Chestnut Mannikin (Lonchura malacca); House Sparrow (Passer domesticus) and Warbling Silverbill (Lonchura malabarica).

Feral Mammal:

The introduced Small Indian Mongoose (Herpestes auropunctatus) and feral cats were seen on this property. No trapping was conducted in order to assess the relative abundance of feral mammals. In addition rats and mice undoubtedly also are common in this area.

Oahu records of the endemic and endangered Hawaiian Hoary Bat (Lasiurus cinereus semotus) are limited (Tomich 1986; Kepler and Scott 1990). Data on the bat's distribution and behavior are extremely limited. They forage for flying insects at dusk and are known to

roost solitarily in trees. They occur in upland forests as well as in coastal habitats. I have frequently seen bats foraging over bays along the Kona Coast of the Big Island. I have not seen them in coastal habitat on Oahu but they potentially could occur at this site.

DISCUSSION AND CONCLUSIONS

This field survey provides a limited perspective of the wildlife which utilize the area. The number and relative abundance of each species may vary throughout the year due to available food resources and reproductive success. Exotic species sometimes prosper only to later disappear or become a less significant part of the ecosystem (Williams 1987; Moulton et al. 1990). Long term census data could provide a more comprehensive view of the bird and mammal populations in a particular area. The following comments summarize the findings of this survey.

1- All habitats on the property were surveyed. Census stations were established at a number of locations (Fig. 1) and all birds seen and heard were tallied. These data are summarize in the Results Section and Table 1.

2- The Black-crowned Night Heron was the only native resident waterbird recorded on the survey. This species is not endangered or threatened. I have seen the endangered Black-necked Stilt and Hawaiian Coot on the property on past occasions. The Pueo was not recorded but could occur in this area. I have seen this State of Hawaii listed endangered species on lands near Queen's Beach.

3- Three species of shorebirds were found on the survey: Wandering Tattler, Ruddy Turnstone and Pacific Golden Plover. These species are common migrants and are not endangered or threatened.

4- No seabirds were seen nesting or roosting on the property but several species were observed flying overhead or offshore. Predator access limits the use of this site by seabirds.

5- Seventeen species of introduced birds were tallied on the survey. An additional four exotic species may also occur on occasion in this area. None of these species are listed as endangered or threatened.

6- No native mammals were found on the survey. Exotic mammals such as the Small Indian Mongoose and cats are common in this area. The endangered Hawaiian Hoary Bat was not seen but does occur on Oahu and can forage in coastal habitat.

7- Queen's Beach provides a variety of habitats for both native and introduced birds. The mangrove estuaries and coastal shoreline are used by native waterbirds and migratory shorebirds. This area is the most valuable part of the property for native birds. Any development plan should address the question of how these areas can be protected and improved for wildlife. Water quality and disturbance are two important issues. Presently this area has no protection. Rubbish and human intrusion from off-road vehicles have plagued this property for many years. Whether or not this property can be made more valuable for native wildlife will depend on how this area is managed.

Anticipated Impacts:

The shoreline habitat and associated intertidal wetlands contain valuable resources for native waterbirds and migrants. Two possible impacts that could accompany development of adjacent inland areas are:

1- Fouling of the inshore waters due to siltation during clearing of the uplands and subsequent contamination of the wetlands from herbicides and pesticides associated with the golf course maintenance.

2- Disturbance of foraging and resting birds by pedestrian traffic on the planned adjoining golf course.

Mitigation Measures:

Before, during and following construction water quality testing of the inshore waters fronting the entire property, including the estuaries, should be conducted. This water testing should look not only at chemical contaminants but suspended solids that could lead to siltation problems. The preparation and maintenance of the golf course must be designed to avoid degradation of the shoreline wetland resources.

The question of disturbance is a more difficult issue. People demand shoreline access for recreational activities. Maintaining a buffer of vegetation in the form of dense tall trees and brush between the golf course and the wetlands may help minimize disturbance. Posting signs to ask people to not wade through the intertidal areas near the mangroves where native birds feed and rest may also be a worthwhile approach.

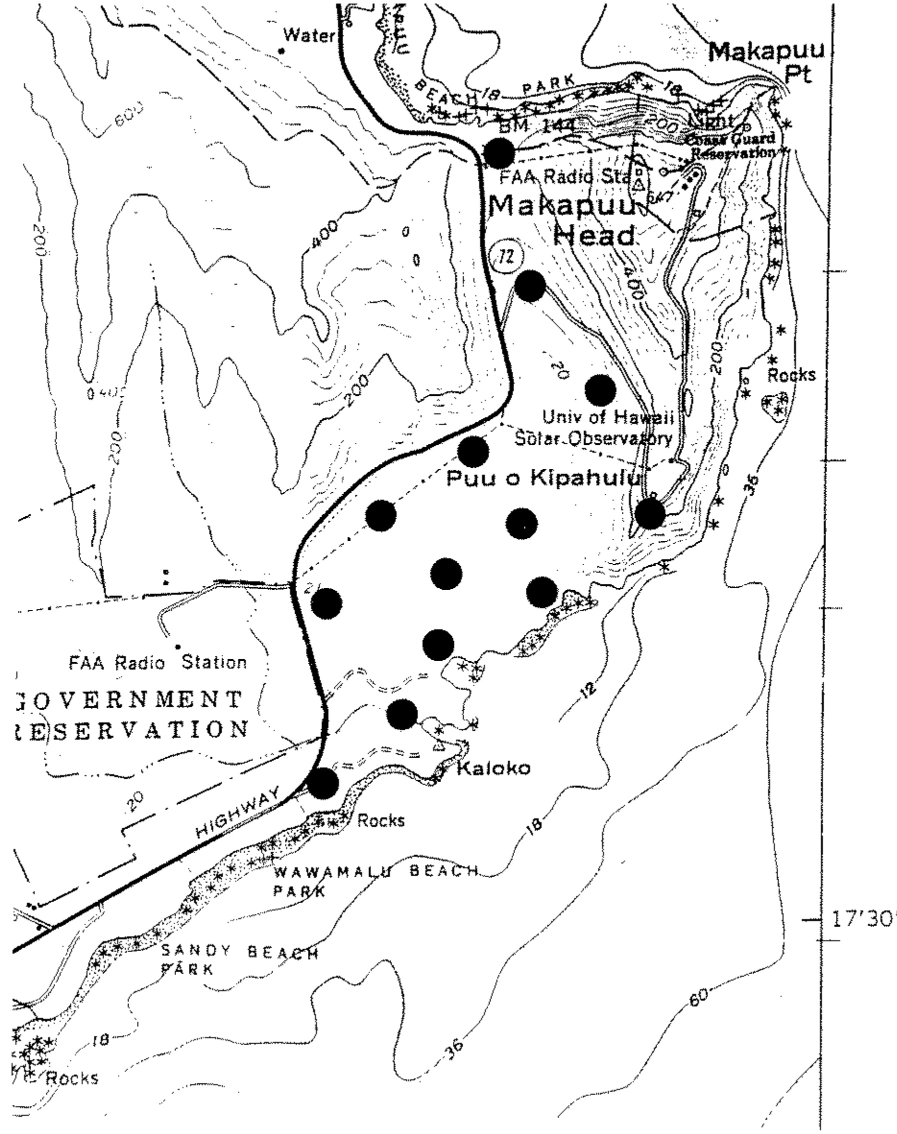


Fig. 1. Location of faunal (bird & mammal) survey with census stations marked as solid circles.

TABLE 1

Introduced birds recorded at Queen's Beach, Oahu, Hawaii.

COMMON NAME	SCIENTIFIC NAME	RELATIVE ABUNDANCE*
Cattle Egret	Bubulcus ibis	R = 2
Ring-necked Pheasant	Phasianus colchicus	R = 1
Spotted Dove	Streptopelia chinensis	C = 8
Zebra Dove	Geopelia striata	A =11
Rock Dove	Columba livia	R =25
Common Myna	Acridotheres tristis	C = 6
Red-vented Bulbul	Pycnonotus cafer	A =12
Northern Mockingbird	Mimus polyglottus	R = 2
Northern Cardinal	Cardinalis cardinalis	U = 2
Red-crested Cardinal	Paroaria coronata	C = 6
Japanese White-eye	Zosterops japonicus	U = 4
House Finch	Carpodacus mexicanus	C = 7
Japanese Bush-warbler	Cettia diphone	R = 1
Java Sparrow	Padda oryzivora	R = 5
Eurasian Skylark	Alauda arvensis	R = 2
Nutmeg Mannikin	Lonchura punctulata	C = 7
Common Waxbill	Estrilda astrild	A =10

*(see page 14 for key to Table 1)

Fig. 2. Location of important waterbird and migratory shorebird habitat. Solid line indicates limits of this resource.

KEY TO TABLE 1

Relative abundance = Number of birds tallied on census stations in appropriate habitat.

A = abundant (10 or more per census station)

C = common (5-9 per census station)

U = uncommon (1-4 per census station)

R = recorded (seen on survey on one occasion or not on census stations)

SOURCES CITED

American Ornithologists' Union (AOU) 1993. Thirty-ninth supplement to the American Ornithologist's Union Check- list of North American Birds. Auk 110:675-682.

Bruner, P. L. 1988. Survey of the the avifauna and feral mammals at Koko Head and Koko Crater, Oahu, Hawaii. Prepared for Belt Collins and Associates.

________ 1989. Survey of the avifauna and feral mammals at Oceanic Institute property, Oahu, Hawaii. Prepared for Applied Analysis, Inc..

________ 1993. Influences on the past and present distribution patterns of Pacific Golden-Plover (Pluvialis fulva). Paper presented at Seminaire Manu connaissance et protection des oiseaux, Papeete, Tahiti.

Hawaii Audubon Society. 1993. Hawaii's Birds. Fourth Edition. Hawaii Audubon Society, Honolulu.

Honacki, J. H., K. E. Kinman and J. W. Koeppl ed. 1982. Mammal species of the World: A taxonomic and geographic reference. Allen Press, Inc. and the Association of Systematic Collections.

Kepler, C. B. and J. M. Scott. 1990. Notes on distribution and behavior of the endangered Hawaiian Hoary Bat (Lasiurus cinereus semotus) 1974-1983. 'Elepaio 50(7):59-64.

Johnson, O. W., and P. M. Johnson. 1993. Plumage-molt-age relationships in "over-summering" and migratory Lesser Golden-Plovers. Condor 85:406-419.

Johnson, O. W., P. M. Johnson and P. L. Bruner. 1981. Wintering behavior and site faithfulness of Golden-Plovers on Oahu. 'Elepaio 41:123-130.

Johnson, O. W., M. L. Morton, P. L. Bruner and P. M. Johnson. 1989. Fat cyclicity, predicted migratory flight ranges, and features of wintering behavior in pacific Golden-Plovers. Condor 91:156-177.

Johnson. O. W., P. G. Connors, P. L. Bruner and J. L. Maron. 1993. Breeding ground fidelity and mate retention in the Pacific Golden-Plover. Wilson Bull. 105(1):60-67.

Moulton, M. P., S. L. Pimm and N. W. Krissinger. 1990. Nutmeg Mannikin (Lonchura punctulata): a comparison of abundance in Oahu vs. Maui sugarcane fields: evidence for competitive exclusion? 'Elepaio 50(10):83-85.

Pratt, H. D., P. L. Bruner, and D. G. Berrett. 1987. A field guide to the birds of Hawaii and the Tropical Pacific. Princeton Univ. Press.

Tanino, L. 1994. Honolulu Count: 50th annual Honolulu Christmas count - 1993. 'Elepaio 54(3):13-15.

Tomich, P. Q. 1986. Mammals in Hawaii. Bishop Museum Press.

Williams, R. N. 1987. Alien Birds on Oahu. 1944-1985. 'Elepaio 47(9):87-92.

QUEEN'S BEACH GOLF COURSE

Appendix

H

Archaeological Inventory Survey

(Cultural Surveys Hawaii)

ARCHAEOLOGICAL INVENTORY SURVEY OF THE 166-ACRE QUEEN'S BEACH PROJECT AREA, *AHUPUA'A* OF MAUNALUA, ISLAND OF O'AHU (TMK 3-9-11)

by

Matthew J. McDermott, B.A.
Douglas F. Borthwick, B.A.
&
Hallett H. Hammatt, Ph.D.

Prepared for

Helber, Hastert, and Fee

Cultural Surveys Hawaii
May 1997

ABSTRACT

Field work was carried out Jan. 21, 22, 31 and Feb. 5, 1997 by Douglas Borthwick, Brian Colin, Tom Devereux, and Matt McDermott. From oral traditions and historic documents it is clear that the project area once contained Hawaiian settlement. By the time of the first archaeological survey of the area in 1930 (McAllister 1933) traditional Hawaiian settlement had ceased, having been replaced primarily by ranching. The project area was heavily impacted by the 1946 tsunami and by the subsequent grading, dredging, excavation, and material stockpiling associated with Henry Kaiser's development plans in the 1960s and 1970s. Archaeological and cultural resource studies in the 1980s and early 1990s report the archaeological resources noted in 1930 were all destroyed, with the exception of a historic roadway. During the current inventory survey, including the subsurface testing, this historic roadway was the single archaeological site remnant that was located. The road remnant, state site number #50-80-15-03 (McAllister's site 3 Kealakipapa Valley Road), was heavily impacted by ground clearing and mossrock picking over the last three decades. The site has been transformed into its present state--that of a cleared area in the *kiawe* which has been used as a bull-dozer and four-wheel-drive road. All available information was documented for this site remnant and it is considered no longer significant.

ACKNOWLEDGEMENTS

The authors would like to thank Scott Ezer for his assistance with obtaining project area maps, aerial photographs, and previous archaeological reports. Much thanks to Rodney Chiogioji who assisted with the document research, obtaining much needed aerial photographs and pointing out valuable historic references. Thank you to the field crew for remaining stalwart in the face of the dangerous "armor rock" traversals. Finally, thank you to the staff at the State Historic Preservation Office for their assistance locating previous archaeological reports.

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

The Queen's Beach project area is located within the *ahupua'a* of Maunalua, district of Kona, on the southeastern end of the island of Oahu (see Figures 1, 2, and 3). This more arid region was traditionally an *ili* of the *ahupua'a* of Waimanalo. This traditional boundary would have tied Maunalua more to the windward District of Ko'olaupoko, than to the Kona district.

The archaeology, oral traditions, history, and cultural resources of Maunalua record a rich prehistory and history. The prehistoric population of Maunalua was centered around the Kuapa Fishpond and around several coastal villages. Within the project area this settlement was centered around the coast at Kaloko, Ka'ili'ili, and Kaho'ohaihai. The abundant marine resources of the region were harvested and added to the traditional Hawaiian diet which was in this region dominated apparently by sweet potatoes because of the arid environment. The traditional and mythological accounts of Maunalua contain many references to Pele and Pele's sister Hi'iaka. Between 1778 and the mid-1800s Maunalua thrived under the influence of the victualing trade. When this trade declined after 1850, traditional settlement and land use, as well as population, declined. Ranching and commercial fishing were their replacements. Ranching continued until the 1930's although it was becoming less and less profitable.

This region, and more specifically the present project area, are the subject of numerous publications dealing with its cultural resources. McAllister (1933) did a reconnaissance of the archaeological remains still extant in the region as of 1930. He described and located the remains of habitations, religious structures, and agricultural features. Subsequent to McAllister's work, the archaeology within the project area was adversely impacted by the 1946 tsunami and then in the 1960s and 1970s by the development of the Queen's Beach area as part of Henry Kaiser's development plans for Hawaii Kai. Reports of the cultural resources of Queen's Beach area since this disturbance have documented the disappearance of most of the archaeological features.

The goal of the present inventory survey was to locate any remaining archaeological features within the project area. The methods of investigation were 100 percent pedestrian inspection and limited subsurface testing.

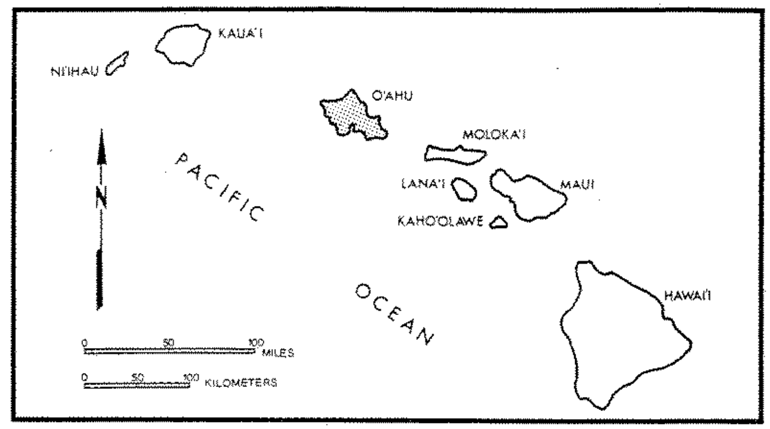


Figure 1 State of Hawai'i

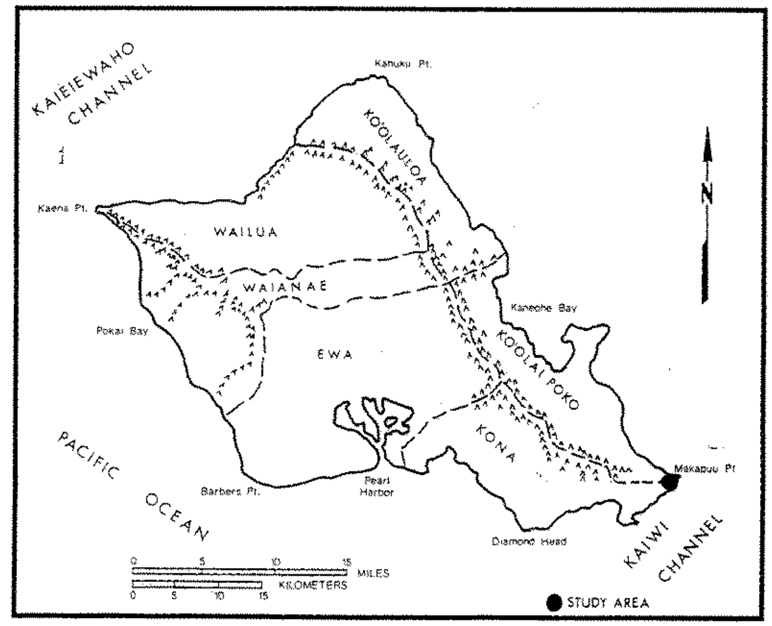


Figure 2 General Location Map, Oahu Island

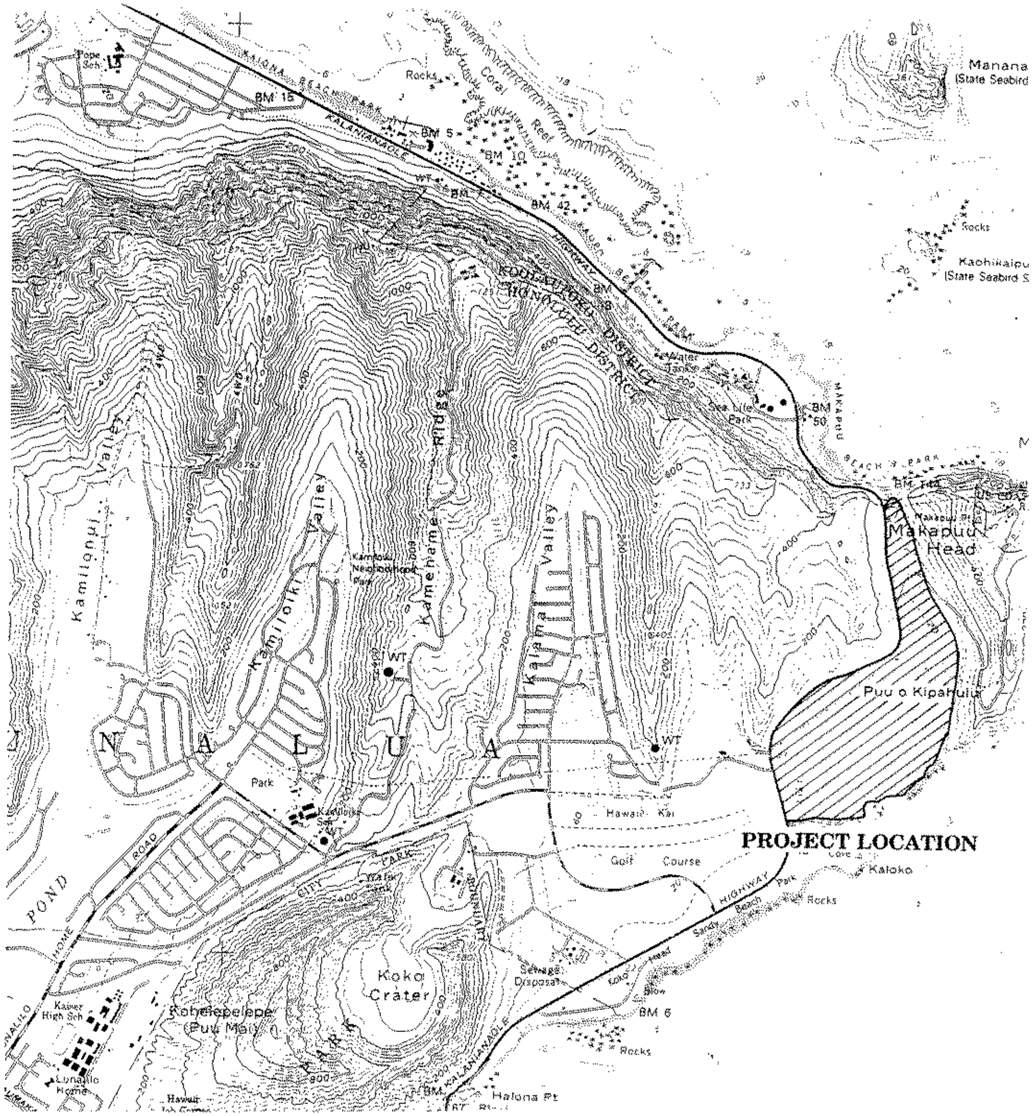


Figure 3 Portion of USGS 7.5 minute series, Koko Head Quad, showing project area

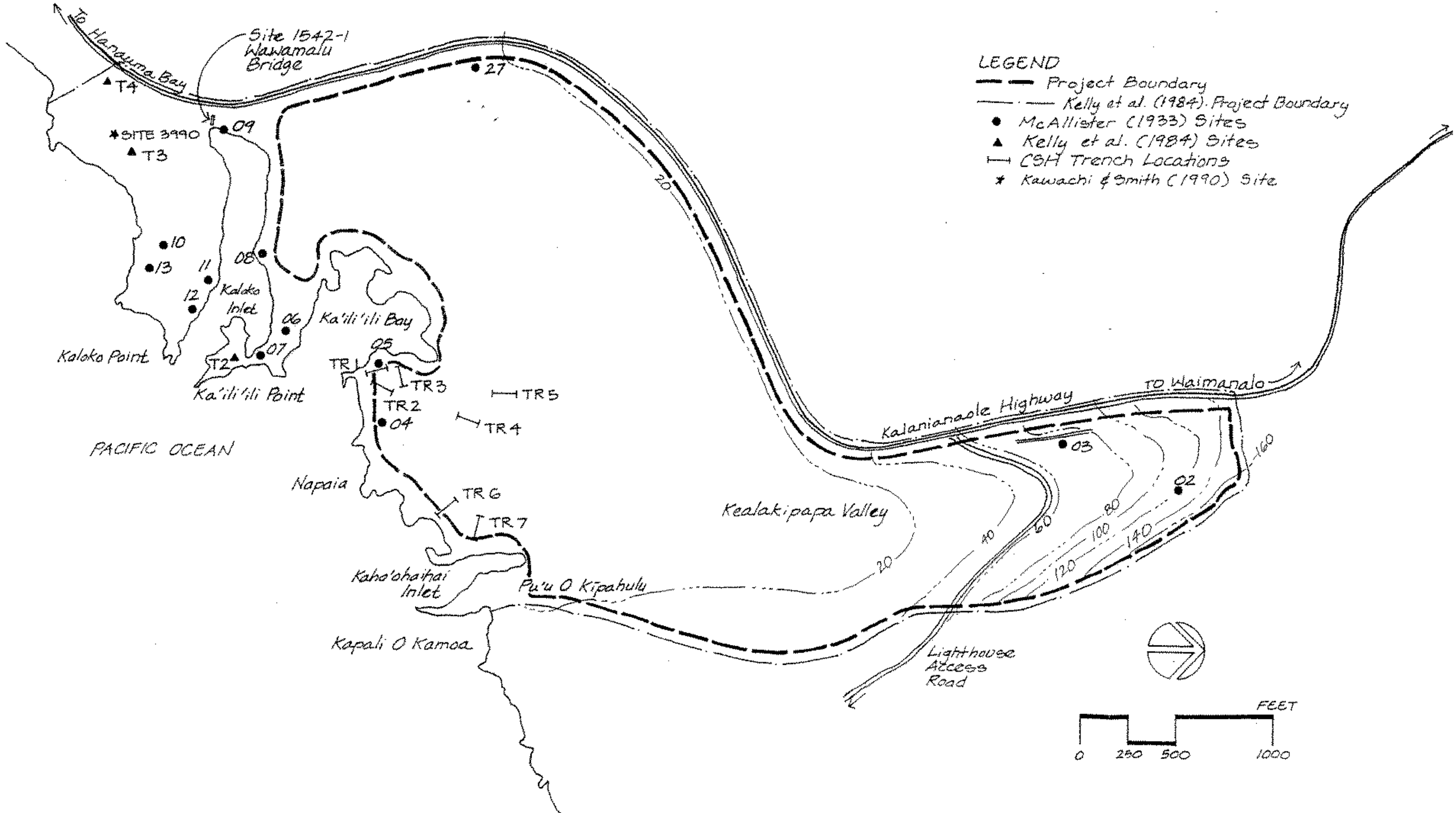


Figure 4 Project Area Map (after Walker et. al 1996) showing McAllister's (1933) site Locations, Kelly's (et. al 1984) site locations, and Cultural Surveys Hawaii trench Locations.

A. Project Area Description

The project area consists of approximately 166 acres in Kealakipapa Valley, the flats below the valley, and along the coast of Queen's Beach. The traditional Hawaiian names for the Queen's Beach area are Kaloko, Napa'ia, Ka'ili'ili, and Kaho'ohaihai (Kelly et. al 1984:59). Together this coastal area has become known over the years as "Queen's Beach". Specifically, the project area's boundaries are the following: to the north the cliff overlooking Makapu'u Beach Park; to the east the western slopes of Makapu'u Head; to the west Kalanianiole Highway; and to the south the shoreline of the Queen's Beach area. The Ka'ili'ili and Kaloko peninsulas are not within the project area (see Figures 4 and 5). The Coast Guard access road to Makapu'u lighthouse on top of Makapu'u Head runs through the northern portion of the project area. This is the only paved road within the project area. Modification of the project area since 1960 has been extensive. Henry Kaiser's development plans for this region resulted in grading, dredging and material stockpiling. The results of this activity are obvious throughout the project area. Numerous four-wheel-drive roads cross the project area, the result of the material stockpiling operations and continuous use by unauthorized off-road vehicles.

The geology, topography, and coastline of the project area are the result of the erosional history of the Koolau Volcanic Series and the more recent activity of the Honolulu Volcanic Series. The ridge of the Koolau mountains was created by the cutting of windward and leeward valleys into the Koolau Shield Volcano. At Makapu'u the windward side of the Koolaus are actually sea cliffs. Kealakipapa Valley is a leeward valley that was "gradually beheaded by the recession of the windward sea cliff" at Makapu'u, creating the Waimanalo Gap (Stearns 1939:26). The shoreline and the majority of the coastal plain within the project area were once covered by lava from the Kalama eruption of the Honolulu Volcanic Series. This predominantly a'a flow came down from Kalama Valley, forming the shoreline from just east of Sandy Beach eastward to Kapali o Kamoa. The flow's surface is partially covered by alluvium (McDonald et. al 1983:448-450).

The project area is easily divided into three zones: the coast; the coastal plain behind the coast; and Kealakipapa Valley.

The coast-line stretches from the artificial breakwater at Kaho'ohaihai Inlet to the northeast portion of Ka'ili'ili Bay. This coastline has been modified by the grading and dumping of dredge materials, the construction of the inlet and breakwater at Kaho'ohaihai below Kapali o Kamoa, and by the scraping of former dune areas (Kelly et. al 1984:59-61). The shoreline is rocky and exposed to fairly high energy wave action. Behind the exposed rock are high surf deposited coarse grained marine sediments, consisting mostly of coral sand, gravel, and cobbles but with some basalt and andesite sands mixed in (Foote et al. 1972:28). There are also numerous basalt boulders and cobbles. The coast is the site of numerous modern campsites related to fishing. Vegetation along the coast consist of *naupaka* (*Scaevola frutescens*), various grasses, *koa haole* (*Leucaena leucocephala*), and, in the interior of Ka'ili'ili Bay, mangrove (*Rhizophora mangle L.*). The project area does not include the 75-150 ft wide beach between Kaho'ohaihai Inlet and Ka'ili'ili Bay.

The coastal flat behind the beach has been greatly modified by the grading, dredging, and material stockpiling associated with the development of Hawaii Kai. Dredging activities included the attempted excavation of an artificial waterway from the Ka'ili'ili Bay to a planned boat harbor at Kaho'ohaihai, adjacent to Kapali o Kamoa. This

excavated trench cuts through the *makai* portion of the coastal flat. Another trench was excavated further *mauka* in the western half of the project area midway between the coast and Kalaniana'ole Highway. This east-west trending drainage channel directs run-off from *mauka* valleys and the adjacent Hawaii Kai golf course. Huge basalt boulders (known as "armor rock") as well as dredged sediments have been stockpiled throughout most of the coastal plain. The boulders are precariously piled, unstable, and intermixed with large rusted-metal and concrete construction fragments--leading to unsafe and difficult walking conditions. In fact, much of the coastal plain, off of the four-wheel-drive roads, must be negotiated very carefully using hands as well as feet.

Foote (et. al 1972) classified the soils in this portion of the project area as Lualualei clay and Lualualei extremely stony clay. Lualualei clay is found on alluvial fans (0-2% slopes) and consists of well drained, very sticky and very plastic clay (Foote et. al 1972:84). The central portion of the project area consists of this soil. The Lualualei extremely stony clay is found more commonly on talus slopes (3-35% slopes) and consists of a similar clay to that noted above except it contains many stones on the surface and in profile (Foote et. al 1972:85). This extremely stony clay is found along Kalaniana'ole Highway in the north-central portion of the project area. Vegetation in the coastal plain consists predominantly of *koa haole* (*Leucaena leucocephala*), *kiawe* (*Prosopis pallida*), and various grasses.

The Kealakipapa Valley portion of the project area has also been impacted by the development activities associated with the development of Hawaii Kai. At the lower (southern) end of the valley approximately 200 feet south of where the light house access road meets Kalaniana'ole Highway is a large, artificial, plateau-like, terrace of bulldozer deposited sediments. Flat on top, this terrace extends out from Kalaniana'ole Highway, measures approximately 300 feet north-south by 250 feet east-west, and is raised 15 feet above the surrounding topography. There is less four-wheel-drive traffic in the Kealakipapa Valley portion of the project area--but numerous old bulldozer and truck paths can be discerned crossing the landscape. These pathways in most cases lead to and/or are bordered by crude linear alignments of huge boulders that were dumped from trucks as part of the "armor rock" stockpiling. These boulders often have drill holes and scars from mechanized quarrying. To a lesser extent, mossrock pickers have been responsible for changing the landscape as they removed stones (Kelly et. al 1984:76).

Kealakipapa Valley consists primarily of Rock land, described by Foote (et. al 1972:119) as "areas where exposed rock covers 25-90% of the surface . . . rock outcrops and very shallow soils are the main characteristics . . . rock types are mainly basalt and andesite. This land type is nearly level to very steep". Some Lualualei very stony clay is also present in the lower valley along Kalaniana'ole Highway in the vicinity of the light house access road. Vegetation consists predominantly of various grasses, dense stands of *kiawe* (*Prosopis pallida*), with scattered *panini* cactus (*Opuntia ficus-indica*).

Walker (et. al:4) reports the following endemic and indigenous plants within the project area: *'Akulikuli kai (Batis maritima), Hinahina (Heliotrophium anomalum), 'Ihi (Portulaca sclerocarpa), 'Ilima (Sida fallax Walp.), Ma'o (Gossypium sandwicensis), Milo (Thespesia populnea), Nalo (Myoporum sandwicensis), Naupaka (Scaevola frutescens), Pa uohiiaka (Jacquemontia sandwicensis), Pohuehue (Ipomoea pes-caprae)*, and *'Uhaloa (Waltheria americana)*. Figure 6 is a summary of the different land alterations that have modified different portions of the project area.

Elevations within the project area range from approximately 200 feet amsl. at Waimanalo Gap, to sea level at Ka'ili'ili Bay. Rainfall in this portion of O'ahu is

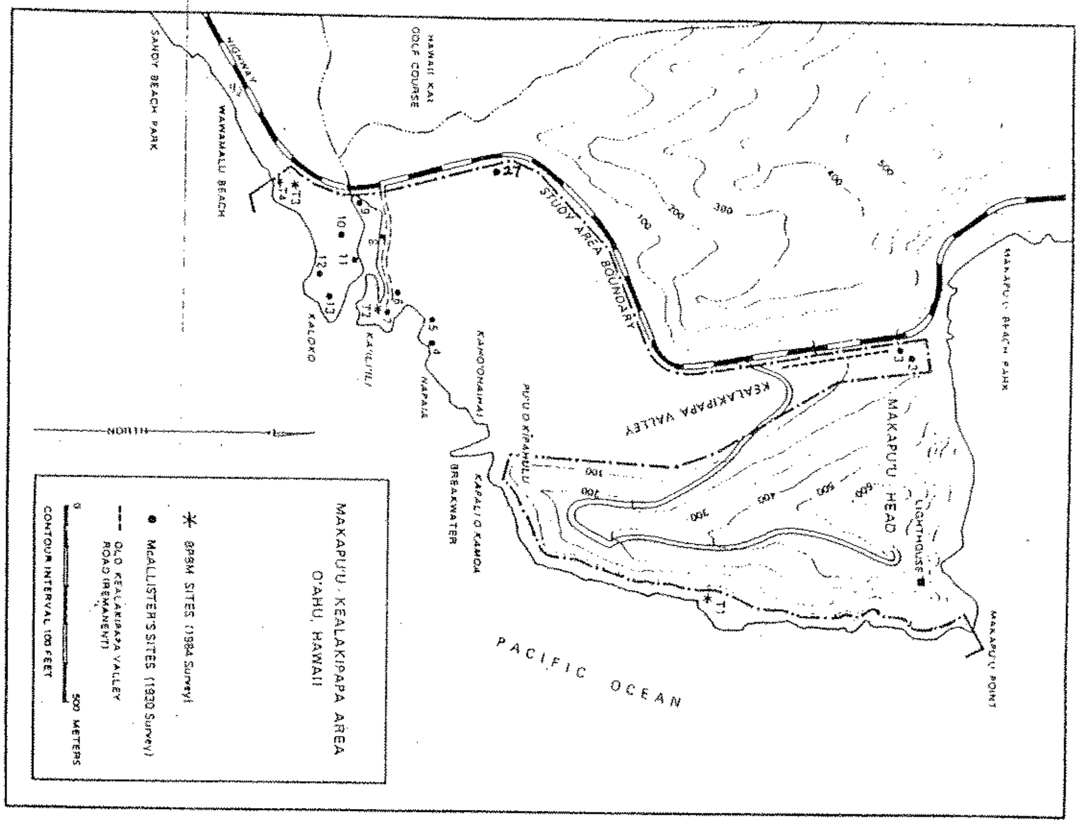


Figure 5 Project area of Kelly (et. al 1984) showing McAllister's sites as well as those of the Bishop Museum assessment.

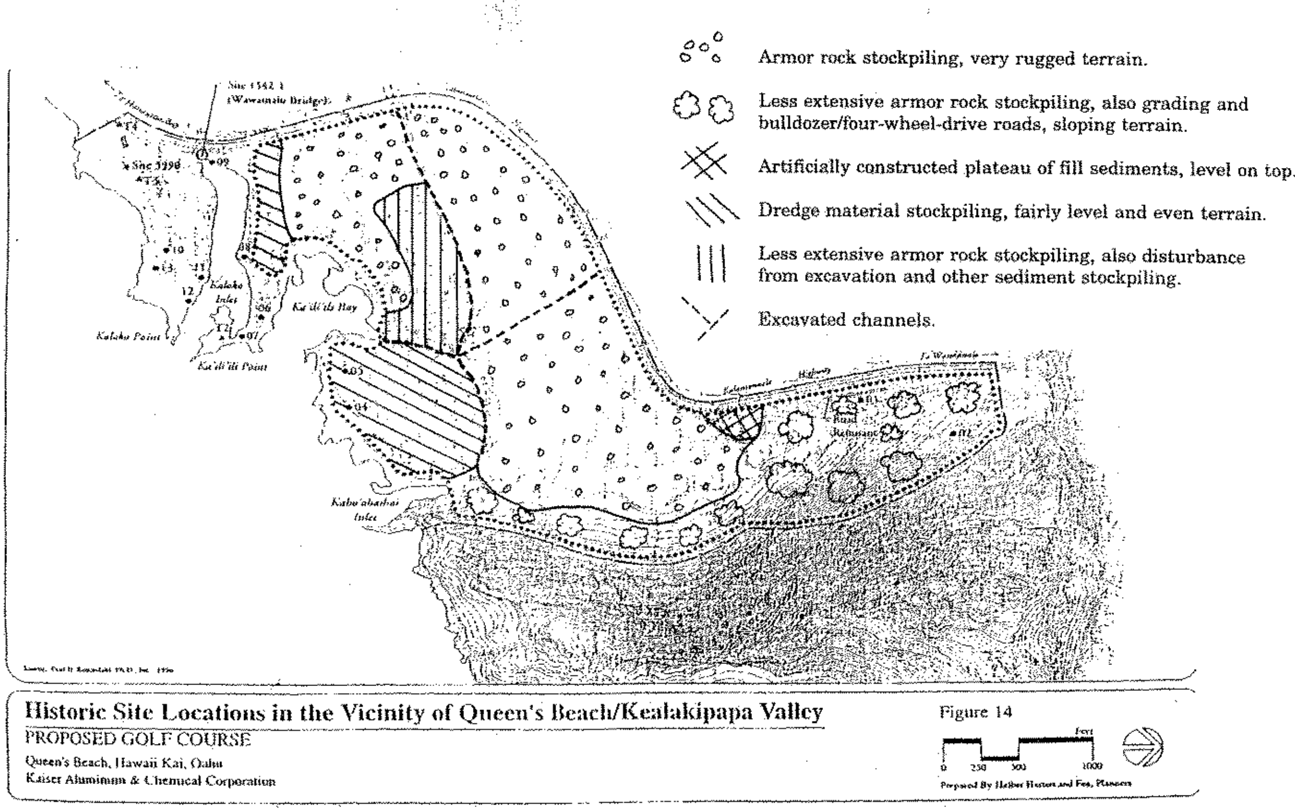


Figure 6 Summary of different land alterations observed within the project area during the inventory survey.

reported as 20-30 inches a year and the mean annual temperature is approximately 70-75 degrees F (Armstrong 1983:63-64). During the field work the project area was well watered from recent rains, resulting in thick, green vegetation. Standing water, even running water, were observed in portions of Kealakipapa Valley and in many portions of the coastal flat. Ground surfaces appeared saturated. This condition seemed extreme for this usually arid part of the island--even for the rainy season. Through most of the year the project area is dry and vegetation is less dense. (Figures 32-40 in the Photo Appendix show different views of the project area during the inventory survey field work.)

B. Scope of Work

In addition to complying with the general requirements set forward by the State Historic Preservation Division of the Department of Land and Natural Resources for archaeological inventory survey, any archaeological inventory survey scope of work should be tailored to the individual project area being surveyed. The Queen's Beach project area is uncommon because of the number of previous archaeological and cultural resource studies that have been carried out there. These studies document not only the archaeology and history but the prehistoric, historic, and modern land use changes and land alterations within the project area as well (McAllister 1933; Takemoto 1975; Kelly et. al 1984; Carpenter 1992; Walker et. al 1996). From McAllister we have a fair idea of the types of archaeological features and their distribution within the project area circa 1930. Subsequent studies have documented how natural and man-made land alterations have affected these archaeological features. From this previous research and Cultural Surveys Hawaii's own preliminary research it was clear that surface archaeological remains were likely destroyed. Testing for buried archaeological deposits was therefore a priority, in agreement with the recommendations of the archaeological assessments by Kurashina and Sinoto (Kelly et. al 1984) and PHRI (Walker et. al 1996).

One hundred percent of the project area was covered by systematic pedestrian sweeps during the survey and all work was done to the standards required by DLNR/SHPD. All previously recorded site areas were re-examined and evaluated and in some instances tested for subsurface remains. An evaluation of the level of disturbance/modification that different areas of the project area have undergone was carried out.

The scope of work consisted of the following steps:

1. Research on historic and archaeological background, including search of historic maps, written records, Land Commission Award documents. Oral traditions and mythological accounts dealing with the region were also examined. This research focused on the specific area with general background on the *ahupua'a* and district and emphasized settlement patterns.

2. A complete ground survey of the entire project area for the purpose of site inventory. All sites or former site areas were located and evaluated. Where possible sites were described and mapped with evaluation of function, interrelationships, and significance. Documentation included photographs and scale drawings of selected sites and complexes. All sites were assigned State site numbers or matched to their previously designated State site numbers.

3. Limited subsurface testing to determine depth and quantity of cultural materials within archaeological sites and in previously recorded archaeological sites was carried out. Evaluations of stratigraphy in relation to cultural land modifications were done. All sediments were described and samples were taken.

5. Preparation of a survey report which includes the following:

   a. A topographic map of the survey area showing all archaeological sites and site areas;

   b. Description of all archaeological sites with selected photographs, scale drawings, and discussions of function;

   c. Historical and archaeological background sections summarizing prehistoric and historic land use as they relate to the archaeological features;

   d. A summary of site categories, their significance in an archaeological and historic context;

   e. Recommendations based on all information generated which will specify what steps should be taken to mitigate impact of development on archaeological resources - such as data recovery (excavation) and preservation of specific areas. These recommendations will be developed in consultation with the client and the State agencies.

This scope of work also includes full coordination with the State Historic Preservation Division (SHPD), Elaine Jourdane, and the City and County of Honolulu relating to archaeological matters.

C. Methods

The 100 percent coverage of the project area surface survey was accomplished through systematic pedestrian sweeps. The distance between the four crew archaeologists was determined by vegetation primarily and to a lesser extent by terrain and topography--all factors that determine visibility of archaeological surface features. The interval between archaeologists was generally between 15 and 25 meters, ensuring that no archaeological surface features would be missed. The previous archaeological investigations of the project area found the greatest number of archaeological features on the coast. Therefore, the entire four person field crew inspected the coastline for signs of structural remains or other archaeological deposits. As the surface survey progressed, an evaluation of the level of disturbance and/or modification for each region of the project area was carried out. The locations of previously recorded archaeological features within the project area were examined. Those locations which potentially had subsurface archaeological deposits were slated for subsurface testing. Subsurface testing within the project area was carried out through a program of backhoe testing. Backhoe excavations provide a means to rapidly investigate subsurface deposits over a broad area. Seven backhoe trenches were excavated in the project area. Trenches were dug to investigate specific questions regarding subsurface deposits. Areas that could be tested with a backhoe were limited to those areas of the project area not covered with stockpiled armor rock.

All trenches (with the exception of trench 4) were excavated to ground water or to bedrock and were generally one bucket width (0.9-1.0 m) wide and of variable depths. Three archaeologists were on site at all times to monitor the excavations, to document the exposed sections, and to collect sediment samples. Trench location, dimensions, and orientation were recorded. Exposed trench sections were documented with scale section profiles, photographs, sediment descriptions, and, where useful, sediment samples. Sediment descriptions included Munsell color designations, sediment size, inclusions, compactness, and cultural material present.

II. PREVIOUS ARCHAEOLOGICAL WORK

Extensive summaries of previous archaeology conducted in Maunalua already exist. The following summary is based on information presented in McAllister (1933), Kelly et. al (1984), Walker et. al (1996), and Jones (1996). Table 1 (adapted from Jones 1996) lists the archaeological reports that can be consulted for further information regarding specific areas of Maunalua. The first archaeological survey in Maunalua was conducted by McAllister (1933) in 1930. As part of his 9-month, island wide, archaeological survey of Oahu, McAllister located, mapped, and described 49 archaeological sites in the Maunalua region. Of these 49 sites, 25 were located in the vicinity of the current project area. Descriptions of these 25 sites tell us something of the traditional land use and settlement pattern in the Kealakipapa region. They also hint at the land use changes that occurred in the region as sweeping cultural changes overtook traditional Hawaiian lifestyles after western contact. Only 5 of McAllister's sites (site numbers 2-5 and 27) are within the boundaries of the current project area. Table 2 is a summary of the 25 sites McAllister found in the vicinity of the current project area. Site locations for the 25 sites are plotted on Figure 7.

In the Maunalua region, McAllister described sites of traditional Hawaiian origin as well as historic sites related to activities such as ranching and road construction. The traditional sites documented in the vicinity of the current project area include the following. Sites 6 and 14 were recorded as fishing shrines, or *ko'a*. Site 22 as a likely *heiau* remnant. Sites 5, 7, 10, 15, 16, and 20 were recorded as house sites. Site 12 was reported to be a canoe house. Reported within the site 27 enclosures (historic ranching structures, see below) were 5 stone mounds, reported to be burials, and smaller piled stone mounds thought to be former sweet potato cultivation mounds (according to McAllister's informants) (McAllister 1933:63). Site 1 was the locality associated with a local deity Malei of which there are numerous legends (see the section on legends of Maunalua for further discussion). McAllister discussed the former emplacement of the Malei stone--which he describes as a cement foundation remnant near the cliffs at Waimanalo Gap. Sites 2 and 9 were described as piles of stones. They were likely structural remnants which lacked sufficient structural integrity to suggest a form or function. Sites 8, 11, 17, 18, 19, and 23 which were recorded as walled structures or enclosures. McAllister does not suggest an age for these structures and they could be of either traditional Hawaiian or historic agricultural and/or ranching origin. Site 21 was described as a cave habitation which McAllister's informant suggested was used during warfare as a refuge cave by the local population.

These site and functional types documented by McAllister are typical of traditional Hawaiian coastal settlements, which generally had habitation near the marine resources being exploited, religious structures for supernatural assistance in fishing and other daily activities, canoe houses near natural landing sites, and burials and agricultural features adjacent to the settlement.

Table 1 Previous Archaeology in Maunalua (adapted from Jones 1996:17-18)

Project Name	Nature of Investigation	Number of Sites	Area	Reference
Oahu Survey	Survey	50	Maunalua	McAllister (1933)
University of Hawaii	Excavation	4	Kuliouou	Emory and Sinoto (1961)
University of Hawaii	Excavation	1	Kaluanui	Smart (1964)
University of Hawaii	Excavation	1	Kaluanui	Bayard (1967)
University of Hawaii	Excavation\Survey	1	Kaloko	Wallace et. al (1966)
Kuapa Pond Overview	Overview	0	Kuapa Pond	Takemoto et. al (1975)
University of Hawaii	Survey	2	Hahaione alley	Watanabe (1978-79)
Kaluanui 1-3 Marina Zoning	Survey	11	36 acres	Price-Beggarly and McNeill (1985)
Kaluanui-1 Subdivision	Testing	5	21 acres	Carlson and Rosendahl (1990)
Burial Removal Ka'ili'ili	Field Check/ Excavation	1	Single Sand Burial Site 80-15-3990	Kawachi and Smith (1990)
Kaluanui Park	Testing	2	5 acres	Folk et. al (1993)
Kaluanui 1-3 Assessment	Mapping/Testing	7	36 acres	Schilz (1994)
Pahua Heiau Reconstr.	Excavation and Reconstr.	1	Kamilo Ridge	Davis (1985)
Hanauma Bay Beach Park	Survey	0	Hanauma Beach Park	Connolly (1980)
Queen's Beach Feasibility Study	Survey	4	Kealaki-papa Valley\ Makapu'u	Kurashina and Sinoto (1984)

Project Name	Nature of Investigation	Number of Sites	Area	Reference
Queen's Beach Feasibility Study	Cultural Resource Overview	0	Kealaki-papa Valley\ Makapu'u	Kelley et. al (1984)
Golf Course	Survey	0	30 acres	Barrera (1986)
Golf Course 5\6 Subdivision	Survey	0	31 acres	Spear (1987)
Sandy Beach Park Extension	Survey/Test-ing	0	12.4 acres	Kennedy and Denham (1992)
Fiber Optic Cable Landing	Survey\Test-ing	0	Sandy Beach	Borthwick and Hammatt (1992)
Kealaki-papa Road	Survey	3	Kealaki-papa Valley	Carpenter (1992)
Kamehame Ridge Subdivsion 2	Survey	0	26 acres	Shun (1988)
Kamehame Ridge Water Reservoir	Survey	0	80 linear ft.	Borthwick and Hammatt (1991)
Elect. Trans. Line Relocation	Survey	0	8400 linear ft. Kamehame Ridge	Bothwick and Hammatt (1991)
Nine Parcels in Maunalua	Survey	11	Throughout Maunalua (see below)	Jones (1996)
Arch. Assessment Queen's Beach	Inspection	0	166 acres	Walker et. al (1996)

Table 2 McAllister's Sites in the vicinity of the project area
* denotes sites within current project area

Site number	Site description
1	stone form of *kupua* (goddess) Malei
2*	artificial pile of stones (15 by 45 by 9 ft. high)
3*	Kealakipapa Valley Road, paved with curbstones
4*	small crescent shaped walls--likely modern fishermen's wind breaks
5*	house site--stones probably removed for windbreaks
6	*ko'a* (fishing shrine)
7	house site
8	walled structure
9	pile of stones
10	house site
11	enclosure, connected to site 10
12	canoe house
13	rock shelters, resembling site 4
14	*ko'a* (fishing shrine)
15	house platform (?)
16	house platform
17	inclosure
18	inclosure
19	inclosure
20	house site
21	cave habitation (?)
22	possible heiau
23	inclosure
24	pigpen (?)
27*	enclosures, Wawamalu ranch, containing possible burial mounds and possible sweet potato cultivation mounds

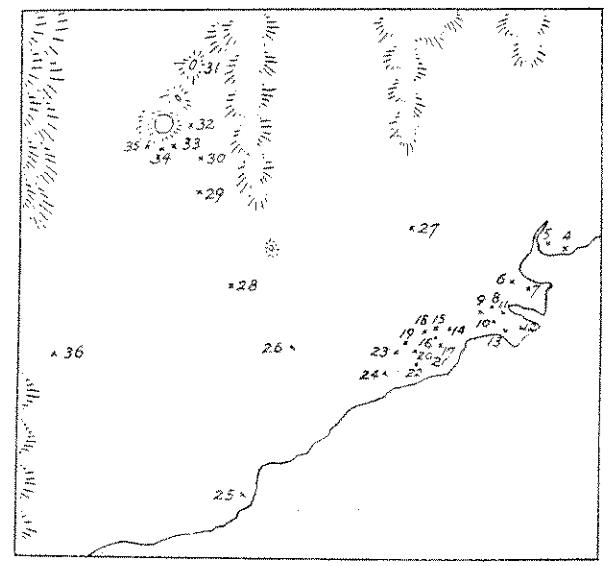


FIGURE 20.—Map of Maunalua, showing location of Sites 4 to 36.

Figure 7 McAllister's site map showing site locations of sites 4 through 36.

The historic or historically utilized sites described by McAllister were sometimes traditional sites or features that were utilized or re-utilized, sometimes with changes in function or form, in the historic period. For example site 3 is a historic road way which was visible to McAllister only in the area of Kealakipapa valley north of the lighthouse access road. McAllister noted that Maunalua was traditionally considered an *ili* (subdivision) of Waimanalo and the path up Kealakipapa Valley and down Waimanalo gap was the obvious route connecting the regions (McAllister 1933:59). It seems clear that this traditional pathway developed into the historic roadway which was recorded by McAllister (See survey results for further discussion of McAllister's site 3).

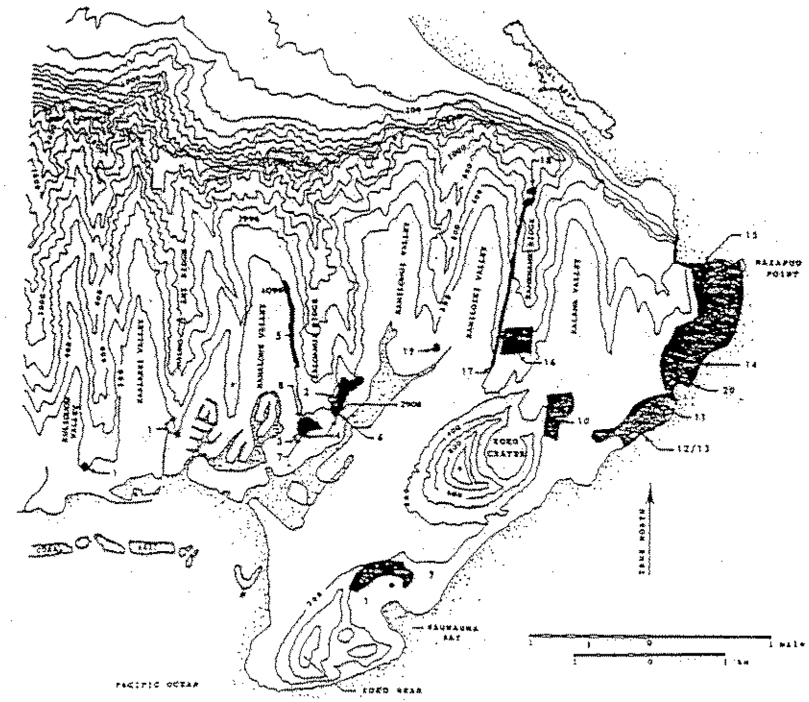
Other historical sites recorded by McAllister included site 27 "enclosures"--which he specifically related to cattle ranching at Wawamalu Ranch. Traditional sites (burials and agricultural mounds) were located within these historic ranching walls (see above). Site 24 was reported as a pigpen (?) which could be of prehistoric origin but is likely historic. Sites 4 and 13 were likely fishing shelters or windbreaks which appeared to McAllister to have been more recently constructed than the other coastal habitation features. McAllister noted that stones were stolen from the more formal habitation structures (e.g. McAllister's sites 5, 7, 10, 15, 16, and 20) to build the less substantial windbreaks (McAllister 1933:59-61). This is an indication that following the abandonment of the region's more permanent habitation, recurrent temporary use of the marine resources continued.

It is clear from McAllister's site descriptions that settlement in the region prior to European contact was well established--if not exactly thriving. The archaeological documentation by McAllister correlates well with the mythological and traditional accounts of settlement in the area--i.e. the area was populated by coastal dwellers who harvested the sea and grew their crops on the plains and into the valleys of Maunalua. From historical accounts and documents it is evident that change came about in the region with western contact. This change was noted by McAllister in terms of changing structural forms, rock stealing from older habitation sites, and the building of large enclosures (such as site 27) for ranching.

In western Maunalua McAllister also recorded sites, a large number located near the Kuapa fishpond that was transformed into the Hawaii Kai residential area. These sites included *heiau*, burial caves, rock shelters, petroglyphs, and agricultural fields. (See Figure 8 for locations of previous archaeological investigations within Maunalua.)

Emory and Sinoto (1961) report the results of University of Hawaii excavations in site 03, a natural rockshelter at the northeastern corner of the beach at Hanauma Bay (carried out in 1952). The majority of recovered artifacts were unsurprisingly related to fishing and the creation and maintenance of fishing gear. The midden consisted primarily of marine shell and fish bone, although a small amount of dog, pig, and bird bone were also recorded within the shelter. The remains of hearths were also recorded.

In 1966 students from the University of Hawaii excavated and conducted limited surface survey at the Kaloko point region--just southwest of the current project area (Wallace et. al 1966). This research was carried out in McAllister's high site density area around the Kaloko point area. Excavations uncovered no structural remains, with the exception of hearths. The artifact and midden deposits characterize the occupation as marine oriented. Surface survey brought to light a few structural remnants--drastically reduced in number from those reported by McAllister. The work made clear that road construction and the 1946 tsunami had heavily impacted the archaeological deposits since they were reported by McAllister in 1930 (Wallace et. al 1966:6).



1. Emory and Sinoto (1961)
2. Smart (Solheim) (1964)
3. Bayard (1969)
4. Price-Beggarly and McNeill (1985)
5. Watanabe (1978-79)
6. Carlson and Rosendahl (1990)
7. Folk et. al. (1993)
8. Schilz (1994)
9. Connolly (1980)
10. Barrera (1986)
11. Spear (1987)
12. Kennedy and Denham (1992)
13. Borthwick and Hammatt (1992)
14. Kurashina and Sinoto (1984)
15. Carpenter (1992)
16. Shun (1988)
17. Borthwick and Hammatt[a] (1991a)
18. Borthwick and Hammatt[b] (1991b)
19. Davis (1984)
20. Wallace et. al. (1966)

* Burial Sites Not Shown
* For information on project/sites see text.
* MacAllister's (1933) Sites Not Shown.

Figure 8 Previous Archaeology Project Areas in Maunalua after Jones (1996).

Further University of Hawaii excavations and survey were carried out at the western and southern margins of Kaluanui Ridge at the mouth of Hahaione Valley. Conducted over a period of three years, these investigations documented features from more than one related complex. Occupation of these features spanned from the late prehistoric to early 20th century (Bayard 1969:1). Features included rock shelters, house platforms, stone "cairns", and a stone enclosure. Bayard also conducted excavations at site 50-80-15-2908, the Hawaii Kai rock shelter. Three dates ranging from AD 1330 to 1800 were obtained (Bayard 1965: 7-8, cited in Jones 1996:181).

Sponsored by the US Army Corps of Engineers, Anne Takemoto wrote a cultural and historical overview for the Kuapa fishpond area in western Maunalua. This report included a literature and document search, an analysis of place names, oral traditions, and 19th century historic accounts, summaries of previous archaeological investigations, as well as recommendations on how the additional information might be obtained with further research (Takemoto 1975). The mythological and historical resources of the region are highlighted. Regarding the archaeology of the region Takemoto states:

> "The quantity and quality of the archaeological sites discovered in the area does not significantly help unfold the history of the Kuapa Pond region. It can be assumed that the area was not extremely populous and that its importance compared to other *ahupua'a* was marginal" (Takemoto 1975:4).

Takemoto further states in her conclusions: "Maunalua and Kuliouou today have only a few archaeological sites still in existence . . . The sites McAllister found in the 1930's have been destroyed" (Takemoto 1975:32).

During the development of the Kuapa fishpond area into the residential neighborhood of Hawaii Kai, Hawaiian burial sites were discovered on Kaalakei Ridge and Maunalua O Ahi Ridge (McCoy 1971 and Bevacqua 1972, respectively, cited in Jones 1996:12).

The area of Kaluanui received several archaeological investigations as the result of development plans. The land around Hawea *heiau* was systematically surveyed and, although previously bulldozed, 11 sites were recorded. The sites found included a historic habitation, caves, platforms, petroglyphs, and the possible remains of Hawea *heiau* (Price-Beggarly and McNeill 1985). Further work was conducted by Rosendahl, Inc. (PHRI) as part of an inventory survey within a 21-acre portion of the same approximately 36-acre Kaluanui parcel investigated by Price-Beggarly and McNeill. PHRI relocated sites and tested the "bedrock cavities" for cultural remains. Results were negative (Carlson and Rosendahl 1990).

In 1993 Cultural Surveys Hawaii surveyed a 5-acre parcel along Hawaii Kai Drive just south of Kaluanui ridge at the site of the proposed Kaluanui Park. Re-location and limited sub-surface testing of sites found by McAllister, Bayard, and Price-Beggarly and McNeill was carried out. The field work documented limited prehistoric subsurface deposits at site 50-80-15-2900 (described by Price-Beggarly and McNeill as a U-shape enclosure) and made several reinterpretations of previously described features. Excavations carried out by Cultural Surveys Hawaii at site 2900 yielded a radiocarbon date of 1800-1940. This supports the interpretation that the site was used in the historic period through Maunalua's prominence in the "victualing trade" into the early 20th century (Folk et. al 1993).

The investigations at Kaluanui document archaeological resources which include

habitations, burials, historic house-sites, petroglyphs, historic road-way remnants, and religious structures. The area was utilized from the prehistoric through the historic era. It is evident that modern development has greatly impacted the archaeological resources of the region.

Davis (1984) conducted excavations and reconstructions at the site of Pahua *heiau*. This work was carried out intermittently from the mid-1970s to 1985 by the Bishop Museum as part of a larger settlement pattern study of the region of southeast O'ahu.

Closer to the current project area, in eastern Maunalua, there have been a number of archaeological and cultural studies since the 1980s. Probably the most relevant concerning the present project area is the Cultural Resource Overview for the Queen's Beach Park Feasibility Study, prepared for the Department of Parks and Recreation by Kelly, Kurashina, and Sinoto (1984). This study consisted of "a historical overview and assessment of the surface archaeological resources" for an area that included all of the current project area as well as the Kaloko peninsula and the coastline from Kapali o kamoa to Makapu'u Point (Kelly et.al 1984).

Kurashina and Sinoto wrote up the assessment of archaeological remains within the project area. In their field reconnaissance Kurashina and Sinoto could not relocate McAllister's sites 5-13 along the coast of the project area. They state that these sites were likely destroyed by the recent dredging, material stockpiling, and bulldozing from the Kaiser development plans--and by the devastating effects of the 1946 tsunami (Kelly et. al 1984:11). The only McAllister sites within the project area that were relocated consisted of sites 2 (a pile of stones with coral), 3 (historic road way), and the cement foundation/emplacement of the Malei stone--all within Kealakipapa Valley. Kurashina and Sinoto failed to detect structural remains of site 2--but did note the presence of coral on the valley slopes in the general vicinity of site 2. They suggest the stones of the structure were removed for construction of the adjacent military pill-boxes on the Makapu'u cliff face (Kelly et. al 1984:9). Related to the McAllister's site 3 paved roadway, they report seeing 11-15 foot wide sections of the stone paved road between the Coast Guard road and Makapu'u Lookout (Ibid.).

Kurashina and Sinoto located previously unrecorded sites outside the current project area--site T-1, T-2, T-3 and T-4. Site T-1 is a cave located on the coast between Kapali o Kamoa and Makapu'u Point. Site T-2 was the Davis Ranch swimming pool, at Ka'ili'ili peninsula, T-3 is a midden site on the Kaloko peninsula, and T-4 is the Davis Ranch boundary wall at Wawamalu Beach--see Figure 5 for the locations of Kurashina and Sinoto's sites.

Barrera (1986) conducted archaeological reconnaissance on 30 acres between the Hawaii Kai Golf Course and Koko Crater. McAllister had recorded a house site (site 36) and terraces (site 37) in this area. No sites of any kind were located during the field work, however. Barrera indicates this was due to modern ground disturbance.

Thirty-one acres of proposed golf course and subdivisions were surveyed by PHRI *mauka* of Sandy Beach (Spear 1987). No surface features were observed and shovel and auguring tests yielded no evidence of subsurface cultural deposits.

Shun (1988) carried out archaeological inventory survey on 26 acres on the southern portion of Kamehame ridge. No archaeological features were found, although numerous small caves and rock overhangs were observed within the project area. Also on Kamehame ridge, Cultural Surveys Hawaii conducted inventory survey for the relocation of an electrical transmission line. Due to the steepness of the slope, survey was generally limited to pole locations along the 8,400 foot transmission line. No archaeological sites were found (Borthwick and Hammatt 1991a). The archaeological survey for the proposed Kamehame Ridge Water Reservoir was also done by Cultural Surveys Hawaii. The reservoir site and the associated access roads contained no archaeological features (Borthwick and Hammatt 1991b).

Cultural Surveys Hawaii conducted survey and subsurface testing for the proposed Fiber Optic Cable Landing at Sandy Beach Park. Although located in the suspected area of Wawamalu village, no archaeological features or deposits were found. This was due to the disturbed beach sediments in the project area (Borthwick and Hammatt 1992).

Archaeological Consultants of Hawaii conducted surface survey and subsurface testing for an extension to Sandy Beach Park at Wawamalu. No surface features were found and subsurface testing located no cultural deposits. Stratigraphy in the project area indicates that road construction (both the original and re-aligned Kalaniana'ole Highway) as well as the 1946 tsunami have removed "any traces of historic or prehistoric sites" (Kennedy and Denham 1992:1).

Not all archaeological coastal deposits were removed from this stretch of coastline between Sandy Beach Park and the current project area. In 1990 State Historic Preservation Division officials were called to the *naupaka*-covered coastal dunes just northwest of Wawamalu Beach--just northeast of the boundary wall between the beach park and the former Davis Ranch. Approximately 30 m northwest of the water-line, off-road recreational vehicles had disturbed an *in situ* prehistoric burial (Kawachi and Smith 1990). This burial was located in the general area of the midden deposit (site T-3) recorded by Kelly, Kurashina, and Sinoto. They noted a gray stained area of compacted sand containing a disturbed stone alignment, marine shell midden, and basalt flakes. They suggest this may represent a prehistoric occupation floor (Kelly et. al 1984:14).

In 1992, as part of the feasibility study for the inclusion of the Makapu'u Head and Queen's Beach area within the State Parks System, Alan Carpenter did a field check of the Kealakipapa Road remnants (McAllister's site 3) (Carpenter 1992). Carpenter reports two sections of the road that could still be discerned. One section consisted of switchbacks (paved road surface with terraced road bed) extending down the steep cliff from Makapu'u Lookout towards Waimanalo. This portion of the road is outside the current project area. The second section is located in the same area described by Kelly, Kurashina, and Sinoto (1984) parallel to Kalaniana'ole Highway, just up slope of the light house access road. Carpenter describes this section as "straight . . . conspicuously clear of large rocks and . . . very level . . . The sides of the road are roughly defined on the west by a border of stones and on the east by a rough boulder alignment modifying a natural ledge" (Carpenter 1992:5). He also describes the road as nearly devoid of flat paving stones and very much over grown (Ibid.). From this description it appears that the mossrock pickers observed by Kelly in 1984 have continued to degraded the road remnant.

PHRI conducted an archaeological assessment of the current project area in 1994. The report's primary objective was to "assess the potential impacts of proposed development upon any significant archaeological resources that might be present within the project area" (Walker et. al 1996:ii). Background historical document research and a review of previous archaeology together with one day of limited ground survey was the basis for this report. Three previously identified sites were relocated--only one of which lies in the current project area. Kelly, Kurashina, and Sinoto's site T-3 (midden deposit) at Wawamalu Beach and the 1931 Wawamalu bridge (Kelly et. al 1984) were relocated but are outside the current project area. McAllister's site 3, Kealakipapa Road was relocated within the current project area and was described by Walker et. al (1996:11) as

"a cleared zone within the *kiawe*, usually containing no vegetation other than grasses or small shrubs. The road is relatively straight, and no curb stones or paving were visible". Kurashina and Sinoto recorded seeing stone paving along the road way in 1984 (Kelly et. al 1984:9). Walker's (et. al 1996) description indicates that degradation of the site had occurred since the archaeological assessment of Kurashina and Sinoto in 1984 and possibly since the field check of Carpenter in 1992. The PHRI assessment makes recommendations for a full inventory survey of the project with subsurface testing to locate any buried cultural deposits.

The most recent report within the Maunalua *ahupua'a* was completed by Aki Sinoto Consulting on a total of 375 acres in 9 separate parcels scattered about Maunalua (Jones 1996). The investigation consisted of surface survey and limited test excavations. Four of their parcels (Marina 1/Strip, Marina 4B, Golf Course 2/1A, and Kalama Valley) were found to be without archaeological or historic sites due to extensive prior disturbances. These disturbances included dredging and expansion of land masses with dredged material. The remaining 5 parcels, located in the valleys and ridges west-northwest of the current project area, contained 11 archaeological sites consisting of 71 features--see Table 3 and Figure 9. However, even within the 5 parcels containing archaeological sites, there has been ample modern disturbance from road construction, bull-dozing, and grading.

The 11 sites found within the 5 parcels consist almost exclusively of temporary habitation and/or activity areas, burials, and agricultural features. One of the most common site types reported is a modified rock shelter. These natural shelters are found along the ridges within the project area parcels. They provide ready-made shelter from sun, wind, and rain. They are also located adjacent to the agricultural land in the valley and drainage bottoms. These agricultural areas were renown in historical and traditional accounts for their sweet potato production (Summers and Sterling 1978:257). The rock shelters contain basalt lithic scatters, volcanic glass, *kukui* endocarps, marine shell midden, and fish and bird bone. These midden deposits are consistent with recurrent, temporary habitation and the use of the sites as activity areas, e.g. lithic reduction and tool manufacture. The elevation and distance from the ocean of these sites, in most cases, allowed good accessibility to agricultural land as well as marine resources.

The rock shelters are also the sites of human burials. Internment in lava tubes and bedrock cavities was a common practice in prehistoric and early historic hawaii. Jones (1996) described incomplete burials and bundle burials which often appeared disturbed or redeposited.

The agricultural features reported by Jones are located further from the current project area, in the vicinity of Kamilonui and Kamiloiki valleys. Site 4950 is an extensive agricultural complex which incorporates "much of the traditional Hawaiian types of irrigation and agricultural systems in its construction" (Jones 1996:183).

Five radiocarbon dates were obtained from charcoal samples excavated within the 11 sites recorded within the project area. Three rockshelter features were dated to the precontact period. Sites 4941-8, 4945-1, and 4951-2 were dated to 1655 AD, 1475 AD, and 1665 AD, respectively. Site 4942-1, a rock shelter located in the Mau'uwai parcel was dated to the late historic period (1880 AD). This late date is credited to ranching activity. The large agricultural complex, site 4950, was dated to AD 1900-1930. Jones suggests the complex "represents the efforts of Chinese lessees common in Kamilonui Valley from the 1860s to modern times (1996:160).

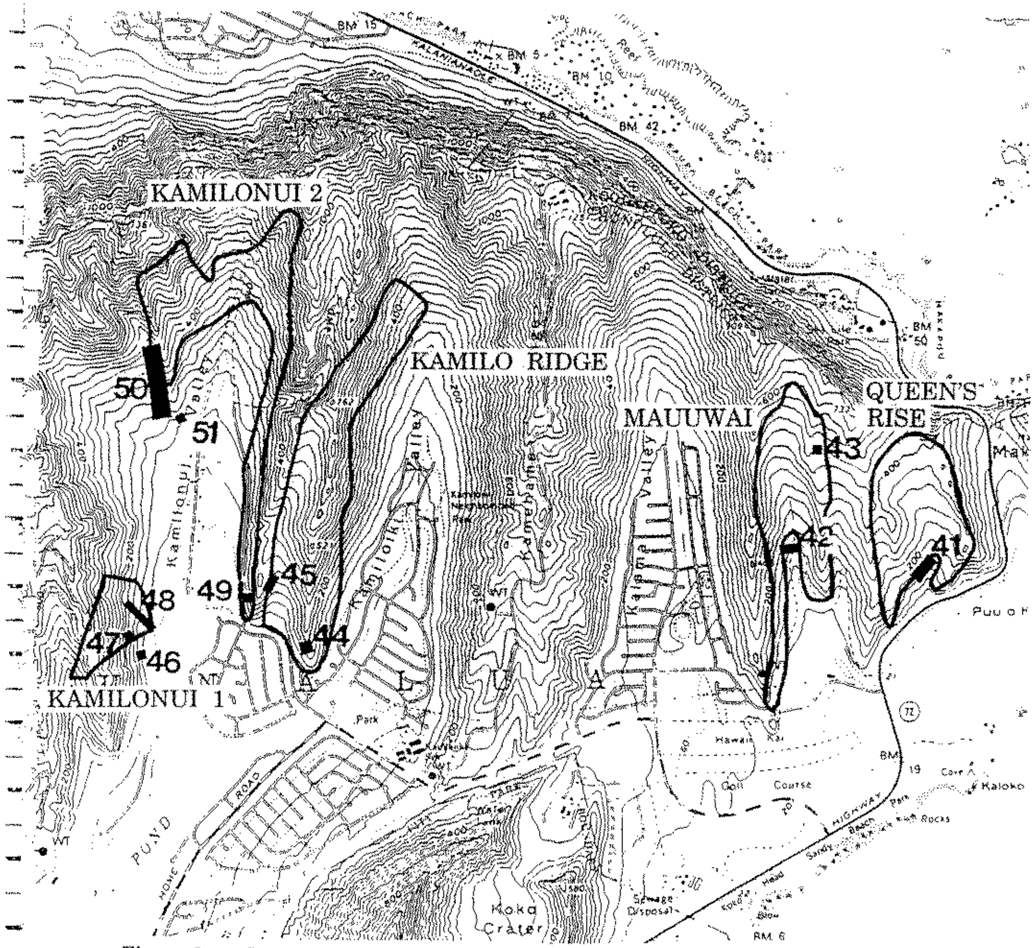


Figure 9 Jones' (1996) project area showing site locations.

Table 3 Archaeological Sites from Aki Sinoto Consulting's 9 Parcel Project Area (after Jones 1996).

Site # 50-80-15-	Site-Feature Type	Function Inter-pretation	Project Parcel	Size (m^2)	Ele-vation (ft)
4941	Bedrock cavities (8)	Temp. Hab.	Queen's Rise	4536	80-160
4942	Bedrock cavities (2)/lithic scatter	Temp. Hab./activity areas	Mau'uwai	2600	320
4943	Mod. out-crop	Indeter-minate	Mau'uwai	25	650
4944	Bedrock cavities (3)/ terraces (3)	Burial/ Temp. Hab./ Agriculture	Kamilo Ridge	1500	40-75
4945	Rockshelter/ Bedrock cavities (12)	Temp. Hab./ Burials	Kamilo Ridge	3000	80-120
4946	Clearing mound?	Agriculture?	Kamilo-nui 1	6	120
4947	Bedrock cavity	Burial	Kamilo-nui 1	2	190
4948	Wall	Agricultural?	Kamilo-nui 1	80 (lin-ear)	40-250
4949	Bedrock cavity	Burial	Kamilo-nui 2	9	50
Site # 50-80-15-	Formal Site/ Feature Type	Functional Inter-pretation	Project Parcel	Size (m^2)	Elev-ation (ft)
4950	Wall/mound terraces/ platforms/ C-shape/ modified outcrop	Agriculture/ Temp. Hab.	Kamilo-nui 2	10, 800	100-180
4951	Bedrock cavities (2)	Tem. Hab.	Kamilo-nui 2	168	110

Summary

McAllister's early (1930) survey of the archaeology of Maunalua documents 49 archaeological sites, consisting of *heiau*, *ko'a*, burials, house sites, petroglyphs, and agricultural features. These features reflect both the traditional Hawaiian settlement pattern of the region as well as the subsequent changes that came about with western contact. At the time the report was written, ranching was the dominant activity in Maunalua. Eighty years of ranching had not removed the archaeological remains of the pre-ranching activities. McAllister's report is important because it documents the landscape before it was impacted by the 1946 tsunami and modern development--most notably Kaiser's development of Hawaii Kai.

Reports subsequent to McAllister's nearly all note the destruction of archaeological features due to the tsunami of 1946 and development. In coastal areas, such as at Wawamalu and at Sandy Beach, the effects of the 1946 tsunami and the re-alignment of Kalaniana'ole Highway had varying effect. At Sandy Beach the archaeology appears to have been destroyed (Kennedy and Denham 1992; Borthwick and Hammatt 1992). At Wawamalu and Kaloko subsurface deposits remain intact (Kawachi and Smith 1990; Kelly et. al 1984; Wallace et. al 1966). Recent archaeological assessments have documented that no surface structural remains are within the coastal portions of the current project area (Kelly et. al 1984; Walker et. al 1996). It remains to be seen whether buried subsurface deposits exist within the current project area.

In the interior sections of Maunalua the dredging and development of Kuapa Pond and the construction of housing developments and golf courses have heavily impacted the lower elevations (Barrera 1986; Kelly 1984; Takemoto 1975). Remaining archaeology is found on the undeveloped ridges and higher valley portions (Jones 1996; Price-Beggarly and McNeill 1985; Folk et. al 1993). Common archaeological features found include modified rock shelters or overhangs (temporary habitation, activity areas, and burials) and agricultural features. However, previous archaeological assessments failed to encounter such sites within the current project area (Kelly et. al 1984; Walker et. al 1996).

Kelly, Kurashina, and Sinoto, in their archaeological assessment specific to the present project area, noted the extreme impact of dredging, grading, bull-dozing, and material stockpiling:

> "In the coastal plain, significant portions of the area bounded by the highway and coastline have been covered with recently introduced large lava boulders and soil used as fill. They have either buried or obscured as much as 40% of the original land surface of the coastal plain. Many of the introduced boulders are massive, and measure 1 m or more in maximum dimensions. These boulders can be found all the way up to the head of Kealakipapa Valley, where they are placed in several linear formations" (Kelly et. al 1984:9).

In the upper project area, rock stockpiling and mossrock picking were noted as ongoing activities that were destroying the archaeological remains, specifically McAllister's site 3 Kealakipapa Valley road (Kelly et. al 1984:76).

In summary, the previous archaeology of Maunalua documents a procession of changes which transformed the landscape. Traditional Hawaiian settlement consisted of

coastal settlement (house sites, *ko'a*, canoe sheds, and *heiau*) with agricultural features in the plains and valleys behind the coast. Natural rock shelters were utilized as temporary habitations or activity areas as well as internment places for the dead. *Heiau* were constructed in the interior. The large Kuapa fishpond was constructed and was another location of settlement. Trails connected these settlements.

Unfortunately, the small number of radiocarbon dates from Maunalua offer little towards settlement chronology. We do know that utilization of the ridge rock shelters was occurring by at least the 15th century (Jones 1996:180). Bayard's excavations at the Hawaii Kai rock shelter yielded three dates spanning AD 1330-1800 (Bayard 1965: 7-8, cited in Jones 1996:181). From these dates it is clear that settlement occurred by the 14th century, possibly earlier.

In the historic era traditional settlement gave way to ranching and cash-crop farming. More permanent coastal settlement was replaced in many areas with recurrent temporary habitation. Agricultural fields were maintained in some areas, and abandoned and incorporated into ranch lands in others. The 1946 tsunami was a major destructive force. In the 1960s and 1970s, the development of Hawaii Kai drastically changed large portions of Maunalua--including the current project area.

III. HISTORIC BACKGROUND

The history of Maunalua has been well documented by the work of Marion Kelly (Kelly et. al 1984) and Anne Takemoto (1975). The following is a brief overview of the mythological accounts, oral traditions, and history of Maunalua.

A. Mythological and Traditional Accounts

"Mauna-lua"--literally "two mountains" (Pukui et. al. 1981:149) probably refers to Koko Head and Koko Crater, the prominent volcano remnants that dominate the landscape. It seems only fitting that the mythology of a region named after its two prominent volcanos would contain references to the volcano goddess Pele. The mythical activities of Pele and her youngest sister Hi'iaka are the basis for many of the landmarks and place names in Maunalua (Takemoto 1975:6). According to tradition, Pele and her supernatural brothers and sisters came to Hawaii and began searching throughout the islands for a home. After investigating all of the islands, Pele eventually settled at Kilauea on the island of Hawai'i. Being the goddess of fire and volcanos, Pele was in constant strife with the god of forests and growing things, Kamapua'a. Maunalua, as a more arid region, would be the domain of Pele, and the adjacent windward region of Koolau would have been the domain of Kamapua'a (Kelly et. al 1984:23).

One mythical account of the inter-deity strife between Pele and Kamapua'a is tied to Koko crater. Pele was once attacked by Kamapua'a near Kalapana, Hawai'i. In order to save Pele from being raped, Pele's sister Hi'iaka sent her *kohe lele*, or flying vagina, as a lure to distract Kamapua'a and lead him away from the scene of the attack. The ploy worked and Kamapua'a followed the lure to Koko Crater, O'ahu, where it left an imprint, giving the volcano remnant its name, *Kohelepelepe*, literally, vagina labia minor. (Pukui and Elbert 1971:388; Pukui, Elbert, and Mookini 1974:115 cited in Kelly et. al 1984:23).

Another Maunalua location specifically tied to Pele mythology was a stone called *Kawa'aopele*, "Pele's Canoe". Originally located on the Honolulu side of the Davis ranch house (at Kaloko), this rock had the mark from Pele's canoe when she landed after the Pele migration came to Maunalua (Sterling and Summers 1978:260). The stone was washed away by the 1946 tsunami.

Pele battled and conquered Namaka-o-Kaha'i, another goddess. The Namaka-o-Kaha'i stone at Hanauma Bay was left by the defeated goddess--but the landmark has since disappeared. "The stone was covered with dregs of *awa*, a narcotic drink made by chewing roots and used in religious ceremonies, which gave the dark stone a florescent glow in the night" (Summers and Sterling 1962:46 cited in Takemoto 1975:6).

At the southern end of Kapali o Kamoa stands the large geologic formation known as Pele's Chair or Pele's Throne. Clearly visible on its promontory, from a distance this natural formation looks like a throne and is said to be one of the places from which Pele departed O'ahu for other islands (James 1991:42).

Pele's youngest sister Hi'iaka, plays further roles in Maunalua mythology. Before the 1946 tsunami, between Makapu'u Point and the Davis ranch house, were a set of stones. The story goes that the site of the "balancing stone" was made up of the lithified remains of a brother and sister from Maui who incurred the wrath of Hi'iaka. The woman was turned to stone first for wasting Hi'iaka's gift of an *uhu* fish. Her brother, in failing to reach his sister before the sun came up, was subsequently turned to stone (Sterling and Summers 1978:260).

Hi'iaka was also involved with two *kupua* (supernatural beings) associated with the Makapu'u area, Makapu'u and Malei. Makapu'u was a supernatural woman of frightening appearance because of her many glowing eyes [Makapu'u means literally 'hill beginning' or 'bulging eye' (Pukui et. al. 1981:142)]. In one account Hi'iaka was traveling to O'ahu in a canoe with companions. When the canoe passed Makapu'u Point and was nearing the shore at Waimanalo, the *kupua* Makapu'u was sighted on the beach by the men on board. Although Hi'iaka invited all to have a meal with her friend Makapu'u, the men were too frightened and only willing to land on the Kona side of Makapu'u Point where they left Hi'iaka as they hurried away. Hi'iaka had to walk to Makapu'u, who had prepared a meal for them (Sterling and Summers 1978:257-258). Legend has it that the *kupua* Makapu'u came from Kahiki with the famous priest Pa'ao (Sterling and Summers 1978:258, quoting Green 1926:21). Another legend identifies Makapu'u as one of two sisters that came to O'ahu with the Kaua'i chief, Moikeha when he came from Kahiki (Kelly et. al 1984:4).

Malei is another female *kupua* associated with the Makapu'u area. She "assumed various bodily forms" and was associated with the *uhu* fish (Sterling and Summers 1978:258). The Malei stone was originally placed in the Waimanalo Gap overlooking Makapu'u. According to one legend, the Malei stone was placed at Makapu'u by Ai'ai, the son of the famous fish god, Ku'ula (Kelly et. al 1984:4).

> "From Makapuu to Hanauma Bay, the *uhu* fish multiplied under her [Malei's] care. When she was established on this land all the chiefs and commoners went to give offerings of leis made of *lipoa* seaweed. They were placed on the stone Malei with prayers. The fisherman were lucky on these beaches and Malei was happy with her leis of lipoa seaweed . . . The stone Malei remained there for a long time at Makapuu. The fisherman of Waimanalo constantly ascended the cliff at Makapuu" (Sterling and Summers 1978:259).

According to legend the Malei stone stood over Makapu'u until it was removed by John Cummings and taken to his house during the time of King Kalakaua. With Cumming's death the stone was returned only to be removed or thrown into the sea by a Makapu'u lighthouse keeper who died not long after (Kelly et. al 1984:4-5). By the time of McAllister's visit (1930) only a cement foundation remnant was visible at the previous location of the Malei stone (McAllister 1933:58-59).

Legend credits Hi'iaka with giving the *kupua* Makapu'u and Malei encouragement and advice. The region of Kealakipapa Valley and Makapu'u lacked vegetable foods, which had to be supplied from adjacent Waimanalo. Hi'iaka encouraged the legendary women Malei and Makapu'u to cultivate the plain by planting sweet potatoes to relieve their hunger (Sterling and Summers 1978:257-258).

Maunalua was traditionally "an *ili* of the *ahupua'a* of Waimanalo and originally belonged to Ko'olaupoko district" (Sterling and Summers 1978:257). As a part of Ko'olaupoko, Maunalua surely had a trail that connected it with Waimanalo. The easiest communication between these two regions would have been through Kealakipapa Valley and down the Waimanalo Gap. Kealakipapa means literally "paved road", the road from Wawamalu to Makapu'u (Pukui et. al. 1981:102). This name implies that the Kealakipapa road (McAllister's site 3) could possibly be of prehistoric origin. Pukui (cited in Sterling and Summers 1978:260) believed the road was pre-European. Described as

Kealanuikipapa, Pukui states that "an *ali'i* who lived at Wawamalu had the road built. He made the people who annoyed him build the road".

Summary

Maunalua was associated through mythological accounts with the volcano goddess Pele and her sister Hi'iaka. The fishing off shore was famous for the *uhu* fish which were caught in abundance under the blessings of the *kupua* Malei. Although the agricultural resources of this drier region could not offer the diversity of nearby, well-watered Waimanalo, Maunalua was famous for its sweet potato cultivation, which cured the hunger of its populations. Maunalua was traditionally part of the district of Ko'olaupoko and Kealakipapa Valley was the communication route between the two regions. McAllister's site 3 road way, by Pukui's testimony, may be prehistoric in origin, built on the commands of an *ali'i* who lived at Wawamalu.

B. Early Historic Period

During the inter-island warfare that preceded Kamehameha's unification of the Hawaiian archipelago, Maunalua's natural harbors of Hanauma and Koko (Maunalua Bay) were considered vulnerable points in the defense of O'ahu. Alapai, the 18th century *ali'i nui* of the island of Hawai'i attempted an attack of O'ahu. After his warriors were driven back first at Waikiki, then at Waialae, and then at Koko, Alapai's troops were beaten a final time at Hanauma Bay (Kamakau, 1961:71 cited in Takemoto 1975:12). Following this successful defense of O'ahu, O'ahu's rulers maintained the rulership of their island for a number of years. However, in 1783, Kahekili, the King of Maui, defeated the forces of the ruler of O'ahu in a battle at Honolulu and took control of the island (Ibid.).

It was during the rule of Kahekili that the first Europeans landed and traded at Maunalua. On June 1st, 1786 the English ships *King George* and *Queen Charlotte*, under the commands of captains Nathaniel Portlock and George Dixon, respectively, anchored in Maunalua Bay. The next day in quest of water, Portlock and Dixon went ashore near Koko Head. They found a small, insufficient spring in the dry landscape 50 yards back from the coast--and were told that any substantial fresh water sources were a considerable distance westward. Traveling by boat northward from the first landing, Portlock and Dixon landed on a sand beach, where they were told that water sources were further to the west. Setting off on foot to the west along the beach with a guide, the landing party came up against a "salt water river" that stopped their progress along the coast. This salt water river is likely the waterway between Kuapa Fish Pond and Maunalua Bay (Takemoto 1975:13-15). Returning to the boats, the landing party experienced difficult passages through the reef and trouble with waves. The captains realized too great an effort would be required to water at this location. Water was eventually purchased around Diamond Head, in Honolulu (Ibid.).

Informants told Portlock that Honolulu was a more populous, more productive place where plenty of hogs and vegetables could be obtained. However, because Portlock already had his needed supply of water, the ships remained in Maunalua until June 5th (Ibid.). Portlock described the Maunalua landing site as follows: "the low land and vallies being in a high state of cultivation, and crowded with plantations of taro, sweet potatoes,

sugar cane, &c. interspersed with a great number of cocoa-nut trees" (Portlock 1968:74 cited in Takemoto 1975:14).

Portlock and Dixon returned in November of the same year to a less hospitable welcome. Until King Kahekili's official visit the ships were placed under tabu and no commerce or visitors to the ships were allowed. A priest warned Portlock that Kahekili was considering attacking the ships. Kahekili was dissuaded by a demonstration of the power of the ship's guns. Following Kahekili's arms lesson, Portlock observed the demolition of a *heiau* on the shore--the same structure he had watched being constructed before his encounter with Kahekili. It appeared that Kahekili's plans for the structure were abandoned once he appraised the fighting potential of Portlock and Dixon's ships (Takemoto 1975:15).

Kahekili died in 1794, splitting his kingdom between his sons Kalanikupule and Kaeo. Kalanikupule briefly ruled O'ahu and Moloka'i before being defeated by Kamehameha in 1795 at the battle of Nuuanu. Following this conquest Kamehameha followed custom and made a tour of the island he had conquered. Concerned that the productivity of the land be restored rapidly after the disruption of war, Kamehameha is said to have worked on several fishponds during his tour, including the Kuapa Fishpond at Maunalua. Kamehameha did this to demonstrate to his people the importance of hard work and productivity (Takemoto 1975:16). One account cited in Handy and Handy (1972:485) describes the route that Kamehameha took in his work tour of the Oahu, ". . . Kamehameha and his followers left Kailua and proceeded on to Waimanalo. From Waimanalo they went to Makapu'u and from there to Honolulu".

Kamehameha gave the *'ili* of Maunalua to his faithful warrior Kuihelani. However Kuihelani lost his lands due to the indiscretions of his wife and Maunalua reverted to Kamehameha's control (Takemoto 1975:19). Kamehameha next gave Maunalua to his father-in-law Ke'eamoku (father of Ka'ahumanu). Ke'eamoku died in an epidemic (thought to be cholera) that passed through Maunalua in 1804 (Ibid.). The population of Maunalua including the eastern coastal area of O'ahu, may have been reduced drastically during this epidemic (Schmitt 1968:24 cited in Kelly et. al 1984:25). Following Ke'eamoku's death the ownership of Maunalua passed on to Ka'ahumanu, his daughter. It was during this period that the land ownership of Maunalua became tied to the title of premier. Ka'ahumanu passed the land ownership and title of premier to Kinau, a daughter of Kamehameha. Kinau in turn passed on both the land of Maunalua and the title of premier to her daughter, Victoria Kamamalu (Takemoto 1975:20). It was Victoria Kamamalu who secured the land title of the *'ili* of Maunalua during the Mahele.

John Ii, a member of Kamehameha's court, visited Maunalua sometime around 1810. Traveling aboard the ship *Apuakehau* from Honolulu to the island of Hawaii, Ii stopped at Kawaihoa--the landing at Maunalua Bay that was a common stop-over point for inter-island and circle-island navigation at this time (Ii 1983:108). Ii also discusses the old trails systems extant on O'ahu "about" the year 1810. Regarding the route to southeast O'ahu from Honolulu Ii notes several trails that met at "the sand and go along Keahia and so on to Maunalua, to the sea of Koko, to Makapuu, and so on" (Ii 1983:94). Undoubtedly the route ran through Maunalua, through Kealakipapa Valley, to Waimanalo via the cliff at the Waimanalo Gap. There are several accounts of early missionaries taking this route in their tours of O'ahu.

Gilbert Mathison most likely followed this same route during his excursion around the island of O'ahu in 1821. Within Maunalua he noted the large salt water lake (Kuapa Fishpond) around which he saw scattered approximately 100 huts. The people of the area were described as fisherman (Takemoto 1975:17).

In July and August of 1826 Ka'ahumanu made a tour of the island of Oahu to talk with her subjects and preach the new Christian religion. In her company was the missionary Hiram Bingham, along with 200-300 other people. Bingham described the journey as follows:

> "Availing myself of the facilities thus afforded for our work, I made the tour with them [Ka'ahumanu's entourage], employing a month to good advantage, giving my attention chiefly to preaching, and the care and establishment of schools, and reading the Scriptures . . . Several horses, two wagons, and two canoes, constituted the principal accommodations, as vehicles for parts of the company, much of the way. Most of the company travelled on foot, some making the whole circuit, of about one hundred and thirty miles, and some but smaller portions of it, as we passed round from Honolulu to the east, north, west, and south, then to the east again . . . We spent a Sabbath at Kaneohe, and passed through Palikoolau . . . "
> (Bingham 1847:294-295)

From this account it is clear that Ka'ahumanu's party passed through Maunalua and continued on through Waimanalo to reach Kane'ohe, where, after spending the Sabbath, they crossed the Ko'olau Mountains via the Nu'uanu Pali. Unfortunately, no mention was made of the settlement and population of Maunalua, or the Kealakipapa Road, although the party most certainly observed them. This testimony does indicate that this route around the southeast end of O'ahu was a commonly traveled one.

Levi Chamberlain made two tours of O'ahu (1826 and 1828) to inspect and bolster the newly founded mission schools. On Chamberlain's first trip around the island, he approached the settlement at Kuapa Fishpond (called Keawaawa) from Makapu'u. Chamberlain did address 30 people at what must have been a sizeable village at Kuapa Fishpond (Handy and Handy 1972:483). Chamberlain suggests that during his visit much of the population was away cutting sandalwood, although Maunalua had little in the way of sandalwood resources (Takemoto 1975:17). On his second trip, Chamberlain approached Maunalua from Waialae. His descriptions indicate Maunalua was once populous. However, based on the decrease in student enrollment in the mission school over a four year period, the community was undergoing steady depopulation (Takemoto 1975:17-18).

During Chamberlain's first tour of O'ahu he described the road way or path at Kealakipapa leading down from the Waimanalo Gap (McAllister's site 3):

> "(Leaving Makapu'u to cross Maunalua) After descending gradually some distance over a raised walk formed of rocks and pieces of lava brought together for the natives the road took a turn in a west-south-west direction giving me the sea on the left and a ridge of barren hills on the right . . ."
> (Levi Chamberlain, "Trip around Oahu in 1826" cited in Sterling and Summers 1978:260).

Once the sandlewood gave out, economic activities of Hawaiian settlements focused on the cultivation of crops that could be exchanged with the foreign sailing vessels--in particular those of the whaling industry which had its boom period from 1820-1850 (Jones

1996:20; Takemoto 1975:18). Maunalua was no exception. At least two settlements were active as anchorage and provisioning sites for foreign vessels in the early 19th century. Wawamalu village was located at Queen's beach and exploited the famous sweet potato agricultural land of Kealakipapa Valley for cash/barter crops. At Kuapa Fishpond, Keawaawa village also raised trade crops for the whaling and trade vessels that anchored off Maunalua for provisions.

> "According to the last surviving *kamaaina* of Maunalua, sweet potatoes were grown in the small valleys, such as Kamilonui, as well as on the coastal plain. The plain below Kamiloiki and Kealakipapa was known as Ke-kula-o-Kamauwai. This was the famous potato-planting place from which came the potatoes traded to ships that anchored off Hahaione in whaling days. The village at this place, traces of which may still be seem, was called Wawamalu" (Handy "Hawaiian Planter" Vol. I, p. 155 cited in Sterling and Summers 1978:257).

Another similar village was located in Waimanalo, at the current site of Sea Life Park (see Jackson's 1884 map, Figure 11). Referred to as Kaupo, its proper name according to an official Bishop Estate map was Koanapou (McAllister 1933:193). Kelly (et. al 1984:25) suggests this village shared the cultivation lands of Kealakipapa Valley and coastal plain below with the inhabitants of Wawamalu, Kaho'ohaihai, and Ka'ili'ili. Certainly the trail up the Makapu'u cliff at the Waimanalo gap would have provided easy access to these agricultural lands. When McAllister visited the ruins Kaupo/Koanapou in 1930 his informants said the village had been built during the small pox epidemic of 1853 (McAllister 1933:193). Kelly suggests, because of the sites excellent location and resources for a traditional Hawaiian village, that the village was abandoned during the early part of the 19th century and only re-inhabited in 1853 during the small pox epidemic (Kelly et. al 1984:25).

In the early historic period, the victualing trade was the life's blood for many traditional Hawaiian settlements, including those at Maunalua. It maintained resident populations in areas that would have otherwise become depopulated under the dual effects of epidemics and the relocation of inhabitants to growing towns such as Honolulu (a fate that seems to have befallen Kaupo village). When the victualing trade gave out--settlement in these regions declined. By the early 1850s the hey-day of whaling was passing. In 1852 the Hawaiian government passed legislation requiring all foreign vessels to call at Honolulu where they could be taxed. This further reduced the number of ships that pulled in at smaller landing sites such as those at Maunalua (Jones 1996:21; Takemoto 1975:20). "It is clear that Maunalua lost much of its population and economic independence as an agricultural *ili* with the end of the whaling ships" (Takemoto 1975:25).

The depopulation of Maunalua by the mid-18th century preceded and facilitated the replacement of traditional Hawaiian land use with ranching and commercial fishing.

C. Mid-1800s to 1900

After the mid-1800s, Maunalua became predominantly ranch land for the next 80 years. Land ownership and land use rights were complicated through much of this period by numerous leases, frequent litigation, and the frequent deaths of land holders and/or lease-holders (Takemoto 1975:27).

Prior to the Mahele, the land of Maunalua was part of the lands held by the premier. Ka'ahumanu had passed the land and title to Kinau, who had in turn passed them on to Victoria Kamamalu (Takemoto 1975:20). On April 7, 1854 Kamamalu was granted Land Commission Award 7713, the land title to Maunalua. No *kuleana* land grants were awarded within this overall land award--another indication that population may have declined drastically by the time of the Mahele.

In 1856 all of Maunalua, except for the Kuapa Fishpond, was leased to William Webster--the government employee and land surveyor who had surveyed the region five years earlier and produced the regions first map (see Figure 10). (Interestingly, this map shows the Kealakipapa Valley road extending from Waimanalo Gap, down the valley to the coastal flat, to nearly the mouth of Kalama Valley.) Webster used the land for ranching, adding it to the other lease hold land he used for ranching in Waimanalo. When Webster died in 1864, the remainder of his Maunalua lease was taken over by Manuel Paiko, who was leasing the adjacent lands at Kuliouou. Maunalua continued to be used as ranch land.

Victoria Kamamalu mortgaged her lands in Maunalua to Charles Bishop in order to pay off accumulated debts. When Kamamalu died in 1866 it fell to her father, Kekuanaoa, to pay off the debts and the mortgage in order to be awarded the title to Maunalua (Jones 1986:22-23; Takemoto 1975:21). With the death of Kekuanaoa, the land of Maunalua passed into the hands of Lot Kamehameha V. When Lot died without a will, the probate court decided that his half sister, Ruth Keelikolani, would inherit his entire land holdings. When Ruth died in 1883 Maunalua was passed down to Bernice Pauahi Bishop. Bernice Pauahi Bishop was the last surviving Kamehameha and as a result inherited all of the Kamehameha lands, becoming the largest land-holder in the Kingdom of Hawaii. When Bernice Pauahi Bishop died in 1884 her husband Charles Bishop, followed her will and set up the Bishop Estate Trust, of which Maunalua became a part (Takemoto 1975:21-23). Maunalua continued to be used as ranch land throughout this period.

It was at this time that a second map of Maunalua was completed by Geo. E. Gresley Jackson (1884)--see Figure 11. This map shows roads circling Kuapa Fishpond. A road extends between Kamehame Ridge and Koko crater, crosses the coastal flat of Wawamalu, climbs Kealakipapa Valley to Waimanalo Gap and descends the gap into Waimanalo. The structural remains of Kaupo Village are visible makai of this roadway in Waimanalo. No other indications of habitation are made on the map--suggesting that by 1884 habitation in eastern Maunalua was slight to non-existent. (See Figure 11 for the eastern portion of Jackson's Map, which shows eastern Maunalua and Waimanalo.)

The fishing rights to the Kuapa Fishpond and Maunalua's offshore fishing grounds were important resources that were leased out to various parties from the time Victoria Kamamalu obtained the land title to Maunalua. The Kuapa Fishpond was leased in 1856 at a high yearly sum for the time, indicating the value placed on fishing resources. The offshore fishing rights were leased and sold to various individuals until 1900 when Territorial and United States legislation began deconstructing the legality of the

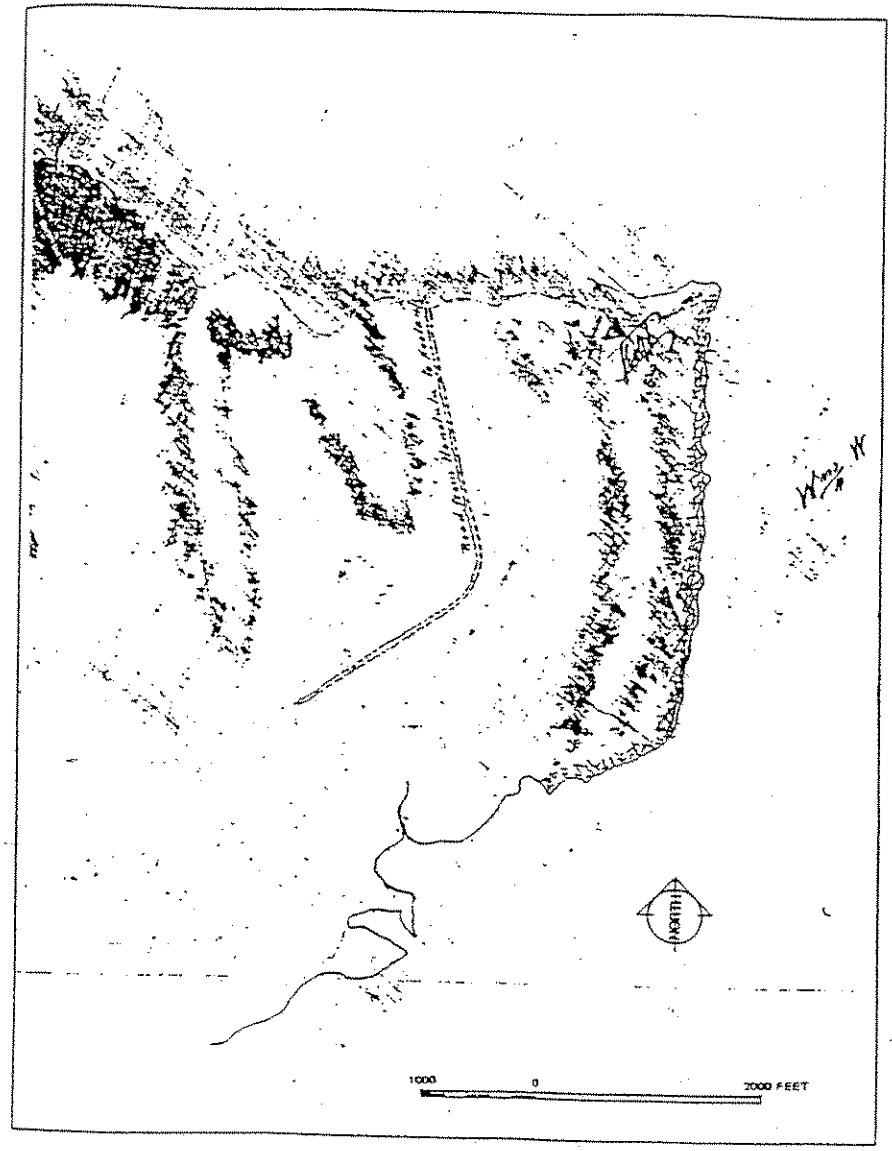


Figure 10 Webster's 1851 map of Kealakipapa Valley and Makapu'u showing "King's Road" (McAllister site 3).

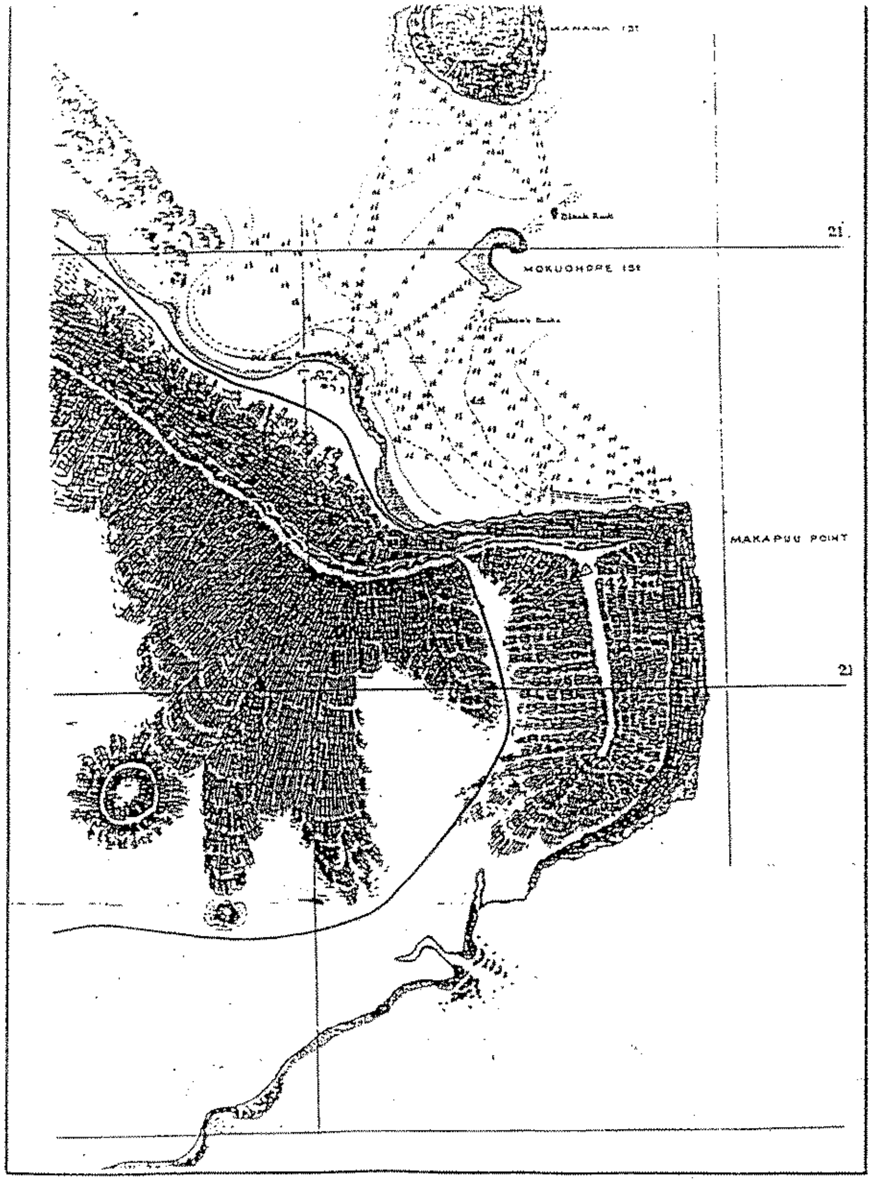


Figure 11 Portion of Jackson's 1884 map showing Kealakipapa Valley and Makapu'u, as well as McAllister's site 3 road.

traditional idea of ownership of offshore fishing rights. It is clear from the high lease rates for the time period that the fishing resources of Mauanlua were productive and highly valued (Takemoto 1975:21-27).

The population of Maunalua continued to decline during this period. Tax records show that in 1855 there were 38 households with 98 people living in Maunalua. This fairly large population owned 68 houses as well as horses, mules and dogs. In 1860 Maunalua had lost over half its population and held only 16 households. By 1870 there were only 6 households and population bottomed out in 1880 with only 4 households. This depopulation is undoubtedly the result, at least in part, of resettlement of inhabitants in more economically viable areas. These decreases in the number of households were accompanied by reductions in the numbers of horses, mules, and dogs--indicating a relatively impoverished population compared to the 1855 inhabitants of Maunalua. In 1900 population had risen once again, however it is clear that traditional settlement and land use had been largely, if not entirely, replaced by ranching and commercial fishing activities (Takemoto 1975:24-25). Takemoto states:

> "By 1900, Maunalua Ranch and Yit Lee Company, who owned a big fishing complex, employed most of the inhabitants. Maunalua Ranch had over 1500 head of cattle, ten oxen, sixty-four horses, thirteen mules and six pigs roaming throughout Maunalua. Five Chinese families were working for the Damons [who held the lease for Maunalua at the time], probably as ranch hands. Five other Chinese families worked for Yit Lee. The eight Hawaiian families on the land, including one blind man, were truck farmers of some sort since all but two owned carts used for bringing goods to Honolulu . . . Thus by the turn of the century most families in the *ili* were ranch hands, fishermen, or truck farmers living a relatively quiet life in an area which would be considered the country (1975:25)."

Maunalua from 1850 to 1900 witnessed the decline of traditional Hawaiian settlement, land use, and population and the rise of commercial ranching and fishing. Although no *Kuleana* land grants were awarded within Maunalua during the Mahele--the 1855 tax records indicate that it was populated and appeared to enjoy a degree of prosperity. Maunalua's prosperity and population drastically declined until 1900, when tax records show an upturn of both based on commercial fishing and ranching.

D. Early 1900s To The Present

Maunalua became more closely tied to the modern world after 1900. In 1906 the luxury steamer *Manchuria* ran aground off Waimanalo. The result of the outcry that followed was the construction, in 1909, of the Makapu'u lighthouse--which then and now contains the largest magnifying lens of all U. S. lighthouses (Dean 1991:Part I4). In 1914, the Marconi Wireless Telegraph Company of America built a receiving station on the slopes of Koko Head on land that was leased from the Bishop Estate for 50 years. The station was built to receive messages 24-hours a day from San Francisco and was billed as the most powerful wireless station in the world. The station linked the Hawaiian islands with the mainland and Asia on a 24-hour basis. Early in the 1920s the Marconi station was taken over by the Radio Corporation of America and was used for transmission

(Takemoto 1975:28).

Agriculture, in the form of truck farming and an agricultural school, increased in Maunalua after the turn of the century. The Kamehameha School for boys ran an agricultural farm in Hahaione Valley with 45 acres for vegetables and 200 acres for livestock (Jones 1996:27). Truck farmers increased in number in the area as well, providing hogs, flowers, lettuce and other vegetables for the growing population of Honolulu. Much of the area around Kuapa Fishpond was occupied by truck farmers by the 1930s and this type of farming would expand (Kelly et. al 1984:47). By 1959 this truck farming community of over 170 families was producing 60 percent of Oahu's hogs and a similar percentage of flowers and lettuce (Takemoto 1975:28).

Maunalua Ranch controlled most of the land of Maunalua outside of the Kuapa Pond. From its inception in 1900 until it closed in 1926 over 1500 cattle made up the ranch's stock (Jones 1996:23). In 1920 the Maunalua Ranch sublet parcels to the Honolulu Honey Company, Ltd., which had 8 apiaries. The ranch land also had charcoal makers harvesting *kiawe* during this time (Kelly et. al 1984:47).

The Maunalua Ranch Co. closed in 1926 and their sublettors were given direct leases from the land owner, Bishop Estate. Alan Davis and others were given a ranching lease in 1932. They started the Wawamalu Ranch. The Davis home and swimming pool were constructed near the shore at Ka'ili'ili, while various ranch infrastructure, such as corrals, wall, and water tanks was situated at Kaloko (Kelly et. al 1984:56).

> "The Alan Davis ranch house at Kaloko was the easternmost private residence on O'ahu during the 1930s and 1940s, until its destruction in the 1946 tsunami. Ranching didn't prove profitable enough, so the subleasing of Maunalua land for truck and flower farms, chicken farms, and piggeries was expanded. Pig farmers and other were pushed out of the Hawaii Kai area and moved over the hill back of Koko Crater and into Kalama and Wawamalu Valleys. As farmers were evicted from other communities, such as when Wai'alae-Kamala, Wailupe, and Niu were urbanized, more of them moved to Maunalua with short-term leases" (Kelly et. al 1984:56).

The construction of Kalaniana'ole Highway through Maunalua was finally completed in 1932, when the last stretch of road from Waimanalo to Wawamalu was completed. The bridge at Wawamalu was constructed in 1931. The coastal portions of this alignment of Kalaniana'ole Highway from Sandy Beach to Kaloko were washed out by the 1946 tsunami. The highway was reconstructed slightly further inland, with a new bridge at Wawamalu, between 1946 and 1948.

Previous to the completion of Kalaniana'ole Highway through Maunalua, there were unimproved roads that provided access to this easternmost part of O'ahu. The USGS Makapu'u quad map from the survey of 1908-1913 (1922) show unimproved roads going both *makai* and *mauka* of the Kupua Fishpond (see Figure 12). The *makai* road forked, providing access to Hanauma Bay and the *makai* portion of Koko Crater. The *mauka* road passes Hahaione, runs between Kamehame ridge and Koko crater and provides access to the Sandy Beach/Blow Hole area, the Wawamalu/Kaho'ohaihai area, and to the lighthouse at Makapu'u. These roads offered access to the primary resources/destinations within Maunalua at this time period (just after the turn of the century). Roads to the coast undoubtedly were used for fishing and other marine exploitation. The roads also provided access for ranching, facilitating the construction and

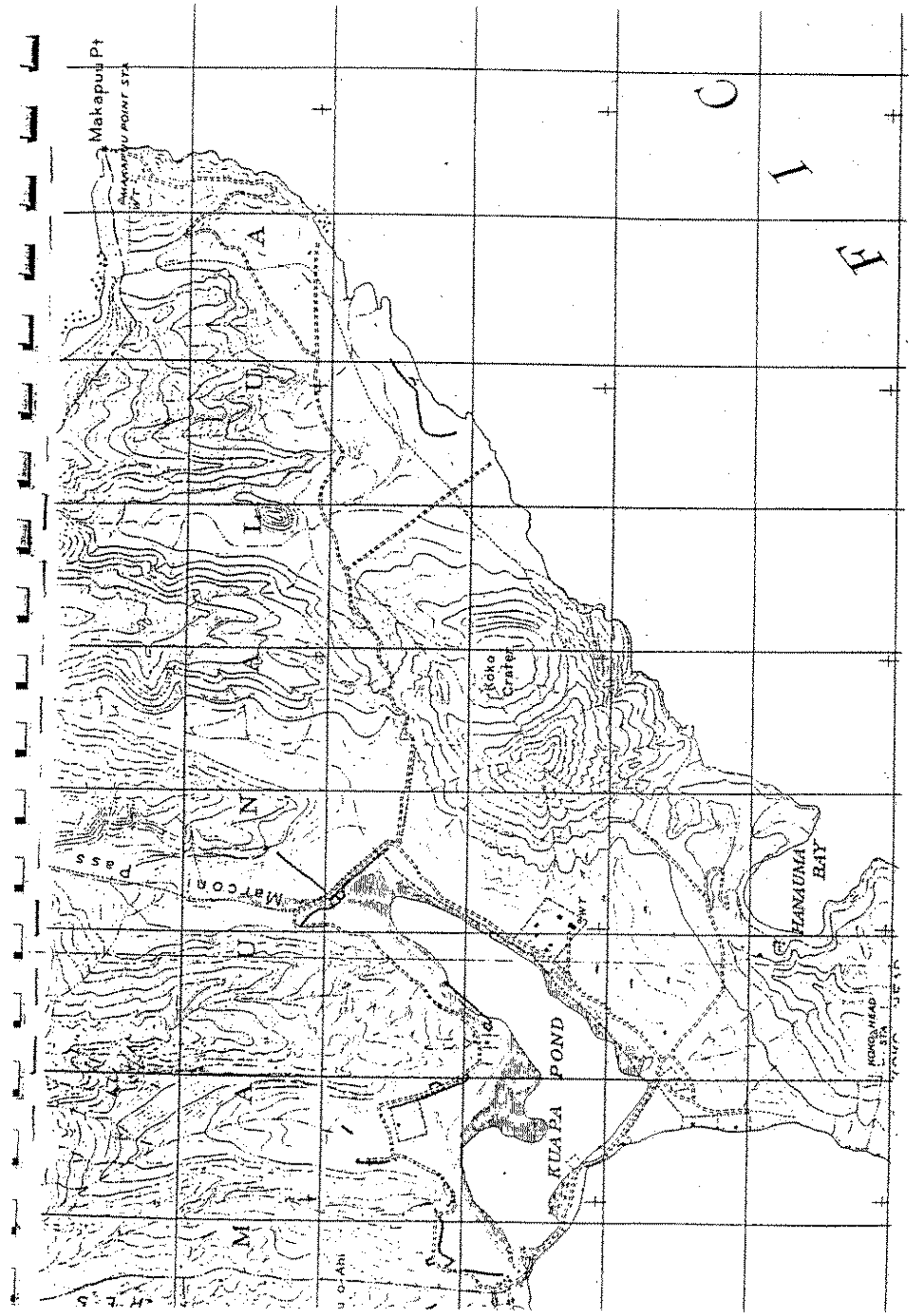


Figure 12 Portion of U.S.G.S. Map, Makapu'u Quad., from the Survey of 1908-1913, Printed in 1922.

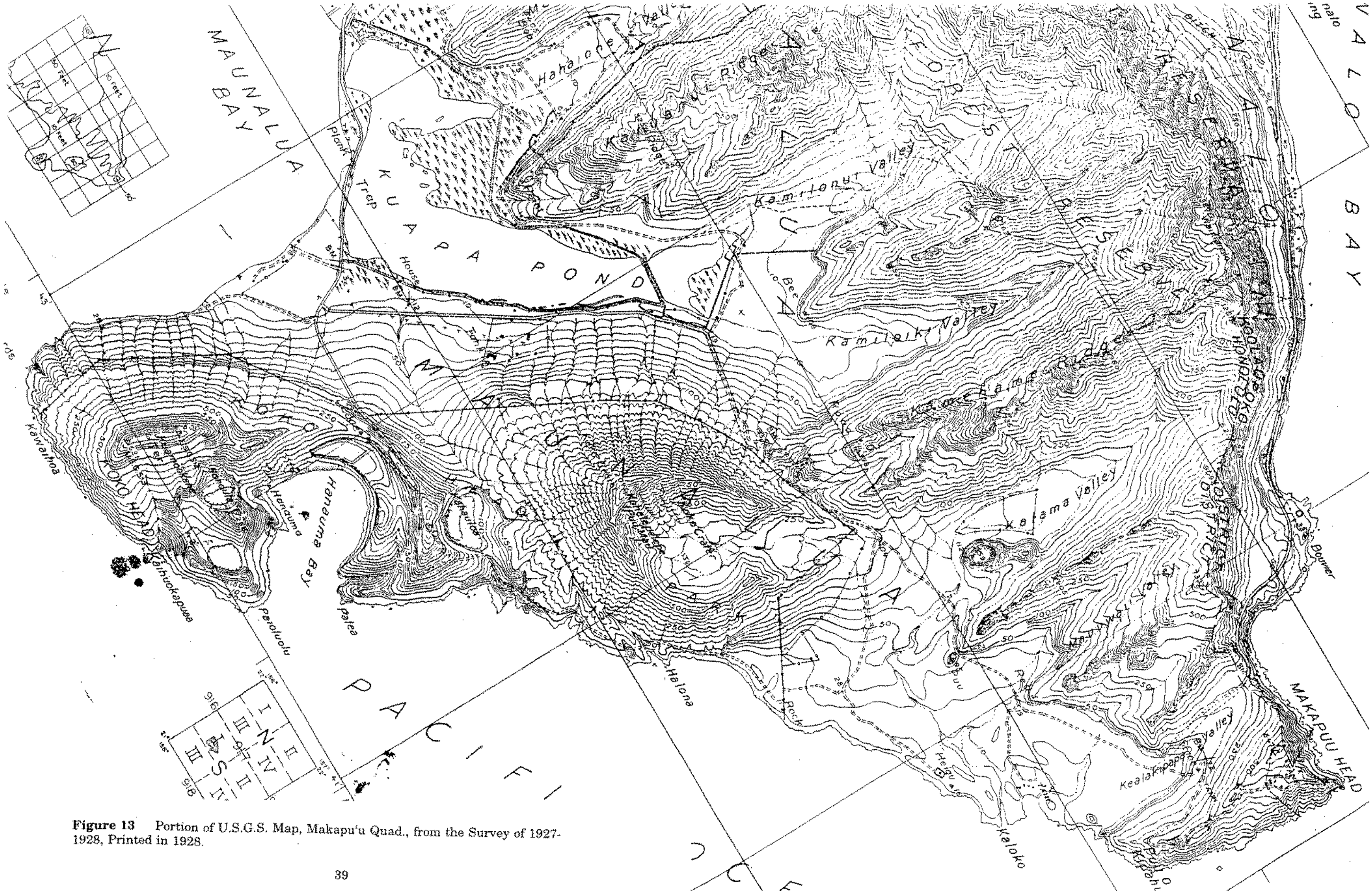


Figure 13 Portion of U.S.G.S. Map, Makapu'u Quad., from the Survey of 1927-1928, Printed in 1928.

maintenance of needed infrastructure such as water tanks and fences. Finally, the lighthouse access road was important for communication with and resupply of the lighthouse caretaker and his family living out on Makapu'u Head.

Also visible on this map is a trail that runs from Waimanalo Gap, through Kealakipapa Valley, across the coastal plain to pass *makai* of Koko Crater where it joined up with unimproved roads. Until it turns *makai* of Koko Crater, this trail has the same alignment of the trail/road marked on both Webster's 1851 and Jackson's 1884 maps. This trail likely utilized the Kealakipapa Valley and Waimanalo Gap portions of McAllister's site 3 (paved roadway).

The USGS Makapu'u Quad. from the survey of 1927-1928 (1928) shows how access had changed in Maunalua between the years 1913 and 1928, see Figure 13. Paved roads extended to Hanauma Bay. The unimproved road from Hanauma Bay had been extended along the coastal trail, *makai* of Koko crater, to the Sandy Beach area. This road would be paved over to complete the southeastern portion of Kalaniana'ole Highway in only a few years. The unimproved access to the Sandy Beach/Blow Hole area had an extension, which ran parallel to the coast to the spot marked "*Heiau*" on the map at Wawamalu. This large rectangular enclosure is undoubtedly the same structure that McAllister recorded as site 22 at a region called Kaiwi and tentatively labeled "*Heiau* Koaia" based on informants testimony (McAllister 1933: 63). The unimproved road to Kaloko/Ka'ili'ili shows the ranching infrastructure that would soon be utilized as part of the Wawamalu Ranch, under Alan Davis. The lighthouse access road had not changed its alignment.

In Kealakipapa valley, the trail (McAllister's site 3, also plotted on Webster's (1851) and Jackson's 1884) maps) marked on the 1908-1913 survey map, was still plotted. Interestingly, whereas on the 1908-1913 survey the trail was plotted extending across the coastal flat to Koko Crater, on the 1927-28 survey the trail terminates at the lighthouse access road. This corroborates McAllister's description of the trail/road (made two years later) which stated that the site 3 trail/road was no longer visible below the light house access road (McAllister 1933:59). Also in Kealakipapa Valley, the alignment of the soon to be constructed final section of Kalaniana'ole Highway was plotted. This section descended Kealakipapa Valley from the already completed section of the highway that ascended Waimanalo Gap from Waimanalo. A more detailed plan of the Kealakipapa Valley extension of Kalaniana'ole Highway under construction from 1930-32 clearly shows the new highway's alignment in relation to the old road, see Figure 14 (Highway Plan 2/20/31, Note Book 522, State Highway Division, Department of Transportation).

In 1942 the Federal Aviation Administration receiver station was constructed in Wawamalu at the current location of the *makai* portions of the Hawaii Kai golf course. This facility allowed point to point communication with stations as far away as Samoa, Guam, and Tokyo. Known as the "Kaloko" facility it was moved to Moloka'i in 1962 (Kelly et. al 1984:56).

The tsunami of 1946 was one of many that undoubtedly effected the coastal sections of Maunalua to varying degrees. Previous to 1946, tsunami of similar scale occurred in 1837, April 2, 1868, and 1877. These tsunami are among the nearly 40 tsunami that were recorded to hit Hawaii, with effects ranging from none to severe, between 1819 and 1946 (Shepard et. al 1950:400-1). Tsunami are known to scour coastlines by both washing material landward with the inrushing waves as well as washing material seaward with the retreating waves. Coastal vegetation, coastline formation, and the force of the wave are some of the factors which influence the destructive force of tsunami (Shepard et. al 1950:460-2). At Queen's Beach the 1946

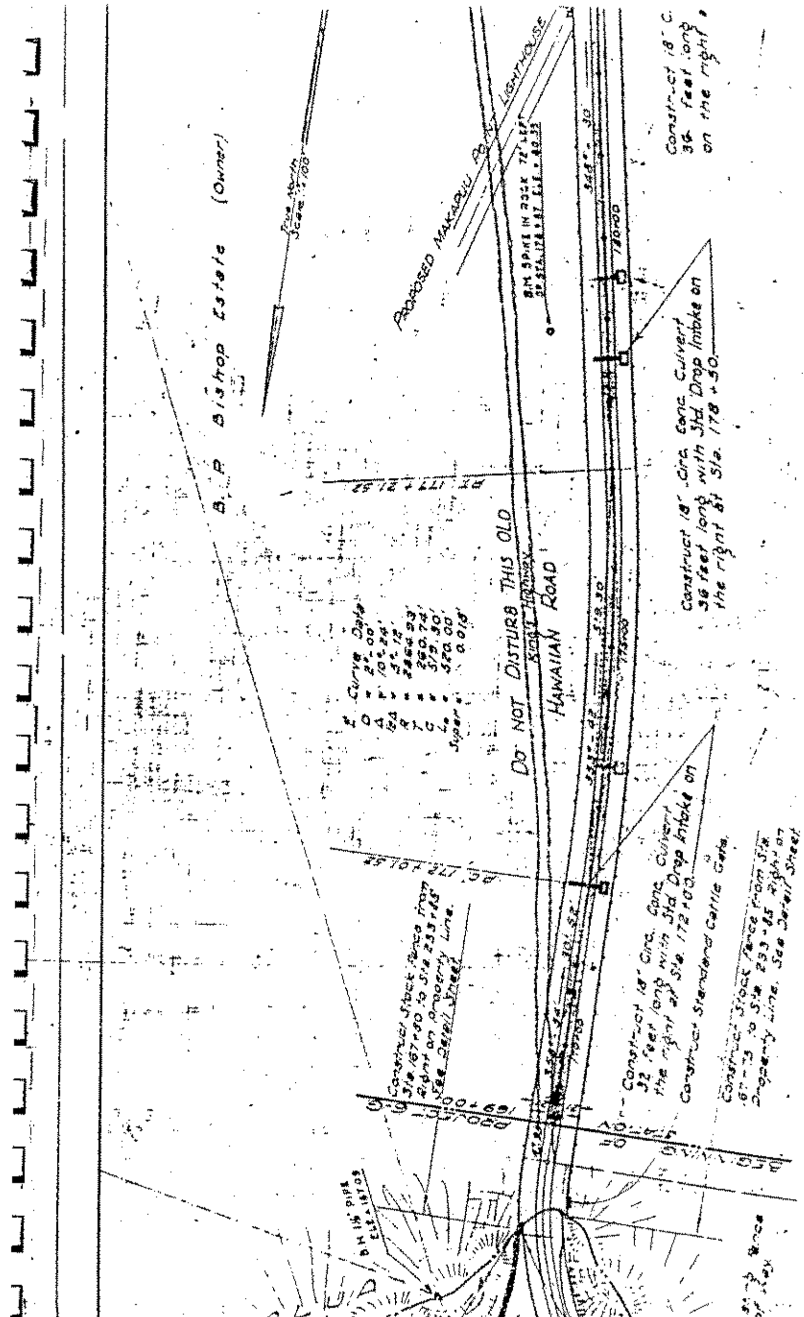


Figure 14 Portion of the plan for extending Kalaniana'ole Highway up Kealakipapa Valley to Makapu'u Lookout. The Hawaiian road is McAllister's site No. 3. Highway Plan 2/20/31, Note Book 522.

tsunami consisted of as many as 5 waves, which appeared to increase in destructive force. The following are descriptions of the destructive force of the tsunami in the vicinity of Queen's Beach--included are descriptions of the destruction of the Wawamalu Ranch buildings.

> "On the north side of Makapuu Head the highwater mark was 37 feet above normal, the highest for Oahu . . . At Kaloko, a mile southwest of Makapuu Point, the water rose only 15 feet but demolished a group of houses just inland from the beach. In spite of the high seas which are characteristic of this area, the water came in rather gently, at least in the first two waves. Mr. A. S. Davis, whose home there was destroyed, waded to his armpits ahead of the advancing second wave, holding a picture above his head. This suggests that no great turbulence existed in this wave. The wreckage indicates that later waves probably were more violent. The houses were swept away and left as a heap of debris against a row of trees 500 feet inland. Southwest toward Koko Head the heights reached by the waves were greater, attaining a height of 31 feet near the famous Blow Hole. Much of the road was washed out in the area. The steep sand beach was greatly eroded, and a series of steep cusps with truncated ends was left" (Shepard et. al 1950:423).

> "On April 1, 1946, one of the most destructive tsunami ever to hit the Hawaiian Islands destroyed the Wawamalu ranchhouse and several other neighboring buildings. On that morning, fortunately, all members of the Davis family were awake, preparing to leave for school or work. Mr. Davis had just finished shaving when he heard water rustling against the sisal fence in his yard. He realized immediately that something was wrong and suspected a tsunami. His suspicions proved to be correct. The *paniolo* on the ranch drove his wife and baby up to Makapu'u Gap, and Mr. Davis followed in another car with his young daughter, Nancy. Then, between the third and fourth waves, Mr. Davis returned alone to his home, to make sure that everyone had vacated the area, to try and save the family's pets, and to salvage his personal belongings. The interior of the house was already a shambles and, as he was picking his way through the interior, the next wave struck. He was so startled that he grabbed the object nearest him, a painting hanging on the wall, and ran for the road, wading knee-deep through turbulent water. Soon after this wave receded, Mr. Davis once again reached the safety of the gap. He and his family watched the next wave totally demolish their house and roll up almost the entire length of Kealakipapa Valley. Fearing that the succeeding waves might wash up the entire length of the valley and spill through the gap into Makapu'u Beach, the whole group drove up to the lighthouse at the very top of Makapu'u Bluff" (Clark 1977:23).

With the devastating power to uproot portions of the paved road between Sandy Beach and Wawamalu, to destroy and push inland 500 feet the house and outbuildings of Wawamalu Ranch, and to inundate portions of Kealakipapa Valley, it is clear that the 1946 tsunami had sufficient force to damage and even obliterate the surface and

subsurface archaeological remains of the Queen's Beach area.

Between 1932 and 1946, as has been noted earlier, ranching was less and less economically viable at Wawamalu Ranch. Increasingly ranch land was sublet to truck farmers, who were being displaced by the expansion eastward of Honolulu and its suburbs. This trend continued until 1959 when fewer leases were awarded and old leases were not renewed.

In 1959 the Hawaii Kai Development Corporation, a subsidiary of Kaiser Industries, received the development rights for Bishop Estate property in Maunalua and the development of the planned community of Hawaii Kai began (Kelly et. al 1984:vii). Kuapa Fishpond was dredged to a consistent depth of six feet and dredge material was used to construct and reclaim land masses in the former swampy landscape. Large portions of former fishpond and ranch land were graded and prepared for construction of housing developments, golf courses, and shopping centers. In the area of Queen's Beach and the current project area three separate development areas were distinguished (Kelly et. al 1984:59).

Kelly (et. al 1984) summarized the development plans for the three Queen's Beach areas as follows. The first area was at Kaloko--Napa'ia--Ka'ili'ili area. The architect's drawings projected substantial changes in the coastline, with dredging and filling and the excavation of waterways, creation of artificial islands and beaches surrounding three large hotel complexes. The second area was at Kaho'ohaihai, extending partly into Kealakipapa Valley. A single large hotel was to be constructed adjacent to a boat harbor lagoon, that was to be protected by a breakwater. The third area of development was to have been at the Waimanalo Gap. Taking advantage of the locations commanding view over Makapu'u Bay, a restaurant and commercial center was planned for construction (Kelly et. al 1984:60-61).

These were the initial plans, the following is a summary of the permits and actual land alterations that occurred within the current project area between 1959 and 1984. In August 1960 permit number 589 was issued to the Queen's Beach developers for "Construction of a harbor in the Queen's Beach Area, a 250 ft. breakwater, and minor dredging" (Army Corps of Engineers files cited in Kelly et. al 1984:59). In September of 1961, permission from the Army Corps of Engineers for a new alignment to the breakwater "now under construction" with armor rock (Kelly et. al 1984:59).

Roger James was the project supervisor for Hawaii Kai Development Corporation's work at Queen's Beach between 1959 and 1964. In an interview with Douglas Meller (Meller Ms. cited in Kelly et. al 1984:70-71) James indicated that he had removed the *kiawe* trees from the area. While the dredging was underway for the breakwater, offshore sand was stockpiled on the south side of Kaho'ohaihai Inlet, and also *mauka* of Ka'ili'ili Bay. The *mauka* portions of Ka'ili'ili Bay were bulldozed and the start of a moat connecting Ka'ili'ili Bay to Kaho'ohaihai Inlet was also bulldozed. This Bay was to be 4 to 5 feet deep at 0-tide, however, the coastal flat turned out to be hard "blue rock". James said Henry Kaiser stopped the project because of this difficulty with the excavation. James told Meller that Kaloko Inlet was dredged and cleaned out--both deepened and widened with shaped charges and dragline. Dredge material was stockpiled around Kaloko Inlet. On the coast James said that a few large boulders may have been moved by bulldozers, but otherwise the shoreline between Ka'ili'ili Bay and Kaho'ohaihai Inlet was not altered. James also told Meller that a road was cut from the light house access road to Kapali o Kamoa and that a rock outcrop was knocked off Kapali o Kamoa with a bulldozer.

Between 1972 and 1975 the Kaiser-Aetna Corporation (a successor to the Hawaii Kai Development Corporation) stockpiled "armor rock" and dirt on the coastal plain of the current project area (Kelly et. al 1984:viii). The development of Hawaii Kai necessitated road building, leveling of residential lots and water reservoir sites, and the excavation and re-channeling of drainage channels. This activity created thousands of tons of large boulders ("armor rock") which had to be removed and stockpiled. On the first of August 1973 grading permit No. 6075 was issued for grading at Queen's Beach. Good for one year it was renewed in 1974 but not since. On the fifth of December 1975 stockpiling permit number 172 was issued. It has been renewed yearly until at least 1984. Some of the stockpiled armor rock was used in the construction of the reef runway at Honolulu International Airport, however most has remained at Queen's Beach (Kelly et. al 1984:69-70). Also within this time period a dirt drainage channel was excavated across the coastal flat to drain storm waters from adjacent Hawaii Kai Golf Course to Ka'ili'ili Bay (Kelly et. al 1984:viii).

E. Survey Of Aerial Photographs

Aerial photographs are powerful documents in the study of land-use change and land alteration over time. The following 8 aerial photographs were obtained from both the Bishop Museum Archives and R. M. Towill Corporation. They clearly demonstrate the landscape change, caused primarily by dredging and material stockpiling, that has occurred within the project area. The photographs will be discussed in chronological order. The photographs (Figures 15 through 22) are located together at the end of this section of the report.

Aerial view of Hawaiian village ruins at Makapuu Point, Oahu, Dec. 13, 1925.

Although outside the current project area, this photograph is an important example of the types of archaeological features that were once extant within the project area. Taken in 1925, only five years before McAllister made his visit to this site (as well as the archaeological sites within the project area), this photograph was taken of the village ruins at Kaupo/Koanapou--at the site of present day Sea Life Park and Makapu'u Beach Park. Clearly visible are large rectangular enclosures, smaller irregular enclosures, C-shape enclosures, and wandering walls enclosing irregularly shaped areas. Within these irregular walls are what appear to be low agricultural mounds. These are the same types of features that McAllister recorded within, and just southwest of, the Queen's Beach project area at Kaloko, Wawamalu, and Ka'ili'ili.

This photo was taken before Kalaniana'ole Highway was extended to Makapu'u. The old coastal trail is visible above the highwater mark. In the bottom left corner two people are visible walking along the trail. Both appear to be walking towards the Waimanalo Gap. This coastal trail would have scaled the cliff at Makapu'u and connected with the Kealakipapa Valley road which Webster (1851), Jackson (1884), and McAllister (1933) all noted.

Aerial view of Maunalua Beach, Oahu, Oct. 2, 1930.

Taken of the Kaloko peninsula in 1930, this photograph shows the roads and structural remains that are indicated on the 1927-1928 (1928) USGS Makapuu Quad. Map. It also shows the landscape at almost exactly the same time that McAllister was doing his survey of the archaeology of Oahu. The large enclosure on the left side of the photo is undoubtedly what McAllister reported as site 22--possible *heiau*. It fits his description (and location) of the enclosure being used as a modern house site (McAllister 1933:63). On Kaloko peninsula itself are a number of structures, at least one of which can be matched to its description by McAllister. The largest notched enclosure on the peninsula is undoubtedly site 10 ("the enclosure resembles a rectangle with a square half the width of the side wall removed from one corner" McAllister 1933:61). The two structure remnants closest to the unimproved road that goes out onto the peninsula probably correspond to McAllister's sites 12 (canoe shed) and 13 (wind breaks). In the bottom right corner of the photo are visible the ranch road and wall, which became part of Wawamalu Ranch under Alan Davis.

R. M. Towill Corporation Aerial Photograph Number 324-7, Queen's Beach, 4/19/1950

This photograph and the next one were both taken in 1950, subsequent to the 1946 tsunami but prior to the changes accompanied by the development of Hawaii Kai in the 1960s and 1970s. This photo shows Queen's Beach and the coastal flat of the project area. The archaeological structural remains on Kaloko point, described by McAllister and clearly visible in the previous 1930 photograph, are no longer visible--even the large notched enclosure (McAllister's site 10) that was clearly visible in the 1930 photograph--can no longer be seen. Either the 1946 tsunami had the force to destroy these remains or they were removed by ranch activities--which seems unlikely as ranch activities were declining after 1930. The new alignment of Kalaniana'ole Highway, with the new Wawamalu bridge are visible in the bottom left corner. This photo was taken before the coastline was changed by the dredging of Kaloko and Kaho'ohaihai Inlets and Ka'ili'ili Bay. All along this shore line there appear to be natural dune deposits behind the active beach. In the top right corner, branching off Kalaniana'ole Highway, is the new light house access road. The higher switchback of this access road in visible in the bottom right corner of the photo. *Makai* of this access road are visible two road remnants. The remnant closest to Kalaniana'ole Highway, with the parallel dark borders, is the remnant of old Kealakipapa Road (McAllister's site 3 (1933), visible in Webster's (1851) and Jackson's (1884) maps of Maunalua). The other remnant, which connects with the new light house access road, is the former light house access road, utilized prior to the construction of Kalaniana'ole Highway. This road remnant continues in the *mauka* portion of the coastal flat, just *makai* and running parallel to Kalaniana'ole Highway. The coastal flat and the lower portions of Kealakipapa Valley are fairly well covered with what appears to be dryland vegetation such as *kiawe*.

<u>R. M. Towill Corporation Aerial Photograph Number 324-8, Kealakipapa Valley, 4/19/1950</u>

Also taken in 1950, this photograph shows Kealakipapa Valley with Kalaniana'ole Highway ascending from the coastal flat (upper left corner of the photo) to the Waimanalo Gap (right side of photo). Like the prior photo it was taken before the development of Hawaii Kai affected the project area. The new lighthouse access road is clearly visible extending off of Kalaniana'ole Highway. Below (*makai* towards Queen's Beach) of this access road are the two road remnants described above. On the other side of the access road, running nearly parallel to Kalaniana'ole Highway is another remnant of the Kealakipapa Valley road. Although it appears overgrown with brush, the road remnant can be discerned by its dark borders, which are likely the "smaller stones heaped about a foot in height on either side" of the road that McAllister noted (1933:59). The road extends from the lighthouse access road nearly to the top of Waimanalo Gap before meeting Kalaniana'ole Highway, the construction of which undoubtedly destroyed part of the road.

<u>R. M. Towill Corporation Aerial Photograph Number 2226-9V, Queen's Beach Coastal Flat, 1/20/1961</u>

This photograph is a good indication of the magnitude of land alterations that occurred in the coastal and coastal plain portions of the project area as the development of Hawaii Kai was underway. Taken early in 1961, this photo was taken during or soon after major dredging and grading operations were performed. This photo confirms the testimony of Roger James (the supervisor of the Hawaii Kai Development Corporation's Queen's Beach operations from 1959-1964--see above). The coastline has been stripped of vegetation. Kaloko Inlet and Ka'ili'ili Bay were dredged and enlarged. The coastal dune areas of Kaloko, Ka'ili'ili, and Kaho'ohaihai were graded and covered with dredge material. The excavation of the artificial channel between Ka'ili'ili Bay and Kaho'ohaihai Inlet is underway. The coastal plain back to the lower portions of the light house access road in Kealakipapa Valley has been grubbed of nearly all vegetation (the occasional *kiawe* tree appears as a dot on the landscape). The coastal plain has clearly been graded and leveled by bulldozers. All traces of the Kealakipapa Road *makai* (below) the light house access road have been removed. Linear bulldozer push piles are visible along with piles of dumped sediment, possibly dredge material. A road from the light house access road to Kapali o Kamoa has been created. One of the two rock outcrops at Kapali o Kamoa visible in the 1950 photograph, has been bulldozed and removed. From this photograph it is clear that there is little chance of archaeological remains within the coastal and coastal plain portions of the project area.

<u>R. M. Towill Corporation Aerial Photograph Number 4887-5, Queen's Beach Coastal Flat, 5/20/1969</u>

The next two photographs were taken in May of 1969--after the grading, dredging, and breakwater construction activities but before the armor rock stockpiling. At Kaho'ohaihai Inlet the two arms of the constructed breakwater are visible. Inland of the breakwater a channel was dug with steep banks on either side. Vegetation has returned

to the coastline and coastal plain. On the coast grasses and what appears to be *Naupaka* are visible. In the coastal plain grasses predominate. Kaloko, and Kaho'ohaihai have numerous dirt trails--what appear to be recreational vehicle or "dune buggy" trails. Access to these trails is from Kalaniana'ole Highway. A *mauka-makai* drainage channel is visible cutting through the central portion of the coastal plain from Kalaniana'ole Highway to the Ka'ili'ili to Kaho'ohaihai channel.

<u>R. M. Towill Corporation Aerial Photograph Number 4887-5, Kealakipapa Valley, 5/20/1969</u>

Also taken in May of 1969, this photograph shows Kealakipapa Valley with Kalaniana'ole Highway ascending from the coastal flat (upper left corner of the photo) to the Waimanalo Gap (right side of photo). Like the previous photo it was taken before the armor rock stockpiling but after the dredging, grading, and breakwater construction. The land below the light house access road has clearly been graded. Remnants of the Kealakipapa Valley road are no longer visible below the access road. Between the access road and the Waimanalo Gap are numerous bulldozer/four-wheel-drive paths created since the 1950 photograph was taken. Above (towards Makapu'u) of the access road the Kealakipapa Valley road alignment is hardly visible, being overgrown by vegetation. It is visible as a slightly lighter spot in the vegetation between Kalaniana'ole Highway and the clearly visible bulldozer/four-wheel-drive road that runs parallel to the highway. The lower portion (closest to the access road) is being used as a four-wheel-drive path.

<u>R. M. Towill Corporation Aerial Photograph Number 8350-10, Queen's Beach Coastal Flat, 12/5/1984</u>

Taken late in 1984, subsequent to the armor rock stockpiling of the 1970s this final photograph documents the landscape for the most part as it appears today. A large drainage has been excavated from the Hawaii Kai Golf Course adjoining the Ka'ili'ili Bay. The areas where armor rock have been stockpiled are discernable by their rough, almost pitted, appearance. Numerous dirt roads provide access for off-road and four-wheel-drive vehicles. In the top right corner of the photo the alignment of the Kealakipapa Valley road between the light house access road and Waimanalo Gap is no longer discernable. The portion closer to the access road appears to have been turned into a four-wheel-drive road. The portion closer to the Waimanalo Gap is not visible in this photo because of the vegetation. The angle of this photograph is not the best for seeing traces of the Kealakipapa Valley road. At the time this photo was taken, Kelly, Kurashina, and Sinoto (1984) found remnants of the road above the lighthouse access road. So, although not discernable in this photo--the road was still discernable on the ground in 1984.

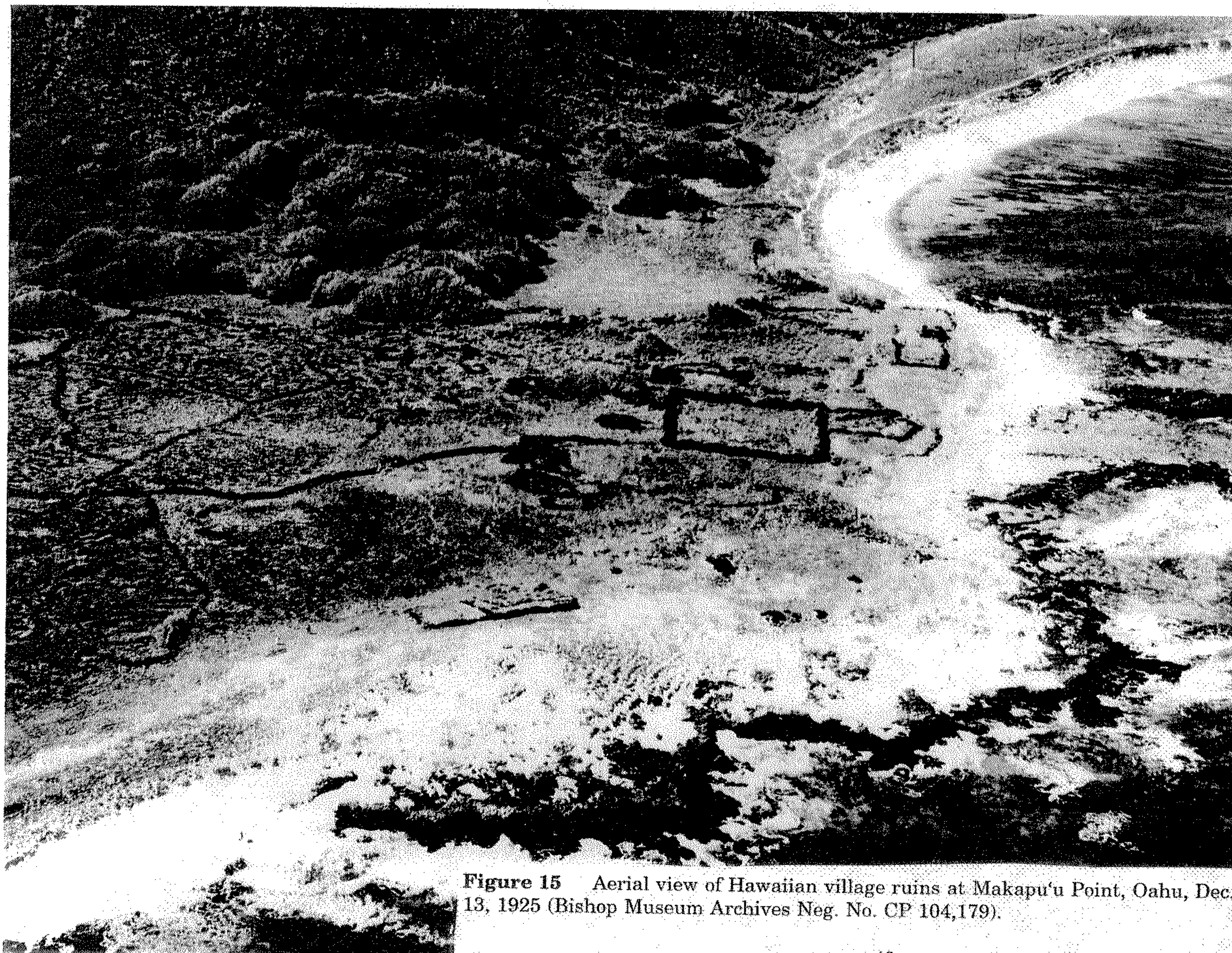


Figure 15 Aerial view of Hawaiian village ruins at Makapu'u Point, Oahu, Dec. 13, 1925 (Bishop Museum Archives Neg. No. CP 104,179).

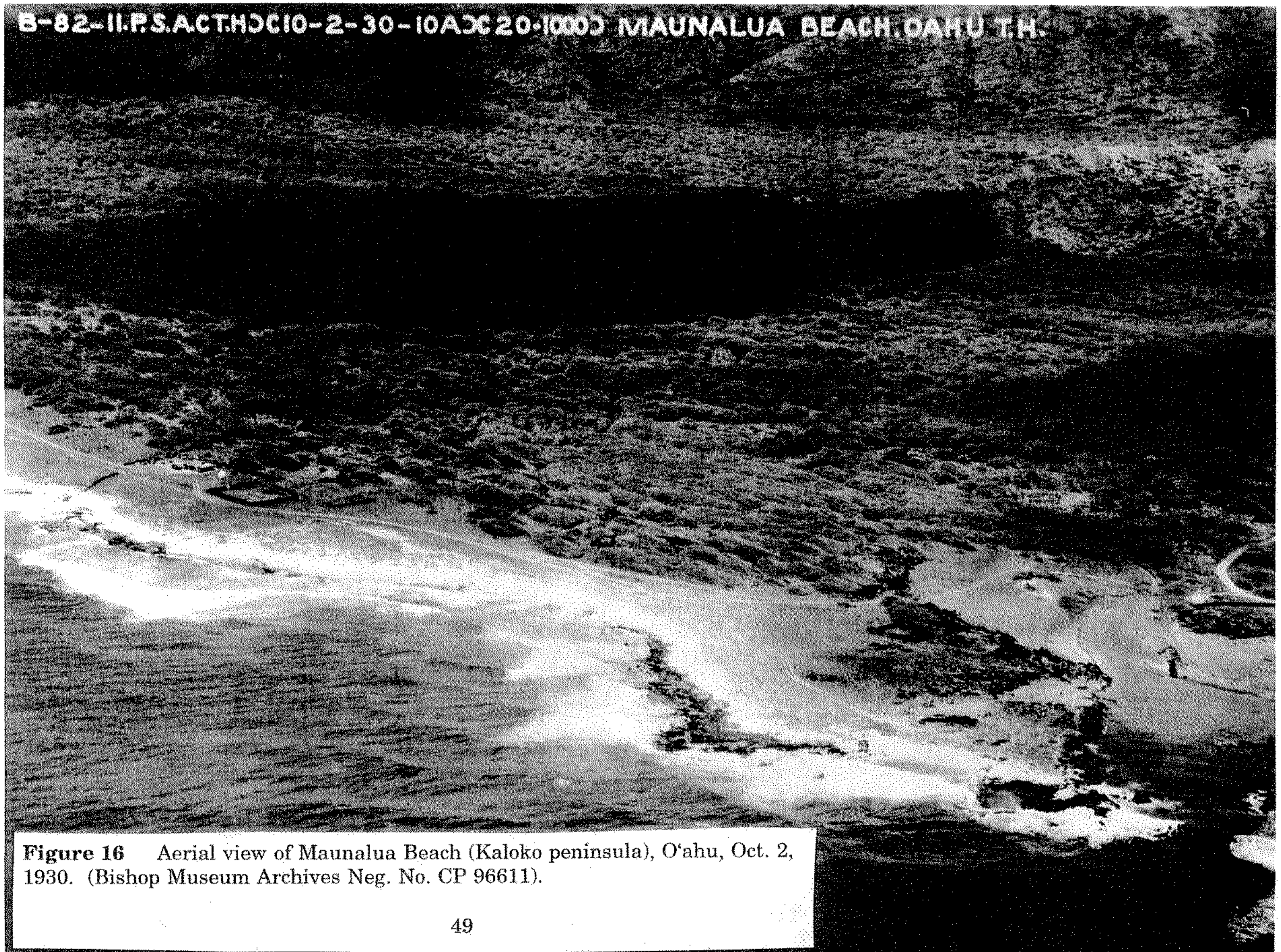


Figure 16 Aerial view of Maunalua Beach (Kaloko peninsula), O'ahu, Oct. 2, 1930. (Bishop Museum Archives Neg. No. CP 96611).

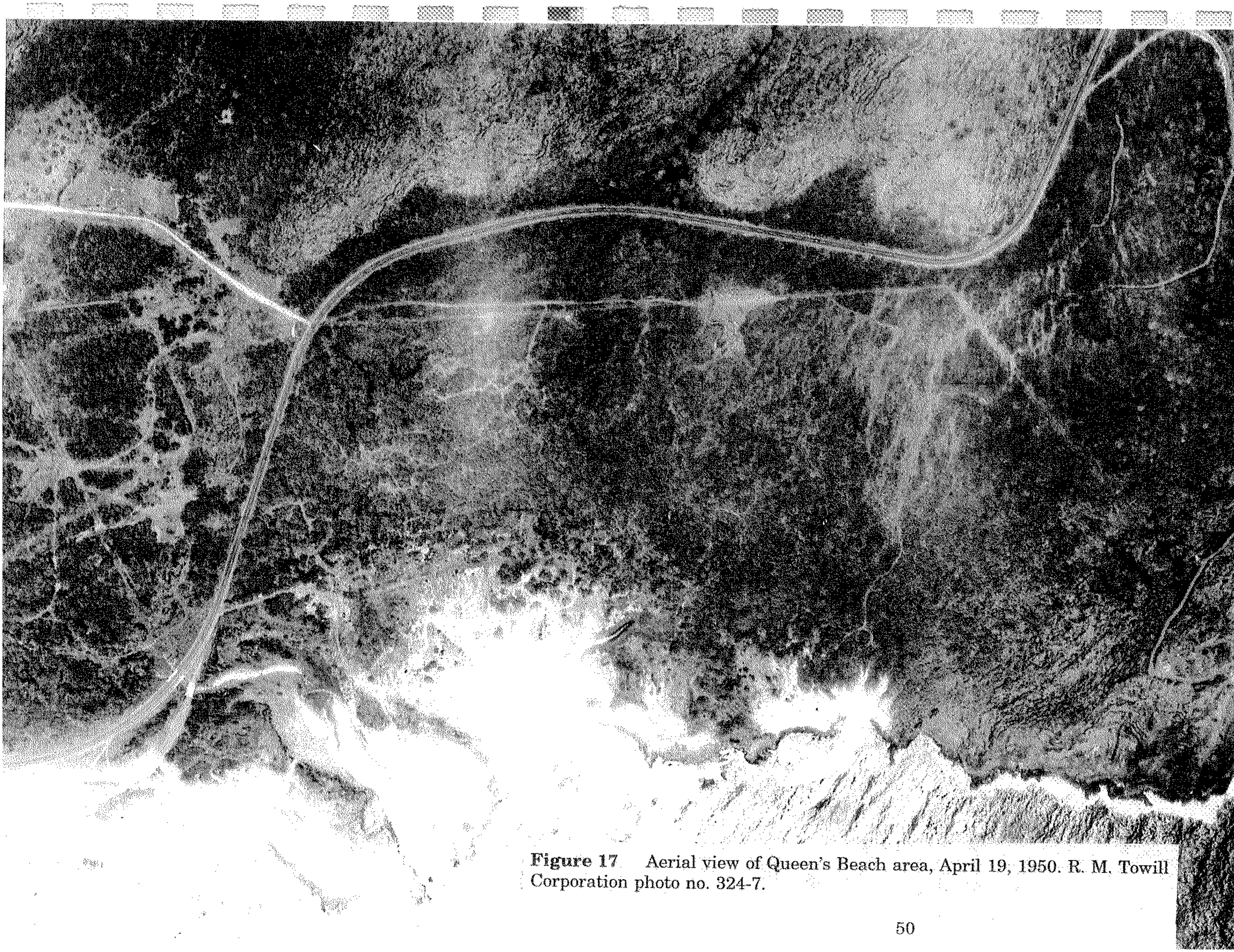


Figure 17 Aerial view of Queen's Beach area, April 19, 1950. R. M. Towill Corporation photo no. 324-7.

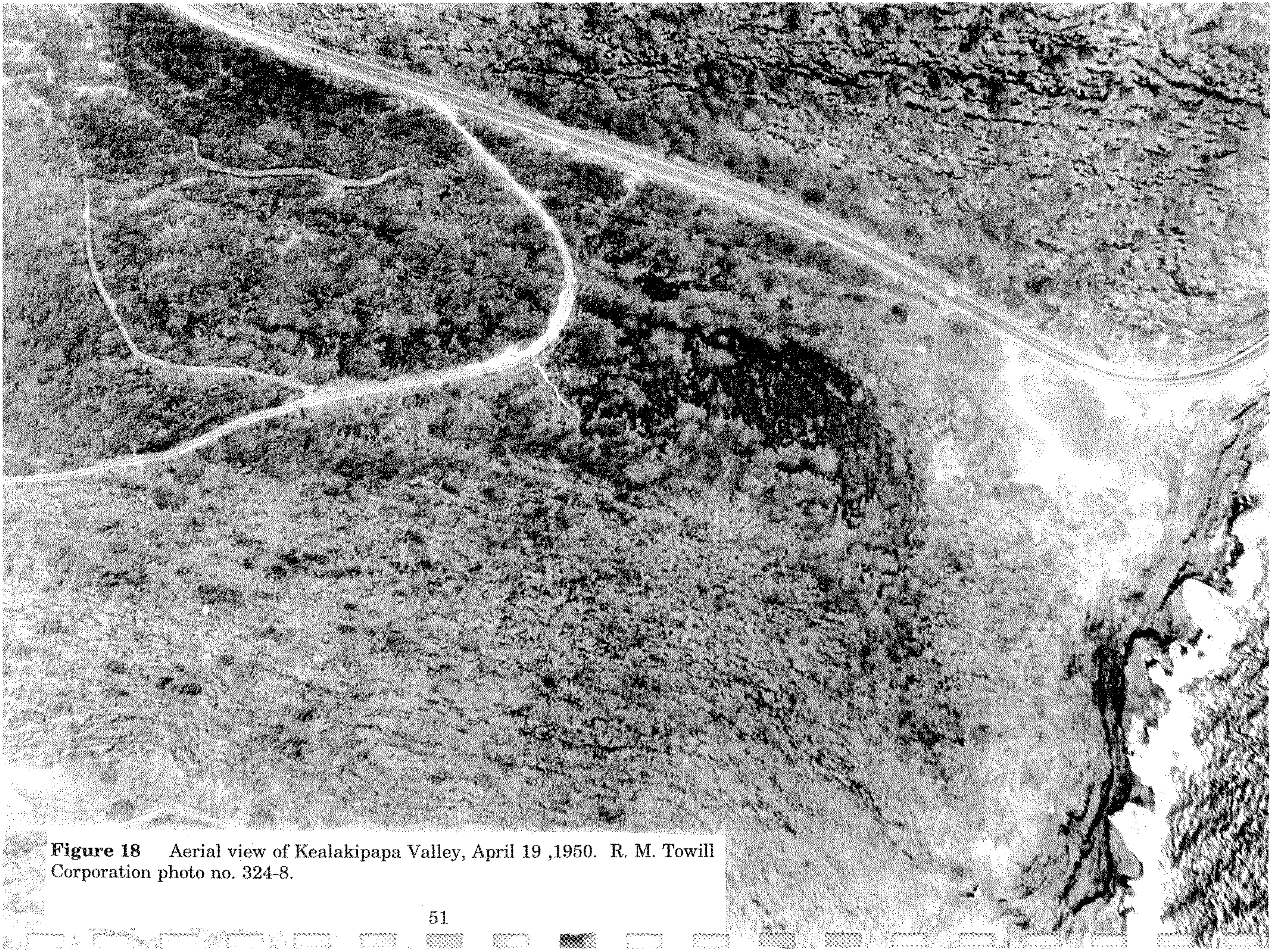


Figure 18 Aerial view of Kealakipapa Valley, April 19 ,1950. R. M. Towill Corporation photo no. 324-8.

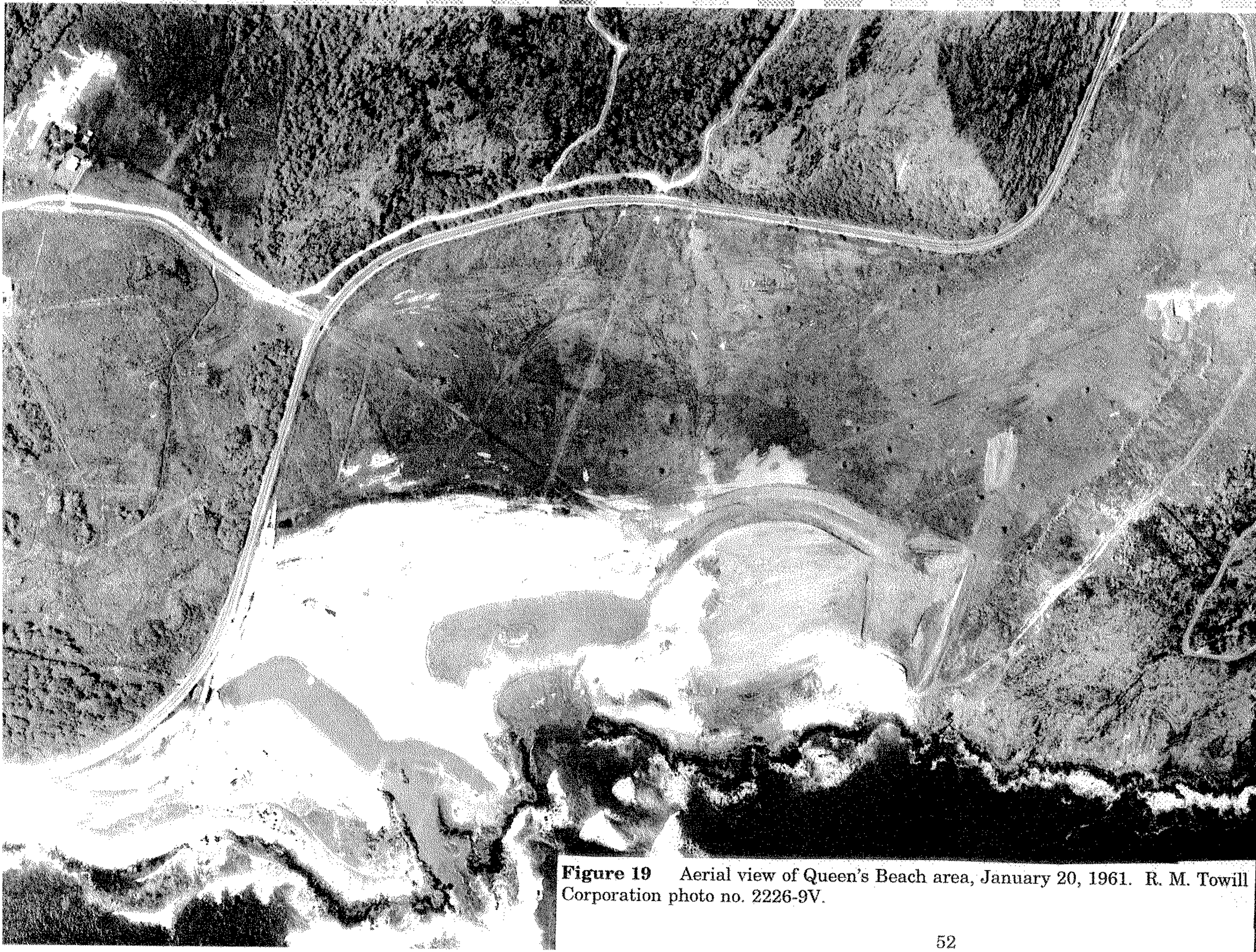


Figure 19 Aerial view of Queen's Beach area, January 20, 1961. R. M. Towill Corporation photo no. 2226-9V.

Figure 20 Aerial view of Queen's Beach area, May 20 1969. R. M. Towill Corporation photo no. 4887-5.

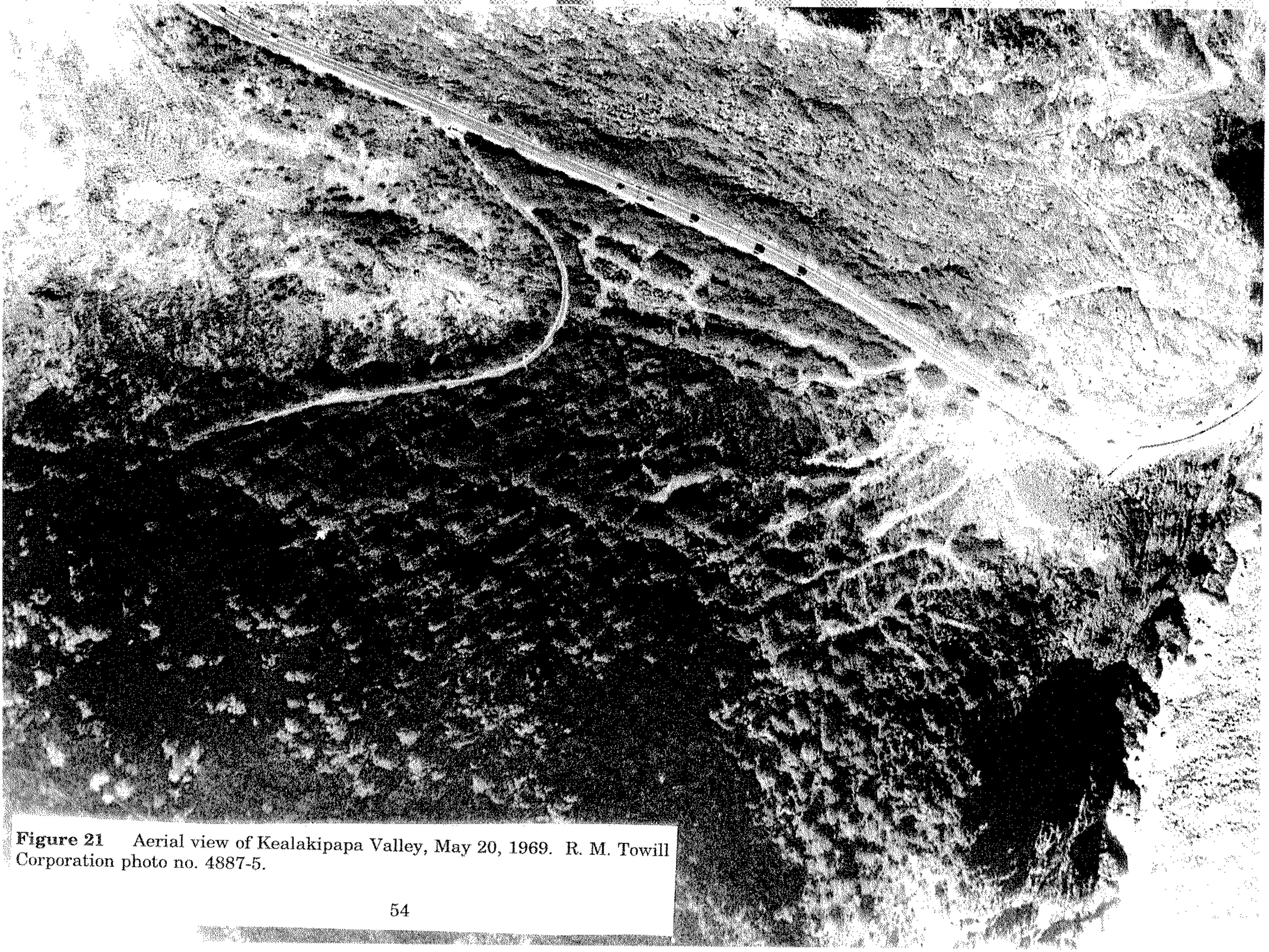


Figure 21 Aerial view of Kealakipapa Valley, May 20, 1969. R. M. Towill Corporation photo no. 4887-5.

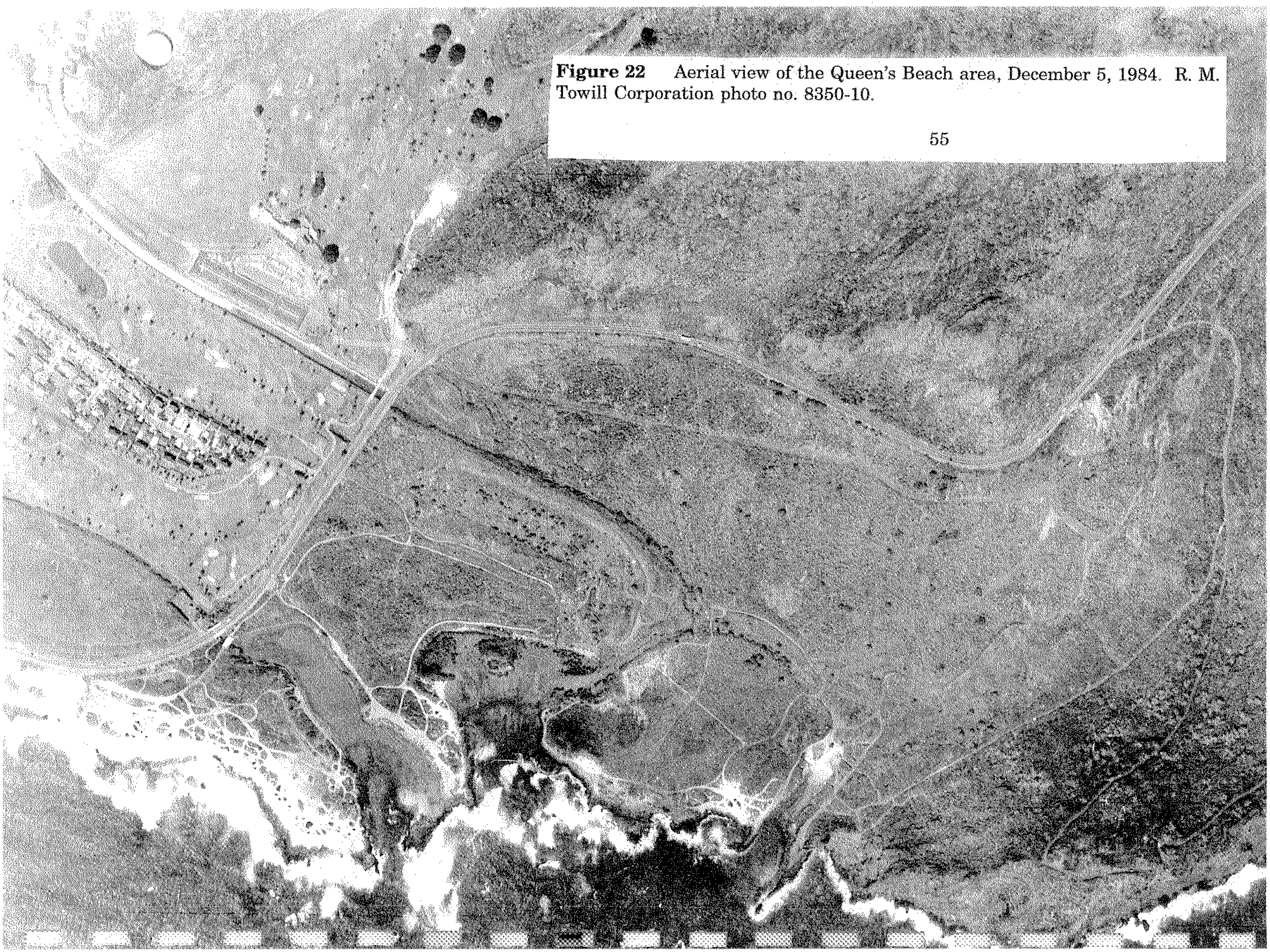


Figure 22 Aerial view of the Queen's Beach area, December 5, 1984. R. M. Towill Corporation photo no. 8350-10.

F. Summary of Historic Background

Maunalua's oral traditions and mythology portray a similar picture of settlement and land use as the early historic accounts. At Queen's Beach prehistoric settlement was concentrated at Kaloko, Ka'ili'ili, and Kaho'ohaihai. Marine resources were abundant, the adjacent coastal plain was fruitful--especially in cultivating the sweet potato for which the region was famous. As an *ili* of the *ahupua'a* of Waimanalo, Maunalua was more closely tied to the windward district of Ko'olaupoko. The prehistoric trail down the Waimanalo Gap was the primary route linking these regions.

Following western contact traditional Hawaiian land use and settlement continued and was maintained by the victualing trade until the early 1850s. Portlock and Dixon's 1786 visits to Maunalua were followed by many more ships--including inter-island and circle island vessels, as well as whaling ships. When this trade declined after the 1850s population and traditional settlement and land use declined. Ranching and commercial fishing became the primary economic pursuits.

At the time of the Mahele Maunalua was the property of Victoria Kamamalu. After changing hands numerous times the land passed to Bernice Pauahi Bishop. When she died in 1884 all of her lands became part of the Bishop Estate Trust, the land owner of the current project area.

Slowly after 1900 Maunalua became less of a backwater and was drawn into the rapidly changing world around. The Marconi Wireless installation and the Makapu'u light house were early inroads of modernity into the region. Population increased once again because of the jobs provided by commercial fishing and ranching after hitting an all time low circa 1880. As ranching became less and less profitable after 1920, truck farming increased. This further increased the population, however, not within the boundaries of the current project area. Unimproved access roads were slowly improved. By 1932 Kalaniana'ole Highway was completed after the last stretch from the Waimanalo Gap around Koko Crater was constructed. The same year the Wawamalu Ranch was formed when Alan Davis leased the land from Koko Crater to Makapu'u for ranching.

The 1946 tsunami destroyed Alan Davis's home at Kaloko and had sufficient force to tear up coastal sections of Kalaniana'ole Highway between Sandy Beach and Wawamalu. In 1959 Henry Kaiser's development plans for Maunalua were implemented. Part of these plans involved the construction of resorts at Queen's Beach. Dredging, grading, and material stockpiling greatly impacted the current project area.

IV. PREDICTIVE MODEL

The Queen's Beach project area has had an unusual number of previous cultural resource investigations. A synthesis of these previous reports provides a useful predictive model concerning the location and state of preservation of archaeological resources in the project area. The following predictive model is based on previous archaeology, the mythological and oral traditions, and the historical background.

Oral traditions, historic accounts, and previous archaeology all indicate that traditional Hawaiian settlement and land use existed in the project area at least in the late prehistoric and early historic period. The region around Kealakipapa Valley was famous for its sweet potatoes according to Handy. The goddess Hi'iaka was credited with urging the *kupua* (supernatural beings) Malei and Makapu'u to plant sweet potatoes in the region to alleviate their hunger. In the early historic period the village of Wawamalu, portions of which were in the southwest corner of the project area, was supported by trading its sweet potatoes to whaling and other vessels. When the victualing trade died in the 1850s, the settlement at Wawamalu declined. Ranching and commercial fishing took over as the primary economic pursuits in Maunalua. These pursuits were, for the most part, non-destructive to the archaeological remains. Ranching may have robbed some of the surface archaeological features for rocks to build walls. Some of the larger structures, such as McAllister's site 22 (possible *heiau*--visible in the 1930 photograph discussed above) was likely more thoroughly modified to create cattle pens. However, within the bounds of the current project area especially, the 75 years of ranching and commercial fishing that preceded McAllister's 1930 initial archaeological survey were nondestructive to the area's archaeology.

McAllister recorded five sites within the Queen's Beach project area: site 2, artificial pile of stones; site 3, Kealakipapa Valley Road; site 4, small crescent shaped windbreaks (likely modern); site 5, house site; and site 27, Wawamalu ranch enclosure containing possible burial mounds and sweet potato mounds. The locations of these sites are plotted on Figure 7.

The next archaeological assessments of the project area were done over fifty years later. By this time Queen's Beach and Kealakipapa Valley had been greatly impacted by the 1946 tsunami, the development plans for Queen's Beach, and the material stockpiling from the development of Hawaii Kai. The archaeological assessments of Kurashina and Sinoto (Kelly et. al 1984) and PHRI (Walker et. al 1996) agree that of the five sites recorded by McAllister, all have been destroyed with the exception of site 3 (Kealakipapa Valley Road) which was rapidly being destroyed.

No previous archaeological work in the project area has excavated in search of subsurface archaeological deposits. Wallace (et. al 1966) excavated at Kaloko peninsula at McAllister's high feature density area, just southwest of the current project area. Although the 1946 tsunami had destroyed the surface features recorded by McAllister, Wallace's excavations documented that subsurface coastal deposits had survived the tsunami. Accordingly coastal deposits may have survived the tsunami within the current project area. However, it is unlikely these deposits would have survived the grading, excavation, dredging, and material stockpiling that occurred in the 1960s and 1970s.

The aerial photographs are the best evidence that subsurface deposits are unlikely to be encountered in the project area. Subsequent to the scouring inflicted by the 1946 tsunami (which likely destroyed and removed the surface features--as it did at Kaloko), starting in the 1960s the Queen's Beach project area effectively underwent a face-lift. The

1961 aerial photograph (Figure 19) clearly shows that coastal dune areas at Kaloko, Ka'ili'ili and Kaho'ohaihai were scoured. This would have effectively removed and/or destroyed any archaeological deposits that had weathered the 1946 tsunami. If they weren't destroyed previously, McAllister's sites 4 and 5 between Ka'ili'ili Bay and Kaho'ohaihai Inlet were surely destroyed at this time. The excavation and extension of Ka'ili'ili Bay and Kaloko Inlet destroyed former land surface and created dredge material stockpiles. According to the testimony of Roger James, this dredge material was stockpiled at Kaloko, Kaho'ohaihai and Ka'ili'ili--effectively burying the already scoured ground surface.

The 1961 aerial photograph also shows that in the coastal flat, up to the light house access road in Kealakipapa Valley, the land surface was stripped of nearly all vegetation, graded and leveled by bulldozers. If McAllister's site 27 had not been destroyed previously by ranch activities or the 1946 tsunami--it was now undoubtedly destroyed. It is probable this activity destroyed all archaeological deposits on the coast and the coastal plain.

The 1969 aerial photograph (Figure 20) shows that the excavation and construction of the inlet and breakwater at Kaho'ohaihai has taken place. This activity created more dredge sediments that were stockpiled within the project area. The 1984 aerial photograph (Figure 22) shows that the excavation of the large drainage channel, in the vicinity of McAllister's site 27 has taken place. Also, the stockpiling of armor rock has further buried large portions of the coastal flat.

McAllister's site 3 (Kealakipapa Valley road) is clearly visible in the 1950 aerial photographs both above and below the light house access road (Figures 17 and 18). In the 1961 photograph it is clear that the portions of site 3 below the access road have been bulldozed. The 1969 aerial photo of Kealakipapa Valley (Figure 21) shows that McAllister's site 3 is in places incorporated into a system of four-wheel-drive roads and in other places it is being covered by thick vegetation (See previous archaeology section for further discussion of the degradation of McAllister's site 3 noted in Kelly (et. al 1984), Carpenter (1992) and Walker (et. al. 1996)).

McAllister's site 2 is the only site within the project area that has not been discussed. Kurashina and Sinoto (Kelly et. al 1984) were the first archaeologists to investigate the locality of this site subsequent to McAllister's visit:

> "The reconnaissance in the interior portion of the project area produced no intact surface archaeological remains. At the head of Kealakipapa Valley near Makapu'u Lookout, however, an observation was made of possible remains of McAllister's Site 2, and of a concrete foundation which once embraced the Malei stone. Site 2 is devoid of stone piles today, and only coral is scattered throughout, as observed by McAllister in 1930. It is probable that small lightweight stones were removed from Site 2 to the nearby cliff for the construction of defensive pillboxes" (Kelly et. al 1984:9).

The PHRI archaeological assessment for the current project area, conducted 10 years after that of Kurashina and Sinoto, found no traces of McAllister's site 2 (Walker et. al 1996:9-11).

Clearly, the project area's "face-lift" in the 1960s and 1970s removed nearly all of the archaeological features and deposits once extant in the project area. From the above

evidence it would appear that McAllister's site 3 (Kealakipapa Valley road) is the only archaeological feature remnant previous investigators were able to find within the project area. It should be noted that even this feature appears to be undergoing rapid destruction due to four-wheel-drive traffic and mossrock pickers. If the Kealakipapa Valley road has not been completely destroyed by mossrock pickers, it is likely to be the only archaeological feature found during the inventory survey. Subsurface archaeological deposits are not expected to have weathered the project area's unique history of land alterations.

V. SURVEY RESULTS

In the project area description, the project area was divided into three zones, the coast, the coastal flat, and Kealakipapa Valley. These same three zones will be used to discuss the survey results.

The archaeology that once existed in the coastal and coastal flat portions of the project area was destroyed by the 1946 tsunami and/or the development activities of the 1960s and 1970s. No traces of McAllister's sites 4, 5, and 27 were observed. In both these zones the landscape is dominated by features related to mechanized land modification.

In Kealakipapa Valley the landscape was also found to have been greatly modified. Bulldozer path and four-wheel-drive road construction and the stockpiling of armor rock have changed the landscape. During the survey field work no direct evidence of moss rock pickers was observed--but their activities have undoubtedly removed stone from this portion of the project area.

In the general locality of McAllister's site 2, a few pieces of coral were observed--but these scattered coral fragments were found in many parts of Kealakipapa Valley. Many of these fragments were likely brought to their present location by the trucks that were depositing armor rock. They are not necessarily archaeological. No traces of McAllister's site 2 are extant.

Our predictive model listed McAllister's site 3 as the single archaeological feature remnant that would be found/relocated within the project area. The remnant of this road was indeed the single archaeological feature found within the project area. Located between the light house access road and Makapu'u Lookout, it stands out as a cleared area in the surrounding *kiawe* where only grasses and shrubs grow. This cleared area matches perfectly the alignment visible on the 1950 aerial photograph, where the roadway can be seen above the light house access road with its dark borders of piled rock or curb stones. The cleared area measures approximately 80 meters long and is an average 5 meters wide. During the inventory field work, the vegetation was green, tall, and thick, hampering the investigation of the road site. Because of this thick vegetation, several hours were spent searching the location of the former roadway. This search did not uncover a single structural remnant of the road--no curbstones, no paving stones, and no "side rock-walls". The roadway is discernable as a clear spot in the vegetation which has been used in the past as a bulldozer and/or four-wheel-drive road.

(It should be noted that the Kealakipapa Valley road, with its associated paved and terraced sections is clearly visible outside the project area where it descends from Makapu'u Lookout to Makapu'u Beach. This portion of the road was investigated during the inventory survey field work and found to be in the same state of preservation described by Carpenter in 1992. The four switchbacks and the historic petroglyph noted by Carpenter were still visible.)

The following is a chronological listing of descriptions of McAllister's site 3, starting with McAllister's own description from 1930 and ending with PHRI's description of 1994. Over the sixty four years the site has clearly been degraded.

McAllister states (1930):

"From the top of the gap down Kealakipapa Valley for about 600 feet the road is in fairly good condition and can be followed with ease. The central part is paved with flat stones 1 to 2 feet in width, with smaller stones

heaped about a foot in height on either side. Along this distance the road averages between 15 and 16 feet in width. Farther into the valley the road runs into a heavy growth of kiawe. Here it is generally without the side rock-walls, about 11 feet wide, and of arched or curved surface. Throughout the lower part of the valley the road is in a poor state of preservation. On the immediate mountain side of the lighthouse road it cannot be found. Seaward of the light- house road it appears again and seems to end some 140 feet from the present road, for on the sea side of this point it cannot be found" (McAllister 1933:59).

Kurashina and Sinoto state (1984):

"Sections of a 11 - 15 ft-wide stone-paved road (King's Highway) were present between the coast guard road and Makapu'u Lookout" (Kelly et. al 1984:9).

Kelly states (1984):

"The site that seems most exposed to looting is the "old King's Highway" paved with stones (McAllister's Site No. 3). Some kind of control over mossrock pickers should be maintained, as at least one was observed taking rock from the old roadway. If nothing is done, it will not be long before the old Hawaiian roadway completely disappears--destroyed because no one cared anymore. Since the gate to the lighthouse access road was moved, and the original gate at the highway turn-off is left unlocked, mossrock hunters are provided with easy access to Kealakipapa Valley and the old Hawaiian roadway makes a convenient quarry" (Kelly et. al 1984:76).

Carpenter states (1992):

"The straight section [of the road] between the lighthouse road and the lookout was identified because it is conspicuously clear of large rocks and is very level. Unfortunately, it is nearly devoid of flat paving stones which apparently once were characteristic of much of its length (McAllister 1933:59). A recent reference can be found attesting to the fact that "mossrock" hunters have removed the paving stones of the road (Kelly 1984). Additionally this road section has apparently been utilized by four-wheel drive vehicles, as suggested by the placement of some large concrete columns across the southern end of this remnant, perhaps in an attempt to prevent activity. The sides of the road are roughly defined on the west by a border of stones and on the east by a rough boulder alignment modifying a natural ledge. The surface of the road in this area is densely overgrown with grasses and shrubs making complete evaluation of the remaining paving stones rather difficult. The total length of this recognizable remnant is approximately 120 meters (394 ft.). Along this length the road ranges between 4.4 and 5.5 meters in width. It may extend further northward, but the vegetation changes to dense kiawe in that area, making survey extremely difficult without vegetation clearing" (Carpenter 1992).

> "Within the project area, the site [Kealakipapa Valley road] is identified as a cleared zone within the *kiawe*, usually containing no vegetation other than grasses or small shrubs. The road is relatively straight, and no curb stones or paving were visible" (Walker et. al 1996:11).

Our description of site 3 matches that of PHRI--a clear spot in the *kiawe* is visible, but no structural remains were found. Figure 23 is a plan view of the remnant of site 3 as observed during the field work. The cleared area is shown in relation to the surrounding four-wheel-drive road, light house access road, and Kalaniana'ole Highway. This portion of the project area has very dense *kiawe* thickets. The remnant of site 3 and the adjacent four-wheel-drive road stand out as grass areas surrounded by *kiawe*. Both the remnant of site 3 and the adjacent four-wheel-drive road have crude alignments of large armor-rock boulders along their edges. These testify to the use of both of these cleared areas during the armor-rock stockpiling activities.

This portion of the project area is littered with concentrations of construction rubble. Immediately south of the site 3 remnant is a concentration of old lumber, tiles, and ply-wood. There is also a pile of asphalt road paving fragments on the eastern edge of the site 3 remnant. Along with the crude armor-rock alignments, this dumping of modern construction rubbish is further evidence of recent use of the cleared areas in the *kiawe* by trucks and off road vehicles. The large cement columns placed between the light house access road and the four-wheel-drive road are clearly an attempt to discourage continued use of these cleared areas by these vehicles.

The ground surface at the site 3 remnant, beneath the tall grass, is fairly even and level, as would be expected at the site of a road remnant. In places erosion has created shallow gullies which cross diagonally across the north-south alignment of the former road. Several large basalt boulders, undoubtedly from the armor-rock stockpiling operations, are scattered about. No evidence of paving stones, curb stones, or "side rock-walls" were observed. The area to the north of the mapped area is also dense *kiawe*. This area was checked for structural remnants of the road, but none were found.

It is clear that this portion of site 3 has remained cleared because, at this location, the former road has become incorporated into the system of modern four-wheel-drive roads that criss-cross this area. This has kept the surrounding *kiawe* from closing in over this portion of the former road. Further north, between this cleared area and Makapu'u Lookout, the former roadway is not visible even as a cleared area in the *kiawe*. This is because this part of the former road did not become part of the four-wheel-drive network of roads and has consequently been covered by thick vegetation. Transects through this thick vegetation did not uncover structural remains. It is probable that Kelly's fears of the mossrock pickers have come to pass and the site has been stripped entirely of its stones.

Summary

The alterations to the project area caused by the 1946 tsunami, development activities at Queen's Beach and Hawaii Kai, and the activity of moss rock hunters, have removed nearly all archaeological remains. In the coastal flat and along the coast,

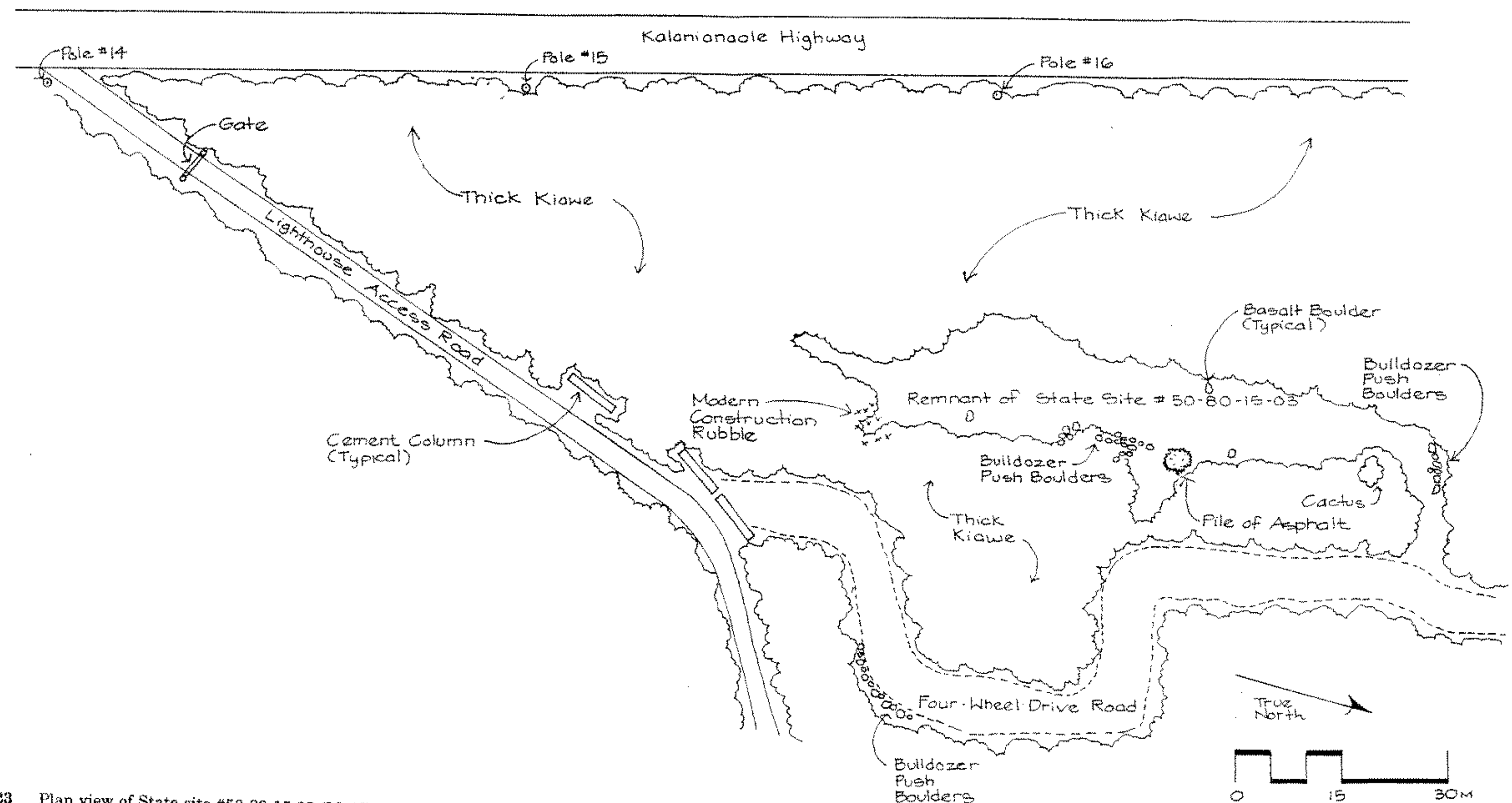


Figure 23 Plan view of State site #50-80-15-03 (McAllister's site 3, Kealakipapa Valley Road) as it appeared during the 1997 field work.

pedestrian inspection confirmed that land modification had completely removed the archaeological features that once were within the boundaries of the project area. McAllister's sites 4, 5, and 27 are gone. McAllister's site 2 in Kealakipapa valley is no longer extant. McAllister's site 3 Kealakipapa Valley road is still visible as a cleared area in the *kiawe*, however no structural remains of this road were found. The persistence of this cleared area is attributed to its past use as a four-wheel-drive road.

The pedestrian survey, through first hand exposure to the magnitude of land alterations, further bolstered the opinion that subsurface deposits would not be found within the project area.

VI. TESTING RESULTS

Introduction

This report documents the first subsurface testing carried out within the Queen's Beach project area. The archaeological assessments of Kurashina and Sinoto (Kelly et. al 1984) and PHRI (Walker et. al 1996) both recommended subsurface testing within the project area to determine whether archaeological deposits were preserved. The predictive model, developed in consideration of oral traditions, mythology, history (including aerial photographs), and previous archaeology, did not predict that archaeological subsurface deposits would remain within the project area. The destructive impact of the 1946 tsunami and the dredging, excavation, grading, and material stockpiling associated with the development of the Queen's Beach area are thought to have completely removed archaeological deposits. Subsurface testing was carried out using a backhoe (see the methods section).

The following is a trench by trench description of the seven trenches that were excavated within the project area. Trench locations are plotted on Figure 4. The areas within the project area which could potentially be tested with the a backhoe were limited to the areas not covered in armor rock--see Figure 6 for a project area break down of different land alterations. Trench profiles (Figures 25 through 31) are located together at the end of this section. Figures 42 to 47 in the Photo Appendix show trench profiles.

Trench Descriptions

Trench #:	1
Length:	4.0 m. (13.1 ft.)
Width:	0.8 m. (2.6 ft.)
Depth:	0.7 m. (2.3 ft.)
Orientation:	126-306°T
Face Profiled:	East (see Figures 24, 25, 41 and 42)

Stratum	Depth (cm.)	Description
I	0-70	Basalt boulders and cobbles, coral boulders and cobbles, majority of basalt and coral is water rounded, no soil is present.
II	0-50	A horizon - 5YR 3/2 dark reddish brown, friable, very humic, loamy sand with organic matter and numerous roots, 20% basalt pebbles and cobbles within the stratum with some mixed in calcarious beach sand, the boundary is abrupt and wavy.

This trench was excavated on a low bedrock knoll just inland of the boulder and cobble beach east of Ka'ili'ili Bay. This is the vicinity of McAllister's site 5 (house site).

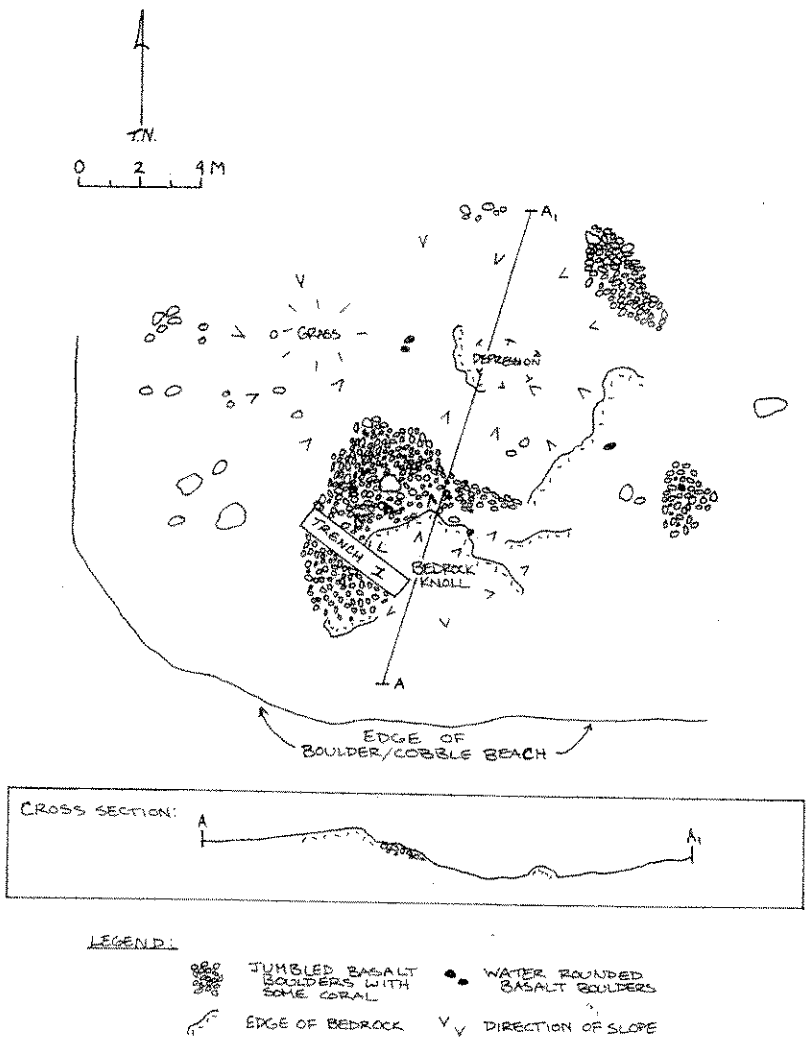


Figure 24 Plan view of locality of trench 1.

The concentration of basalt and coral boulders and cobbles scattered to the west of the knoll were tested to determine if they represented a demolished structure. This shallow excavation yielded no artifacts, charcoal, or midden and no evidence of structural remains. This concentration of boulders and cobbles is thought to represent an accumulation of high surf deposited material. It could also be bulldozer push. The sediments in the trench section represent natural beach deposits, possibly moved by mechanized land moving equipment.

Trench #:	2
Length:	5.3 m. (17.4 ft.)
Width:	0.8 m. (2.6 ft.)
Depth:	1.9 m. (6.2 ft.)
Orientation:	144-324°T
Face Profiled:	East (see Figures 26, 43 and 44)

Stratum	Depth (cm.)	Description
IA	0-20	10YR 4/3 brown coarse, loose, gravelly calcarious sand with numerous shell and coral fragments, a few water rounded basalt boulders, numerous roots and rootlets with gravels, cobbles and boulders making up approximately 10-20% of the stratum. There is a slight amount of terrigenous sediment in the strata. Stratum I consists of dredged material. The boundary between Stratum IA and IB is abrupt and smooth.
IB	20-40	10YR 5/3 brown, coarse, loose, gravelly calcarious sand with whole shells, roots and rootlets, plentiful coral and some water rounded basalt pebbles with 15-25% of the stratum being pebbles and gravel. The boundary between Stratum IB and IC is abrupt and smooth.
IC	40-60	10YR 4/3 brown, coarse, loose, gravelly calcarious sand with whole shells and water rounded basalt and coral pebbles, with 15-25% gravel and cobbles within the stratum. A few roots and rootlets were present. The boundary between Stratum IC and II is abrupt and smooth.
II	60-90	10YR 3/3 dark brown friable sandy clay loam with calcarious (probably dredged material) gravel and mixed in sand with 10% coral pebbles, and water rounded basalt boulders with

		few roots and rootlets. The boundary between Stratum II and III is abrupt and wavy.
III	90-150	10YR 3/2 to 10YR 4/2 dark grayish brown to very dark grayish brown slightly compact to compact silty clay loam with 2% basalt cobbles in the stratum. No roots or rootlets were observed. The boundary between III and IV is abrupt and smooth. Appears to be alluvial sediment.
IV	150-190	5YR 3/3 dark reddish brown with 10YR 5/4 yellowish brown gravelly sandy clay loam slightly compact to compact at the base. Gravel and pebbles ranged from 5 to 10% in the stratum with no observable roots or rootlets. The base of the strata dips to the northwest. Strata consists of mottled decomposing a'a bedrock.

General notes on Trench 2: Stratum IA, IB, and IC are a mix of coral and dredged fill. Stratum II is a mix of Stratum I and Stratum III. Stratum III alluvium or *in situ* sediment. Stratum IV is decomposing a'a bedrock material.

Trench 2 was excavated in flat, graded area in back of the boulder and cobble beach (approximately 33 m from the vegetation line) just east of Ka'ili'ili Bay. The trench was dug to investigate the stratigraphy at this location. Strata IA, IB, and IC are all coral gravel/sand dredge deposits. The abrupt boundaries of these strata are characteristic of rapid "single event" deposition often seen with mechanically deposited fills. Stratum III is the *in situ* silty-clay loam alluvial deposit. Stratum II is a mix of coral gravel/sand and stratum III--this represents the "intermediate zone" where terrigenous sediments were mixed with marine sediments. Such a zone is to be expected where marine beach deposits meet terrigenous deposits. However, considering this locality's history of disturbance (the 1946 tsunami and the 1960s grading and dredging) stratum II most likely represents the disturbance zone, where wave and mechanized scouring mixed terrigenous and marine (possibly fill) sediments. Because we cannot be sure how much original sediment was cut away before the dredge material was deposited, it is difficult to determine where the pre-grading land surface was. Probably *in situ* deposits were cut down to the surface of stratum III and at least a meter of fill and reworked sediment were deposited on top of stratum III. Below stratum III lies stratum IV the *in situ* decomposing a'a bedrock. Solid a'a bedrock was encountered at the base of the excavation.

Trench #: 3
Length: 4.8 m. (15.7 ft.)
Width: 0.8 m. (2.6 ft.)
Depth: 2.7 m. (8.9 ft.)
Orientation: 73-253°T
Face Profiled: South (see Figures 27 and 45)

Stratum	Depth (cm.)	Description
I	0-50	10YR 4/2 dark grayish brown, loose, coarse sand with 20% of the stratum coral pebbles, shells, and basalt pebbles and cobbles. Roots and rootlets present. The boundary between Stratum I and II is abrupt and smooth.
II	50-60	10YR 5/3 brown, loose, gravelly, coarse sand containing coral pebbles, shells, and water rounded basalt cobbles and pebbles. Roots and rootlets present. The boundary between Stratum II and III is abrupt and smooth.
III	60- 80 to 110	10YR 3/2 to 10YR 4/2 dark grayish brown to very dark grayish brown slightly compact to compact silty clay loam with 2% basalt cobbles. No roots or rootlets were observed. The boundary between Stratum III and IV is abrupt and wavy. *In situ* sediment deposit.
IV	80 to 110- 275	5YR 3/3 dark reddish brown with 10YR 5/4 yellowish brown mottles, gravelly, sandy clay loam slightly compact to compact at the base. Gravel and pebbles ranged from 5 to 10% of the stratum with no observable roots or rootlets. The water table was encountered at 230 cmbs. Strata consists of mottled decomposing a'a bedrock.

General notes for Trench 3: The stratigraphy for Trench 3 is very similar to Trench 2. Strata I and II are clearly dredge deposits. Stratum III is the "intermediate zone" discussed above. Possibly below the water line we would have the Trench 2 Stratum IV (decomposing a'a bedrock). Profile shows depth of water table at this portion of the project area.

Trench 3 was excavated along the eastern edge of Ka'ili'ili Bay approximately 5 m from the vegetation line above the boulder and cobble beach. Trench 3 was excavated in the same flat, graded area as trench 2 and these trench's stratigraphy were very similar. Stratum I and II are clearly dredge fill. Stratum III is the "intermediate zone" discussed above. Here, as in trench 2, this zone is thought to represent the disturbance and mixing of terrigenous and marine (possibly fill) sediments due to the 1946 tsunami and/or the mechanized grading of the 1960s. Stratum IV is the *in situ* terrigenous sediment.

Trench #: 4
Length: 2.8 m. (9.2 ft.)
Width: 0.8 m. (2.6 ft.)
Depth: 1.3 m. (4.3 ft.)
Orientation: 21-201°T
Face Profiled: North (see Figure 28)

Stratum	Depth (cm.)	Description
I	0-110	10YR 3/2 very dark grayish brown, loose, fine, sandy loam with 10 to 15% basalt boulders and cobbles in the stratum with numerous roots and rootlets. The boundary between Stratum I and II is gradual and wavy.
II	110-130	10YR 3/1 very dark gray, friable, cinder-like, fine, volcanic sand with 5% basalt pebbles in the stratum and no roots or rootlets were observed.

General notes Trench 4: Both Stratum I and II are redeposited re-worked fill material from excavation and grubbing.

Trench 4 was excavated in the graded coastal flat approximately 250 m from the beach. This trench was excavated to a depth of 130 cm below surface before excavation was terminated because of the undifferentiated nature of the sediment. Stratum I is a sandy loam. Stratum II is a thin lens of volcanic cinder found within stratum I. This cinder is visible in large quantities along the constructed berms and cut banks of Kahoʻohaihai Inlet. Not a sediment natural to the locality of trench 4, this cinder is one of the materials that was excavated, stockpiled, and spread out during the development of the Queen's Beach area. Because of their stratigraphic relationship, clearly both stratum I and II are reworked sediments dating to the grading and material stockpiling events of the 1960s and 1970s. At the locality of trench 4 at least the first 130 cm below surface are reworked sediments from grading activities.

Trench #: 5
Length: 5.9 m. (19.4 ft.)
Width: 0.8 m. (2.6 ft.)
Depth: 2.3 m. (7.5 ft.)
Orientation: 30-210°T
Face Profiled: East (see Figures 29 and 46)

Stratum	Depth (cm.)	Description
I	0-60	10YR 3/2 very dark grayish brown, loose, fine sandy loam (similar to Trench 4 Stratum I except for the mixed in large boulders). Contains roots and rootlets with 20-25% large basalt boulders in the stratum. The boundary between Stratum I and II is abrupt and wavy.
II	60-100	10YR 3/2 very dark grayish brown with 10YR 4/4 dark yellowish brown mottles sandy clay loam, friable, containing 10 to 15% basalt cobbles and pebbles with roots and rootlets present. The boundary between Stratum II and III is abrupt and wavy.
III	100-140	Mottled 5YR 3/1 very dark gray with 10YR 4/3 brown, slightly compact, sandy clay loam with roots and rootlets and approximately 5% basalt pebbles. The boundary between Stratum III and IV is abrupt and wavy.
IV	140-160	10YR 4/4 dark yellowish brown compact clay loam with few roots and rootlets. 0% boulders, cobbles or pebbles in stratum. The boundary between Stratum IV and V is abrupt and smooth.
V	160-230	10YR 4/2 dark grayish brown to 10YR 3/2 very dark grayish brown, slightly compact to compact, silty clay loam, with few roots or rootlets and >5% basalt pebbles in strata. Similar to trench 2 stratum III.

General notes on Trench 5: Stratum V, similar to Trench 2 Stratum III, is *in situ*, everything above Stratum V is fill from other excavations and grading.

Trench 5 was excavated on the graded coastal plain approximately 180 m from the coast. Stratum V is the *in situ* deposit. Strata I through IV are fill deposits which were deposited during the grading and material stockpiling operations of the 1960s and 1970s. At the locality of trench 5 over a meter and a half of fill material has been deposited.

Trench #: 6
Length: 3.0 m. (9.8 ft.)
Width: 0.8 m. (2.6 ft.)
Depth: 1.7 m. (5.6 ft.)
Orientation: 132-312°T
Face Profiled: West (see Figures 30 and 47)

Stratum	Depth (cm.)	Description
I	0-120	10YR 4/3 brown, coarse grained, loose, calcareous sand with whole shells, coral pebbles, and cobbles, basalt boulders and cobbles. 10-20% pebbles, cobbles, and boulders in the stratum. The boundary between Stratum I and II is abrupt and wavy.
II	120-170	5YR 3/2 dark reddish brown, slightly compact to compact, silty clay loam, with few roots or rootlets and >5% basalt pebbles in the stratum.

General notes Trench 6: Stratum I is beach and dredge fill deposit that has been re-worked by grading. Stratum II is *in situ* decomposing bedrock, similar to that seen in Stratum III Trench 7.

Trench 6 was excavated near the beach on the edge of the graded coastal flat approximately 20 meters from the vegetation line. Stratum I is very similar to the current poorly sorted beach deposit adjacent to trench 6. It does contain significantly more calcareous sand, however. Stratum I represents the mixture of the natural beach deposits and the marine dredge sediments that were stockpiled and spread at this locality. Stratum II is the *in situ* sediment with decomposing bedrock at it's base.

Trench #: 7
Length: 3.7 m. (12.1 ft.)
Width: 0.8 m. (2.6 ft.)
Depth: 1.5 m. (4.9 ft.)
Orientation: 152-332°T
Face Profiled: North (see Figure 31)

Stratum	Depth (cm.)	Description
I	0-25	10YR 6/3 pale brown, fine to medium grain, loose, calcarious sand with roots and rootlets. 10% coral pebbles and cobbles and basalt pebbles. The boundary between Stratum I and II is abrupt and wavy.
II	25-40	Mix of Stratum I and III. 10YR 3/2 very dark grayish brown, loose, sandy loam with roots and rootlets. 5% pebbles and cobble in the stratum. The boundary between Stratum II and III is abrupt and wavy.
III	40-145	10YR 3/2 very dark grayish brown friable loam with some roots and rootlets. >5% pebble and cobbles in stratum.

General notes: Stratum I is dredge fill. Stratum II is a mix of Stratum I and III (intermediate zone) and Stratum III is *in situ* deposit with decomposing bedrock at base.

Trench 7 was excavated on the graded coastal plain approximately 60 meters from the beach. Stratum I is dredge material. Stratum II is the intermediate zone discussed above. This zone is thought to represent the disturbance and mixing of terrigenous and marine (possibly fill) sediments due to the mechanized grading of the 1960s. Stratum III is *in situ* deposit with decomposing bedrock at the base. At the locality of trench 7 approximately 40 cm below surface consist of dredge fill and reworked sediments.

Conclusions

No subsurface archaeological deposits were encountered during the subsurface testing. Trench 1 was excavated at what was considered the most probable location for McAllister's site 5, on a low bedrock knoll adjacent to Ka'ili'ili Bay. No cultural deposits were found. There was no evidence that the tested deposit of boulders and cobbles was a structural remnant. No probable location for McAllister's site 4 (the other coastal site McAllister noted within the current project area) stood out on the landscape. Consequently, no attempt was made to find subsurface remains of this feature.

Trenches 2 through 7 documented the layers of fill material and reworked sediments that were deposited over this portion of the project area. The thickness of this deposit was up to 1.6 meters thick (in trench 5). Fill material consisted of terrigenous as well as marine sediment. This fill undoubtedly dates to the grading, dredging, and material stockpiling operations of the 1960s and 1970s. No archaeological deposits are thought to have survived these operations.

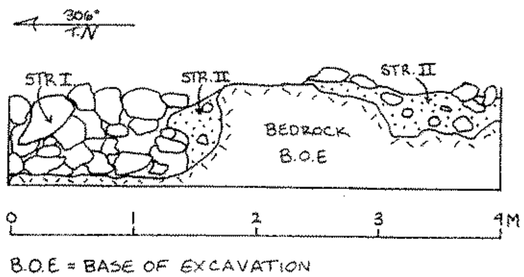


Figure 25 East profile of trench 1.

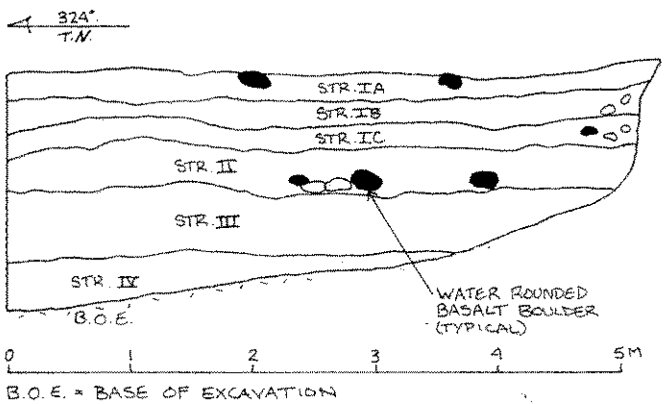


Figure 26 East profile of trench 2.

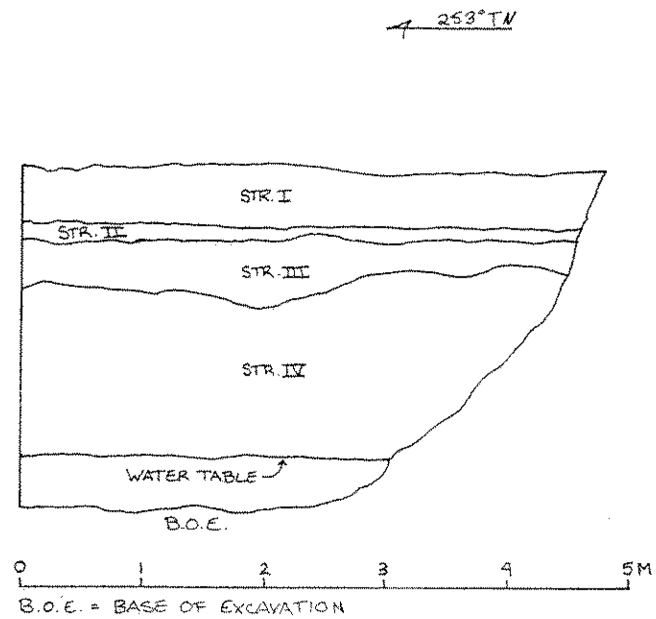


Figure 27 South profile of trench 3.

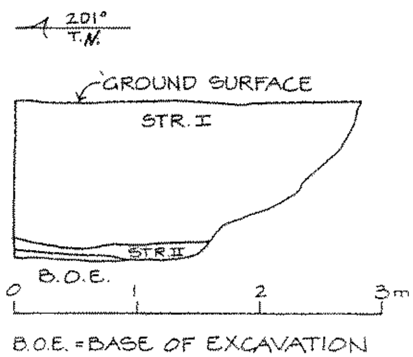


Figure 28 North profile of trench 4.

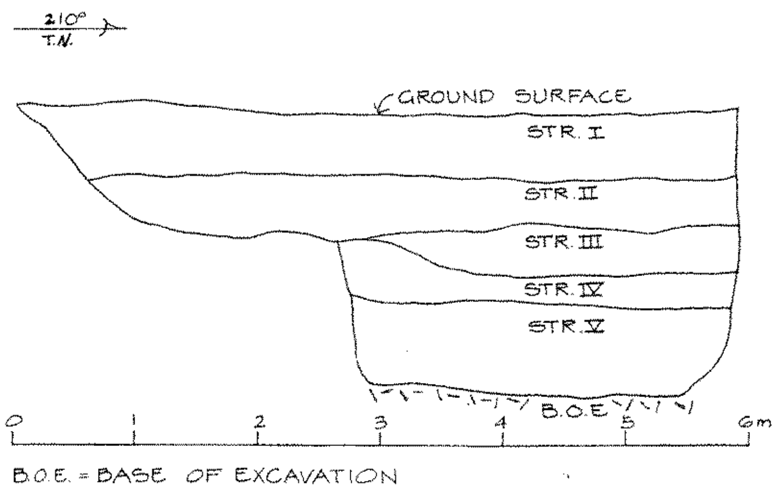


Figure 29 East profile of trench 5.

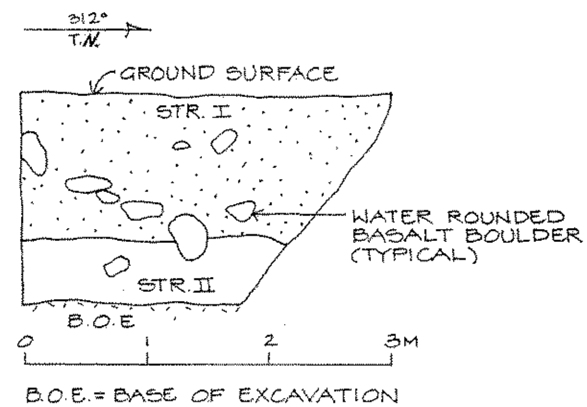


Figure 30 West profile of trench 6.

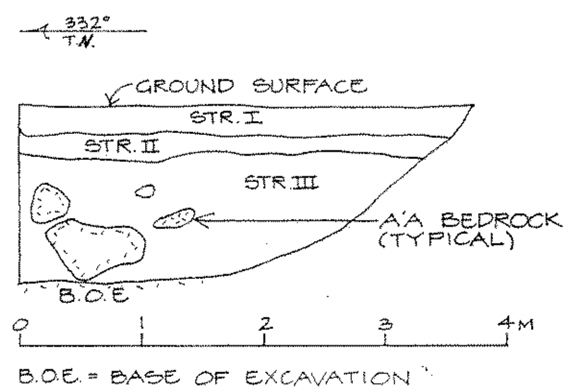


Figure 31 North profile of trench 7.

VII. FINDINGS AND ARCHAEOLOGICAL INTERPRETATIONS

The Queen's Beach project area was the site of major landscape modifications, first, to a lesser extent by the 1946 tsunami, and second, to a much greater extent, by the development of Hawaii Kai.

McAllister, in 1930, recorded five archaeological sites within the confines of the Queen's Beach project area. These included habitations, agricultural mounds, burial mounds, a historic roadway, and ranching infrastructure. Two archaeological assessments were done of the project area subsequent to the land alterations listed above (Kelly et. al 1984 and Walker et. al 1996). These reports concluded that only McAllister's site 3 (Kealakipapa Valley road) had survived the land alterations.

Alterations to the project area are documented in the testimony of Roger James, the supervisor of the Queen's Beach operations from 1959 to 1964. Bays were dredged and expanded, land surfaces were scoured, graded, and leveled, sediments were stockpiled, and a breakwater was constructed. The 1961 aerial photograph further documents these alterations. The 1984 aerial photograph shows that drainage channels have been created through the coastal flat and that large portions of the project area were used to stockpile armor rock.

During this inventory survey one hundred percent pedestrian coverage of the project area along with limited subsurface testing has demonstrated that the archaeological features and deposits previously extant within the project area have not survived. The location of McAllister's site 3 is still visible on the landscape where it has been incorporated into a network of four-wheel-drive roads, but no structural remains could be found of this former paved roadway. It appears that Marion Kelly's fears regarding the activity of moss rock hunters has come to pass--the Kealakipapa Valley road remnants have been stripped of their stones.

McAllister's site 3 represents the single site remnant found within the project area. Previous investigations (McAllister 1933, Kelly et. al. 1984, Carpenter 1992, and Walker et. al. 1994) have described this site in varying detail and the overall trend of site degradation with passing time is clear. The site has been transformed from the historic roadway described by McAllister as well paved, with curb stones, and low bordering side walls, to the site remnant visible today, a cleared area in the grass and *kiawe* without structural remains.

VIII. SIGNIFICANCE AND RECOMMENDED TREATMENT

The structural remains of Kealakipapa Valley road within the project area (previously noted by McAllister, Kelly, and Carpenter, but not observed by the most recent investigation by Walker) were not found within the project area during the inventory survey. Although tall, green vegetation hampered investigation of this site, even several hours of searching did not locate any signs of the paving, curbstones, or "side rock-walls" (McAllister 1933:59) attributed to the site. It is clear from a chronological analysis of the different descriptions of this site that it has undergone steady destruction over the years. Four-wheel-drive roads, and moss rock hunters have taken their toll. It appears that the road has become nothing more than a cleared area in the *kiawe*.

The remains of McAllister's site 3 (State site # 50-80-15-03) was significant under State and National Registers of Historic Places Criterion D (has yielded or is likely to yield information for research on prehistory or history). The site remnant has been mapped, described, and its location has been plotted. This has recorded all the available information for the site remnant. The site is therefore considered no longer significant. Because there are no significant archaeological sites within the project area, no further research is recommended. The project area does not contain archaeological considerations that should influence development.

The following general recommendations are given regarding the intact structural remains of site 3 that lie north of the project area. These remains will not be impacted by development within the present project area and are outside the scope of the current report, however, future investigators should be aware of their presence.

Outside the current project area site 3 is still visible as a paved and terraced series of four switch backs that descend from Makapu'u Lookout toward Makapu'u Beach (as described and mapped by Carpenter [1992]). At this location the site is still fairly well preserved--not having suffered the degradation of moss rock pickers and armor-rock stockpiling. Because site integrity, including structural remains, is largely intact, it is here that the site should be preserved as a significant historical resource.

IX. REFERENCES CITED

Armstrong, Warwick, Ed.
1973 *Atlas of Hawai'i*, University of Hawaii Press, Honolulu.

Barrera, William M., Jr.
1986 *Letter Report, Archaeological Reconnaissance Survey of Kaumana Ke'amuku Transmission Line.*

Bayard, Donn, T.
1969 *Limited Survey and Excavation at Site 0-16, Hawaii Kai* Ms. on file, DLNR, Honolulu

Bevaqua, R.
1972 *A Burial Cave on Mauna O Ahi Ridge* (TMK: 3-9) Site 80-15-3998. Ms. on file, DLNR, Honolulu.

Bingham, Hiram
1847 *A Residence of Twenty-One Years in the Sandwich Islands*, Huntington, Hartford Conn., Convers, New York.

Borthwick, Douglas and Hallett H. Hammatt
1992 *Archaeological Assessment of the Proposed Fiber Optic Cable Landing for East O'ahu, Sandy Beach Park, Maunalua (TMK 3-9-12:02), District of Honolulu,* Cultural Surveys Hawaii

Borthwick, Douglas F. and Hallett H. Hammatt
1991a *Archaeological Survey for the Proposed Na Pali Haweo Electrical Transmission Line Relocation Alignment Kamehame Ridge, Hawaii Kai, O'ahu*, Cultural Surveys Hawaii, Kailua, HI.

Borthwick, Douglas and Hallett H. Hammatt
1991b *Archaeological Survey for the Proposed Kamehame Ridge Unit III Water Reservoir, Kamehame Ridge, Hawaii Kai, O'ahu TMK 3-9-10:1*, Prepared for Pacific Planning and Engineering, Cultural Surveys Hawaii, Kailua, HI.

Carlson, Arne, K and Paul H. Rosendahl
1990 *Supplemental Archaeological Inventory Survey, Kaluanui - 1* Subdivision, Land of Maunalua, Honolulu. PHRI, 1990.

Carpenter, Alan
1992 *Fieldcheck of Kealakipapa Valley Road Remnants, Makapu'u Head, Maunalua, and Waimanalo, Koolaupoko, State Site 50-80-15-03* (TMK: 3-9-11:02, 4-1-14:02), DLNR, Division of State Parks.

Chamberlain, Levi
1826 Diary Insert 1. Manuscript filed in Hawaii Mission Children's Society Library.

Clark, John R. K.
1977 *The Beaches of O'ahu*, University of Hawaii Press, Honolulu, HI.

Davis, Bertell D.
1984 *The Halekulani Hotel Site, O'ahu: Archaeological and Historical Investigations in Waikiki*, Bishop Museum Manuscript 022384, Honolulu.

Dean, Love
1991 *The Lighthouses of Hawai'i*, University of Hawaii Press, Honolulu.

Emory, Kenneth P., and Yosihiko H. Sinoto
1961 *Hawaiian Archaeology: Oahu Excavations*, Bishop Museum Special Publication 49, Honolulu.

Folk, William H., Douglas F. Borthwick and Hallett H. Hammatt
1993 *Archaeological Survey for the Proposed 5-Acre Kaluanui Park Development at Maunalua, Kona District, O'ahu*, (Revised October) Kailua, HI.

Foote, Donald E., E.L. Hill, S. Nakamura and F. Stephens
1972 *Soil Survey of the Islands of Kaua'i, Oahu, Maui, Molokai and Lanai, State of Hawaii*, U.S. Dept. of Agriculture, U.S. Government Printing Office, Washington, D.C.

Green, Elizabeth
1926 *Folk Tales from Hawaii*. Publications of the Folk-lore Foundations, Second Series. Poughkeepsie, New York: Vassar College.

Handy, E.S. Craighill and Elizabeth G. Handy
1972 *Native Planters in Old Hawaii: Their Life, Lore, and Environment*, Bishop Museum Bulletin 233, Honolulu.

Handy, E.S. Craighill
1940 *The Hawaiian Planter*, Volume 1, Bishop Museum, Bulletin No. 161., Honolulu

ʻĪʻī, John Papa
1983 *Fragments of Hawaiian History*, Bishop Museum Press, HonoM & E Plulu.

Jackson, George E. G.
1881-1885 *Jackson's land Survey Notes: Oahu, Hawaii, Maui, Molokai and Kauai.* Bishop Museum?, Honolulu (State Historic Preservation Division).

James, Van
1991 *Ancient Sites of O'ahu*: A Guide to Hawaiian Archaeological Places of Interest. Bishop Museum Press Honolulu, Hawai'i

Jones, Bruce A.
1996 *Aspects of Inland Settlement in the Hawaii Kai Region: Results of an Archaeological Inventory Survey of Nine Parcels, Ahupua'a of Maunalua, Honolulu District, Island of Oahu, (TMK: 3-9-8: Por. 13 and 3-9-10: Por. 1), Aki* Sinoto Consulting, Honolulu, HI.

Kawachi, Carol and Mark Smith
1990 *Field Check and Removal of Burial at Ka'ili'ili, Maunalua, Kona, O'ahu, Site 80-15-3990 (TMK 3-9-11:02)*, Memorandum, State of Hawaii, Department of Land and Natural Resources, Historic Preservation Program, Honolulu, HI.

Kelly, Marion
1984 *Cultural Resources Overview for The Queen's Beach Park Feasibility Study, Maunalua, Kona, O'ahu*, Part I: Legends of Maunalua, O'ahu and Part III: Historical Notes on Queen's Beach and Other Places in Maunalua, O'ahu, Department of Anthropology, Bishop Museum, Honolulu, Hawaii.

Kennedy, Joseph and Tim Denham
1992 *Inventory Survey and Subsurface Testing Report for an extension of Sandy Beach Park at Wawamalu (Awawa-Malu), Island of Oahu, District of Ko'olaupoko, Maunalua Ahupua'a, TMK: 3-9-10:2 & 3, 3-9-12:2 and 3-9-15:1, 19 & 20*, ACH Inc. Haleiwa, Hawaii.

McAllister, J.G.
1933 *Archaeology of O'ahu*, Bishop Museum, Bulletin 104, Honolulu.

McAllister, J. Gilbert.
1933 *Archaeology of Oahu*, Bishop Museum Bulletin 104 Honolulu: B. P. Bishop Museum Press

McCoy, P.
1971 *Exploration of a Burial Rockshelter on Kaalakei Ridge, Oahu* (TMK 3-9-08: 80-15-3995). MS. On file, DLNR, Honolulu

Portlock, Nathaniel.
1968 *A Voyage Round the World*, New York: De Capo Press.

Price-Beggerly, Patricia and J.R. McNeill
1985 *Archaeological Reconnaissance of the Proposed Marina Zoning Project, Kaluanui 1, 2, and 3 (Hawaii Kai)*, J. Stephen Athens, Honolulu.

Pukui, Mary Kawena and Samuel H. Elbert
1981 *Hawaiian Dictionary*, University of Hawaii Press, Honolulu.

Pukui, Mary K., Samuel H. Elbert and Esther Mookini
1974 *Place Names of Hawaii*, University of Hawaii Press, Honolulu.

Pukui, Mary Kawena and Samuel H. Elbert
1981 *Hawaiian Dictionary*, University of Hawaii Press, Honolulu.

Schmitt, Robert C.
1968 *Demographic Statistics of Hawaii: 1778-1965*, University of Hawaii Press, Honolulu.

Shepard, F.P., G.A. Macdonald and D.C. Cox
1950 *The Tsunami of April 1, 1946*, University of California Press, Berkeley, CA.

Shun, Kanalei
1988 *Archaeological Survey of Kamehame Ridge Subdivision, Unit 2, Phase I. Hawaii Kai, O'ahu, Archaeological Associates Oceania, Honolulu.*

Spear, R.
1987 *Archaeological Reconnaissance Survey of Golf Course 5 and 6 Cluster Subdivision Sites, Hawaii Kai Community, Maunalua* (TMK: 2-9-10:por 1). PHRI

Stearns, Harold T.
1939 *Geologic Map and Guide to Oahu, Hawaii, Territory of Hawaii*, Division of Hydrography, Bulletin 2, Honolulu

Sterling, Elispeth P. and Catherine C. Summers (comp.)
1978 *Sites of O'ahu*, Dept. of Anthropology, B.P. Bishop Museum, Honolulu, Hi.

Summers, Catherine and Elispeth Sterling.
1962 *Sites of Oahu*, Book 6, Vol. 1, Honolulu: Bishop Museum Press

Takemoto, Anne H., et. al.
1975 "Historical/Cultural Essay Report on the Kuapa Pond Area, " On file at the State Historic Preservation Division.

Walker, Alan T., and Kepa Maly and Paul H. Rosendahl
1996 *Archaeological Assessment Proposed Golf Course at Queen's Beach Land of Maunalua, Honolulu District, Island of O'ahu (TMK:1-3-9-11:3;Por: 2)* PHRI, Paul H. Rosendahl, Ph.D., Inc.

Wallace, W.J., E.T. Wallace, and V. Meeker
1966 *Excavation of a Coastal Dwelling Site (017) on the Island of Oahu* (TMK: 3-9-11:02). MS on file, DLNR, Honolulu

Webster, William
1851 *Plan of the Land of Maunalua in Oahu,* Map Register no. 980
State Survey Office, Honolulu.

X. PHOTO APPENDIX

Figure 32 Shot east of the north shore of Kaloko Inlet showing the result of mechanized excavation. Dredge material is stockpiled on the bank of the inlet.

Figure 33 Shot north of artificially created berm at Kaho'ohaihai Inlet consisting of different excavated and stockpiled sediments.

Figure 34 Shot north from coastal flat near Kaho'ohaihai towards Kealakipapa Valley. Underneath the vegetation are armor rock deposits.

Figure 35 Shot south of eastern portion of the excavated channel between Ka'ili'ili Bay and Kaho'ohaihai Inlet where four-wheel-drive road crosses channel.

Figure 36 Shot northwest of the level portion of the coastal flat (lacking armor rock) near Kaho'ohaihai Inlet.

Figure 37 Shot south from Kealakipapa Valley towards Kaho'ohaihai with Pele's Throne visible in the distance.

Figure 38 Shot west of graded area in Kealakipapa Valley.

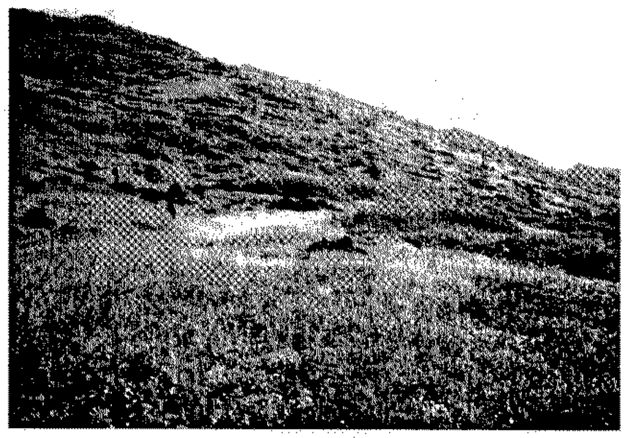


Figure 39 Shot east of Kealakipapa Valley near Waimanalo Gap showing old bulldozer/truck paths and armor rock alignments. This photo shows the approximate location of McAllister's site 2.

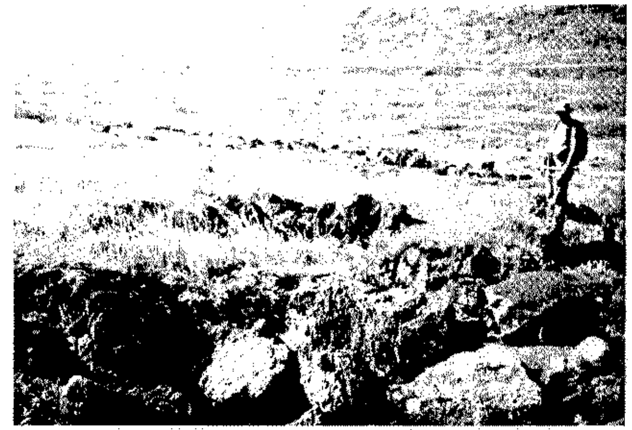


Figure 40 Shot southeast of armor rock piles in Kealakipapa Valley.

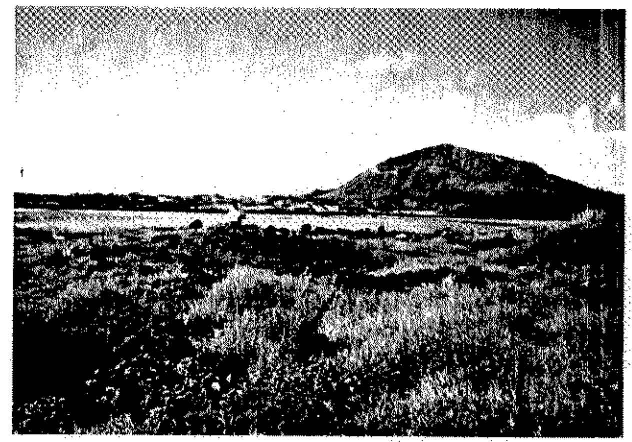


Figure 41 Shot southwest of the general vicinity of McAllister's site 5 just east of Ka'ili'ili Bay. A crew archaeologist is seated on the bedrock knoll tested in trench 1.

Figure 42 Shot north of trench 1 showing the predominant basalt boulder and cobble deposit. This bedrock knoll did not contain a cultural deposit.

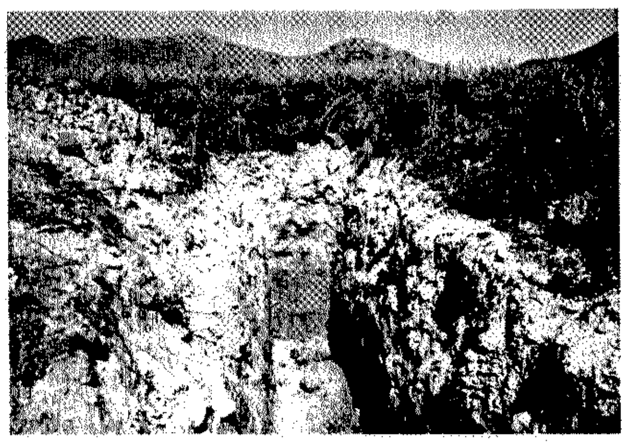


Figure 43 Shot north of trench 2 showing the coral gravel/sand dredge fill over the darker alluvial deposit.

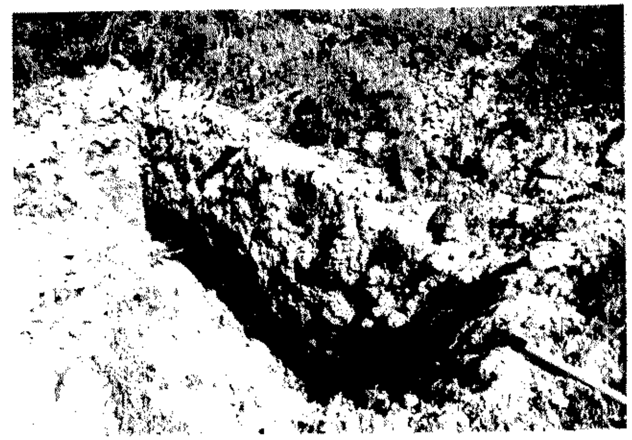


Figure 44 Shot northeast of trench 2 showing layer of coral dredge fill over alluvial deposit.

Figure 45 Shot east of trench 3. Crew archaeologist is standing in 50 cm of water. Layers of dredge fill are visible above the darker alluvial deposit.

Figure 46 Shot southwest of trench 5. The large boulders visible in the back dirt piles came from the numerous fill and reworked sediment layers encountered in this excavation.

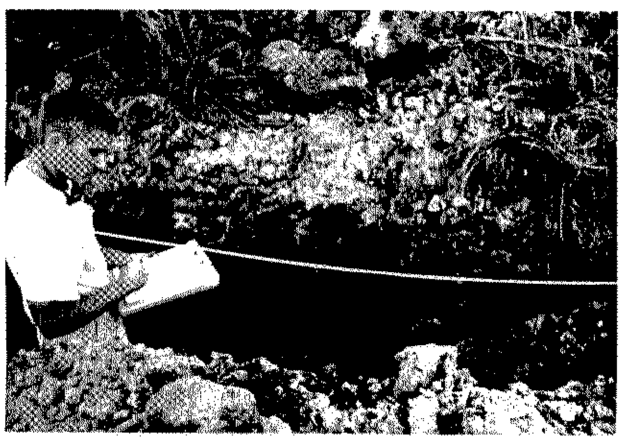


Figure 47 Shot southwest of trench 6, near the coast. Reworked dredge and beach deposit overlays alluvium and decomposing bedrock.

QUEEN'S BEACH GOLF COURSE

Appendix

I

Air Quality Impact Report

(J.W. Morrow Environmental Management Consultant)

AIR QUALITY IMPACT REPORT

HAWAII KAI PROPERTIES
(Revised)

1 July 1996

PREPARED FOR:

Maunalua Associates, Inc.

Kaiser Aluminum and Chemical Corporation

and

Kamehameha Schools Bernice Pauahi Bishop Estate

PREPARED BY:

J. W. MORROW
Environmental Management Consultant
1481 South King Street, Suite 548
Honolulu, Hawaii 96814

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

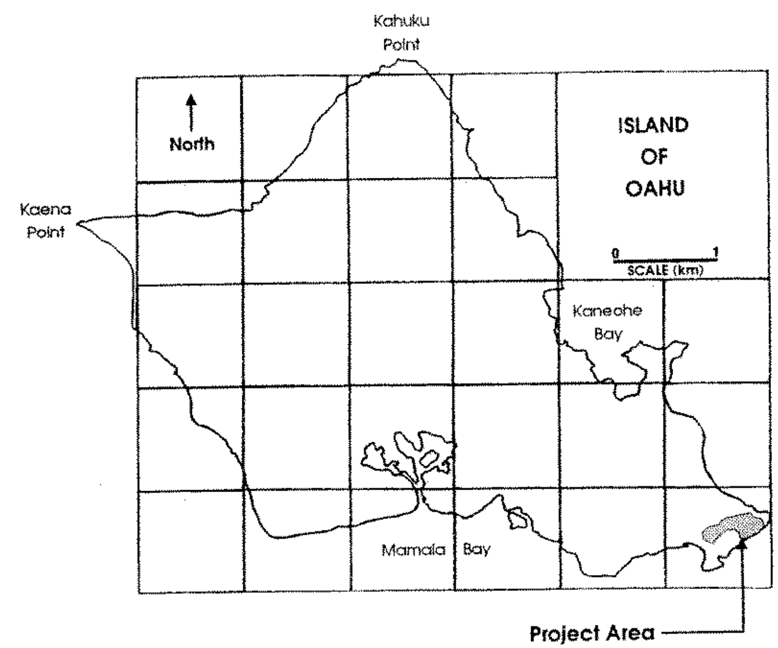
The Hawaii Kai Development Company (HKDC), Kaiser Aluminum and Chemical Company (KACC), and Kamehameha Schools - Bernice Pauahi Bishop Estate (KSBE) are proposing to develop the following land parcels in the Hawaii Kai area of Oahu (Figure 1).

Parcel Name	Tax Map Key:	Land Use	Acres	Units
Kamilonui 1	3-9-8: por 13	Apartment	17.4	510
Kamilonui 2	3-9-8: por 13	Residential	62.8	364
Marina 4B	3-9-8: 29	Residential	5.1	75
Kamilo Ridge	3-9-8: por 13	Residential	36.6	5
Kalama Valley	3-9-82: 61 & 62	Apartment	36.6	176
Mauuwai	3-9-10: por 10	Residential	82.7	143
Queen's Rise	3-9-10: por 10	Residential	101.9	194
Golf Course 2/1A	3-9-10: por 1	Residential	9.8	45
Queen's Beach	3-9-11: 3, por 2	Golf Course	166.0	---
Golf Course 2/1A	3-9-10: por 1	Industrial	10.9	---
"	"	Inn	29.1	140 rooms
Marina 1/Strip 1				
Marina 1	3-9-17: 20	Commercial	4.3	---
Strip 1	3-9-17: 38	Commercial	2.3	---
City Park & Ride	3-9-17: 21	Public Facility	5.0	---
Hawaii Kai Yacht Club	3-9-17: por 13	Yacht Club	2.4	---

The purpose of this report is to assess the impact of the proposed development on air quality on a local and regional scale. The overall project can be considered an "indirect source" of air pollution as defined in the federal Clean Air Act [1] since its

FIGURE 1

PROJECT LOCATION



primary association with air quality is its inherent attraction for mobile sources, i.e., motor vehicles. Much of the focus of this analysis, therefore, is on the project's ability to generate traffic and the resultant impact on air quality. Air quality impact was evaluated for existing (1996) and future (2017) conditions with and without the proposed development.

A project such as this also has offsite impacts due to increased demand for electrical energy which must be met by the combustion of some type of fuel and the incineration of solid waste generated by project residents. Both these processes result in pollutant emissions to the air which have been addressed in this report.

Finally, during construction of the various buildings and facilities air pollutant emissions will be generated onsite and offsite due to vehicular movement, grading, concrete and asphalt batching, and general dust-generating construction activities. These impacts have also been addressed.

2. AIR QUALITY STANDARDS

A summary of State of Hawaii and national ambient air quality standards is presented in Table 1 [2, 3]. Note that Hawaii's standards are not divided into primary and secondary standards as are the federal standards.

Primary standards are intended to protect public health with an adequate margin of safety while secondary standards are intended to protect public welfare through the prevention of damage to soils, water, vegetation, man-made materials, animals, wildlife, visibility, climate, and economic values [4].

Some of Hawaii's standards (CO, NO_2, and O_3) are clearly more stringent than their federal counterparts but, like their federal counterparts, may be exceeded once per year. It should also be noted that in November 1993, the Governor signed amendments to Chapter 59, Ambient Air Quality Standards [3], adopting the federal standard for particulate matter equal to or less than 10 microns in diameter (PM_{10}). Since measurement data in Hawaii indicate that PM_{10} comprises about 50% of total suspended particulate matter (TSP), the adoption of that federal standard with a numerical value equal to the original state TSP standard of 150 $\mu g/m^3$ represents a substantial relaxation of the standard (approximately doubling it).

In the case of the automotive pollutants [carbon monoxide (CO), oxides of nitrogen (NOx), and photochemical oxidants (Ox)], there

TABLE 1

SUMMARY OF STATE OF HAWAII AND FEDERAL AMBIENT AIR QUALITY STANDARDS

POLLUTANT	SAMPLING PERIOD	NAAQS PRIMARY	NAAQS SECONDARY	STATE STANDARDS
PM_{10}	Annual	50	50	50
	24-hr	150	150	150
SO_2	Annual	80	---	80
	24-hr	365	---	365
	3-hr	---	1,300	1,300
NO_2	Annual	100	---	70
CO	8-hr	10	---	5
	1-hr	40	---	10
O_3	1-hr	235	---	100
H_2S	1-hr	---	---	35
Pb	Calendar Quarter	1.5	---	1.5

KEY:
PM_{10} - particulate matter < 10 microns
SO_2 - sulfur dioxide
NO_2 - nitrogen dioxide
CO - carbon monoxide
O_3 - ozone
H_2S - hydrogen sulfide
Pb - lead

All concentrations in micrograms per cubic meter ($\mu g/m^3$) except CO which is in milligrams per cubic meter (mg/m^3).

are only primary standards. Until 1983, there was also a hydrocarbons standard which was based on the precursor role hydrocarbons play in the formation of photochemical oxidants rather than any unique toxicological effect they had at ambient levels. The hydrocarbons standard was formally eliminated in January, 1983 [5].

The U.S. Environmental Protection Agency (EPA) is mandated by Congress to periodically review and re-evaluate the federal standards in light of new research findings [1]. The last review resulted in the relaxation of the oxidant standard from 160 to 235 micrograms/cubic meter (ug/m^3) [6]. The carbon monoxide (CO), particulate matter, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) standards have been reviewed, but no new standards have been proposed.

Finally, the State of Hawaii also has fugitive dust regulations for particulate matter (PM) emanating from construction activities [7]. There simply can be no visible emissions from fugitive dust sources.

3. EXISTING AIR QUALITY

3.1 General. The State Department of Health (DOH) maintains a limited network of air monitoring stations around the state to gather data on the following regulated pollutants:

- o particulate matter ≤ 10 microns (PM_{10})
- o total suspended particulate matter (TSP)
- o sulfur dioxide (SO_2)
- o carbon monoxide (CO)
- o ozone (O_3)

In the case of PM_{10} and SO_2, measurements are made on a 24-hour basis to correspond with the averaging period specified in State and Federal standards. Samples are collected once every six days in accordance with U.S. Environmental Protection Agency (EPA) guidelines. Carbon monoxide and ozone, however, are measured on a continuous basis due to their short-term (1-hour) standards. Lead concentrations are determined from the TSP samples which are sent to an EPA laboratory for analysis. It should also be noted that the majority of these pollutants are monitored only in Honolulu.

TABLE 2

AIR QUALITY DATA
DEPARTMENT OF HEALTH MONITORING SITES
1988 - 1990

POLLUTANT	Concentration (μg/m^3)		
	1988	1989	1990
Total suspended particulate matter (TSP)	15 - 45 26	16 - 48 29	13 - 47 30
Particulate matter < 10 microns (PM_{10})	9 - 25 17	10 - 33 16	8 - 36 15
Sulfur dioxide (SO_2)	<5 - <5 <5	<5 - 8 <5	<5 - <5 <5
Carbon monoxide (CO) DOH Bldg:	0.2 - 10.3 1.7	0.3 - 9.7 1.9	0.1 - 7.1 1.5
Waikiki:	0.3 - 7.3 2.6	0.8 - 9.0 2.9	0.6 - 11.7 2.1
Ozone (O_3)	0 - 92 14	0 - 94 15	4 - 116 36
Lead (Pb)	0 - 0.1 0	0 - 0.1 0	0 - 0 0

Notes:
1. Values indicate range and annual mean.
2. TSP, PM_{10}, and SO_2 are 24-hr values; CO and O_3 are 1-hr; Pb is quarterly average.
3. TSP, SO_2, and Pb are from the DOH building.
4. CO values are mg/m^3.
5. PM_{10} data are from the Liliha site.
6. O_3 data are from the Sand Island site.

3.2 Department of Health Monitoring. There are no permanent air monitoring stations in the Hawaii Kai area . A summary of the most recent published air quality data from the nearest stations is presented in Table 2.

3.3 Onsite Carbon Monoxide Sampling. In conjunction with this study, air sampling was conducted in November 1994, at two locations along Kalanianaole Highway. The sites were selected because of their downstream locations relative to the proposed project and its traffic generators. Site 1 was located at the property line of a makai side residence just east of the Laukahi Street intersection. Site 2 was the makai side sidewalk just west of the East Halemaumau Street intersection. In each case the sampling site was within 10 meters of the nearest traffic lane. A continuous carbon monoxide (CO) instrument was set up and operated during the a.m. and p.m. peak traffic hours. An anemometer and vane were installed to record onsite surface winds during the sampling. A simultaneous manual count of traffic was also performed. The variability of each of the parameters measured during the peak hours is clearly seen in Figures 2 - 5.

Weather conditions during the afternoon of 16 November 1994 at Site 1 were moderate northerly winds, 2 - 8 mph, light showers and neutral stability due to the overcast sky. Total 2-way traffic counted was about 12% lower than the p.m. peak hour volume reported for that highway segment in the traffic consultant's most recent report on existing conditions [16]. CO concentrations measured were low (1 - 2 mg/m^3) due to the wind speed and generally free flow traffic conditions.

On the morning of 17 November 1994, the northeasterly winds at Site 1 were slightly higher than they had been the previous afternoon, running 4 - 9 mph. Skies were overcast yielding a neutral atmosphere again. Total traffic was 10% lower than the a.m. volume reported by the traffic consultant [16], and the CO level was again low, i.e., 1 - 2 mg/m^3.

At Site 2, on the morning of 18 November 1994, winds were gusty northeasterly trades running 6 - 14 mph. Skies were partly cloudy; atmospheric stability was neutral. Traffic level was about 6% lower than the a.m. peak volume reported in the traffic assessment [8]. CO levels were again in the 1 - 2 mg/m^3 range.

FIGURE 2

P.M. PEAK HOUR CONDITIONS
KALANIANAOLE HIGHWAY NEAR WAIHOLO STREET
16 NOVEMBER 1994

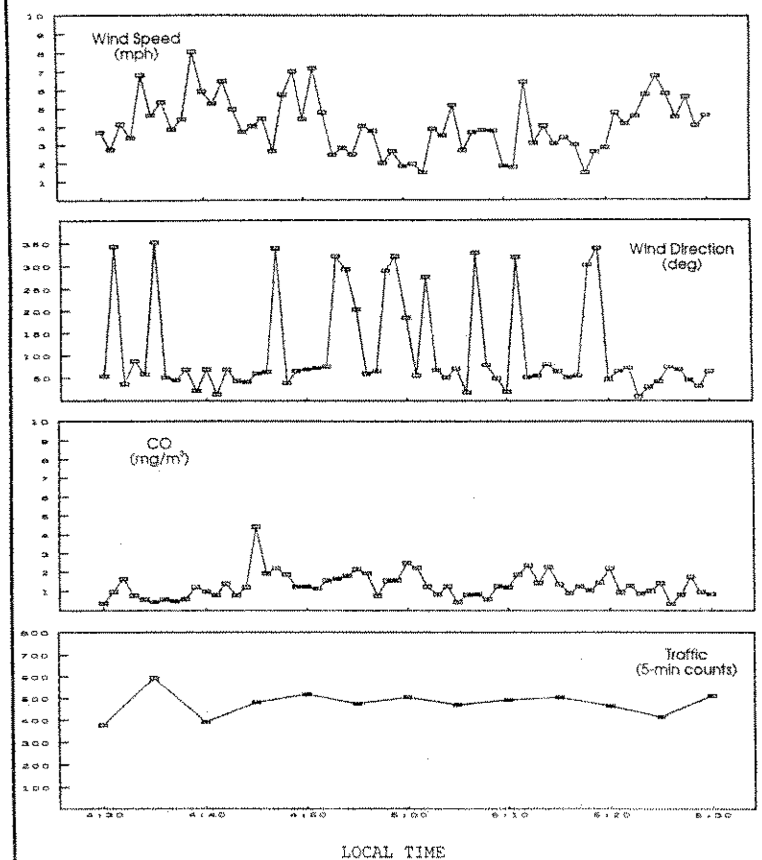


FIGURE 3

A.M. PEAK HOUR CONDITIONS
KALANIANAOLE HIGHWAY NEAR WAIHOLO STREET
17 NOVEMBER 1994

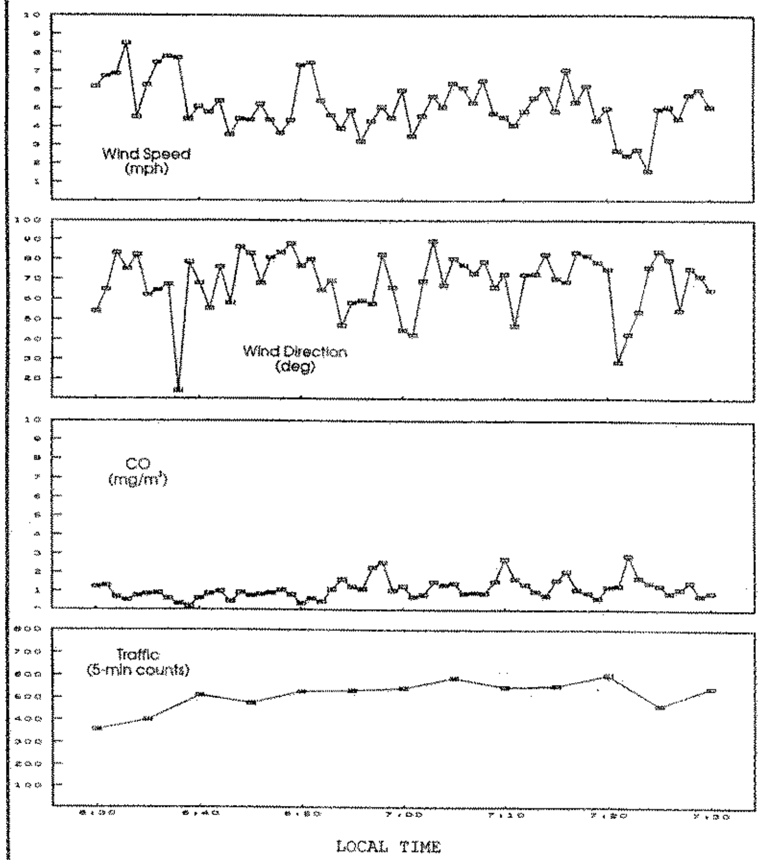


FIGURE 4

A.M. PEAK HOUR CONDITIONS
KALANIANAOLE HIGHWAY @ EAST HALEMAUMAU STREET
18 NOVEMBER 1994

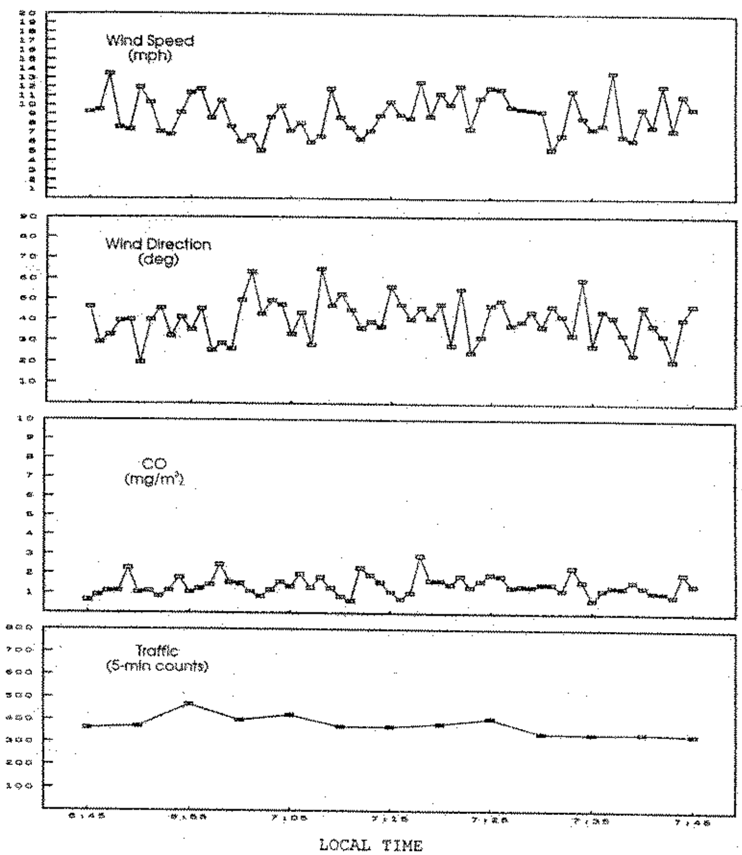
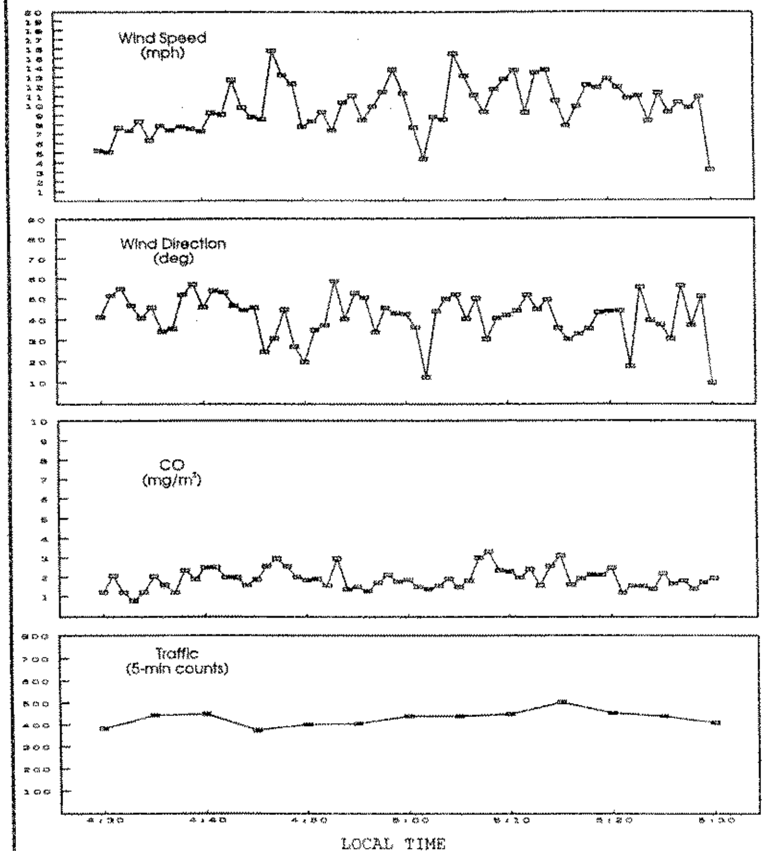


FIGURE 5

P.M. PEAK HOUR CONDITIONS
KALANIANAOLE HIGHWAY @ EAST HALEMAUMAU STREET
18 NOVEMBER 1994



On the afternoon of 18 November 1994, winds were still gusty trades running 5 - 16 mph. Skies were partly cloudy. The atmosphere was slightly unstable. CO levels were slightly higher (1 - 3 mg/m^3) due to the proximity of eastbound afternoon traffic and queues stretching back from the signalized intersection. The traffic count was within 1% of the p.m. peak volume reported for that vicinity by the traffic consultant [16].

4. CLIMATE AND METEOROLOGY

4.1 Temperature and Rainfall. Temperatures in the project area are expected to be similar to those found elsewhere in Hawaii. The nearest long-term weather station operated by the National Weather Service is located at the Honolulu International Airport. In an annual summary for that station, the National Climatic Center has summarized Honolulu's temperature regime as follows:

> Hawaii's equable temperatures are associated with the small seasonal variation in the amount of energy received from the sun and the tempering effect of the surrounding ocean. The range of temperatures averages only 7 degrees between the warmest months (August and September) and the coolest months (January and February) and about 12 degrees between day and night. Daily maximums run from the high 70's in winter to the mid-80's in summer, and daily minimums from the mid-60's to the low 70's. However, the Honolulu Airport area has recorded as high as 93 degrees and as low as 53 [9].

Historical data from the National Weather Service indicate that the project falls within an annual rainfall range of 20 - 30 inches [10]. In accordance with Thornwaite's scheme for climatic classification, the area would therefore be considered semi-arid to subhumid [10].

4.2 Surface Winds. Meteorological data records were reviewed from the Honolulu International Airport and Hickam Air Force Base. The annual prevalence of northeast trade winds is clearly shown in Table 3. A closer examination of the data, however, indicates that low velocities (less than 10 mph) occur frequently and that the "normal" northeasterly trade winds tend to break down in the Fall giving way to more light, variable wind conditions through the Winter and on into early Spring. It is during these times that Honolulu generally experiences elevated pollutant levels. This seasonal difference in wind conditions can be easily contrasted by comparing August and January wind roses (Figures 6 and 7).

TABLE 3

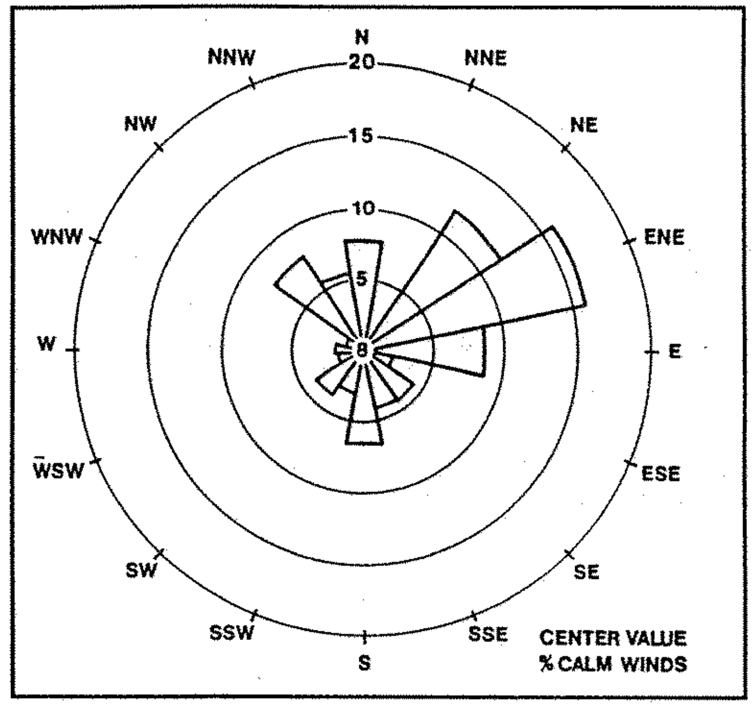
ANNUAL JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION HONOLULU INTERNATIONAL AIRPORT

Dir deg	Wind Speed (mph) 6.2	9.0	11.6	14.4	17.0	>17.0	All
10	0.0065	0.0038	0.0023	0.0016	0.0009	0.0001	0.0151
20	0.0082	0.0041	0.0025	0.0023	0.0011	0.0001	0.0183
30	0.0100	0.0061	0.0051	0.0038	0.0028	0.0007	0.0286
40	0.0188	0.0157	0.0258	0.0222	0.0174	0.0040	0.0039
50	0.0268	0.0290	0.0449	0.0385	0.0307	0.0054	0.0752
60	0.0344	0.0289	0.0436	0.0273	0.0238	0.0041	0.0621
70	0.0250	0.0181	0.0197	0.0122	0.0096	0.0009	0.0855
80	0.0113	0.0081	0.0065	0.0039	0.0009	0.0003	0.0310
90	0.0073	0.0049	0.0040	0.0009	0.0008	0.0000	0.0179
100	0.0031	0.0016	0.0014	0.0006	0.0002	0.0000	0.0068
110	0.0027	0.0019	0.0010	0.0007	0.0005	0.0001	0.0069
120	0.0027	0.0013	0.0019	0.0009	0.0003	0.0003	0.0075
130	0.0022	0.0032	0.0018	0.0015	0.0007	0.0002	0.0096
140	0.0034	0.0033	0.0039	0.0018	0.0011	0.0006	0.0141
150	0.0022	0.0030	0.0019	0.0003	0.0002	0.0005	0.0081
160	0.0024	0.0033	0.0023	0.0010	0.0005	0.0000	0.0094
170	0.0031	0.0046	0.0023	0.0007	0.0003	0.0000	0.0109
180	0.0055	0.0042	0.0018	0.0008	0.0005	0.0000	0.0128
190	0.0065	0.0038	0.0013	0.0002	0.0000	0.0000	0.0117
200	0.0057	0.0032	0.0011	0.0001	0.0000	0.0000	0.0101
210	0.0076	0.0038	0.0016	0.0001	0.0000	0.0000	0.0131
220	0.0083	0.0077	0.0016	0.0001	0.0001	0.0000	0.0179
230	0.0076	0.0049	0.0014	0.0001	0.0001	0.0000	0.0141
240	0.0042	0.0016	0.0013	0.0000	0.0000	0.0000	0.0071
250	0.0040	0.0010	0.0003	0.0000	0.0000	0.0000	0.0054
260	0.0064	0.0023	0.0005	0.0000	0.0000	0.0000	0.0091
270	0.0065	0.0010	0.0005	0.0002	0.0000	0.0000	0.0082
280	0.0099	0.0005	0.0002	0.0000	0.0000	0.0000	0.0106
290	0.0123	0.0003	0.0002	0.0001	0.0000	0.0000	0.0130
300	0.0167	0.0018	0.0011	0.0000	0.0000	0.0000	0.0197
310	0.0235	0.0022	0.0015	0.0001	0.0000	0.0000	0.0272
320	0.0200	0.0022	0.0013	0.0006	0.0001	0.0000	0.0241
330	0.0121	0.0023	0.0011	0.0005	0.0000	0.0000	0.0159
340	0.0094	0.0010	0.0003	0.0001	0.0000	0.0000	0.0109
350	0.0082	0.0025	0.0016	0.0002	0.0000	0.0000	0.0125
360	0.0093	0.0027	0.0022	0.0006	0.0005	0.0001	0.0154
All	0.3537	0.1898	0.1917	0.1240	0.0932	0.0174	0.9698
						Calms:	0.0302

SOURCE: National Weather Service, 1992

FIGURE 6

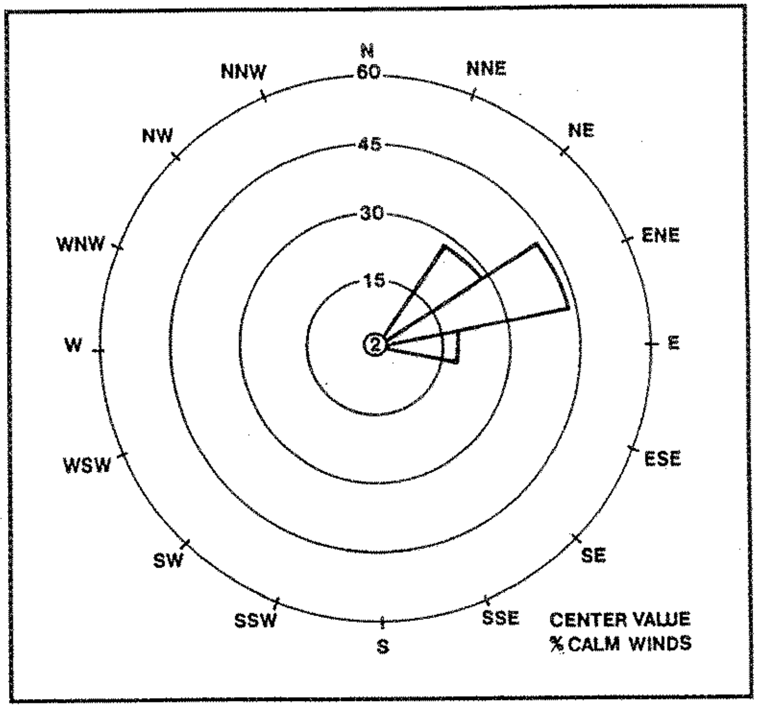
JANUARY WIND ROSE
HONOLULU INTERNATIONAL AIRPORT



SOURCE: National Weather Service
Historical Records, 1940-67

FIGURE 7

AUGUST WIND ROSE
HONOLULU INTERNATIONAL AIRPORT



SOURCE: National Weather Service
Historical Records, 1940-67

Of particular interest from an air pollution standpoint were the stability wind roses prepared for Hickam Air Force Base [11]. These data indicated that stable conditions, i.e., Pasquill-Gifford stability categories E and F [12], occur about 28% of the time on an annual basis and 36% of the time during the peak winter month (January). It is under such conditions that the greatest potential for air pollutant buildup from groundlevel sources, e.g., motor vehicles, exists.

5. SHORT-TERM IMPACTS

5.1 Onsite Impacts. The principal source of short-term air quality impact will be construction activity. Construction vehicle activity will increase automotive pollutant concentrations along the existing streets as well as on the project site itself. The additional construction vehicle traffic should not exceed street capacities although the presence of large trucks can reduce a roadway's capacity as well as lower average travel speeds.

The site preparation and earth moving will create particulate emissions as will building and onsite road construction. Construction vehicles movement on unpaved on-site roads will also generate particulate emissions. EPA studies on fugitive dust emissions from construction sites indicate that about 1.2 tons/acre per month of activity may be expected under conditions of medium activity, moderate soil silt content (30%), and a precipitation/evaporation (P/E) index of 50 [10,13].

5.2 Offsite Impacts. In addition to the onsite impacts attributable to construction activity, there will also be offsite impacts due to the operation of concrete and asphalt batching plants needed for construction. Such plants routinely emit particulate matter and other gaseous pollutants. It is too early, however, to identify the specific facilities that will be providing these materials and thus the discussion of air quality impacts is necessarily generic. The batch plants which will be producing the concrete for foundations, curbing, etc. and the asphalt for roadways must be permitted by the Department of Health Clean Air Branch pursuant to state regulations [7]. In order to obtain these permits they must demonstrate their ability to continuously comply with both emission [7] and ambient air quality [3] standards. Under the recently promulgated federal Title V operating permit requirements [14], now incorporated in Hawaii's rules [7], air pollution sources must regularly attest to their compliance with all applicable requirements.

6. MOBILE SOURCE IMPACTS

6.1 Mobile Source Activity. A revision [16] of previously provided traffic data [8,15] for the proposed project served as the basis for this mobile source impact analysis. Existing peak-hour traffic volumes and projections for 2017 for the major intersections serving the project area were provided. This analysis focused on those intersections previously found to be problematic by the traffic consultant because air quality impacts usually accompany traffic congestion. The specific problematic intersections identified in the traffic assessment were:

- Kalanianaole Highway at Keahole Street
- Hawaii Kai Drive at Kealahou Street
- Hawaii Kai Drive at Lunalilo Home Road
- Kalanianaole Highway at Kalaniiki and Laukahi Streets

See Figures 8 - 10 for existing conditions at these intersections.

6.2 Emission Factors. Automotive emission factors for carbon monoxide (CO) were generated for calendar years 1996 and 2017 using the Mobile Source Emissions Model (MOBILE-5A) [17]. To localize the emission factors as much as possible, the May 1992 age distribution for registered vehicles in the City & County of Honolulu [18] was input in lieu of national statistics. That same age distribution was the basis for the distribution of vehicle miles travelled as well.

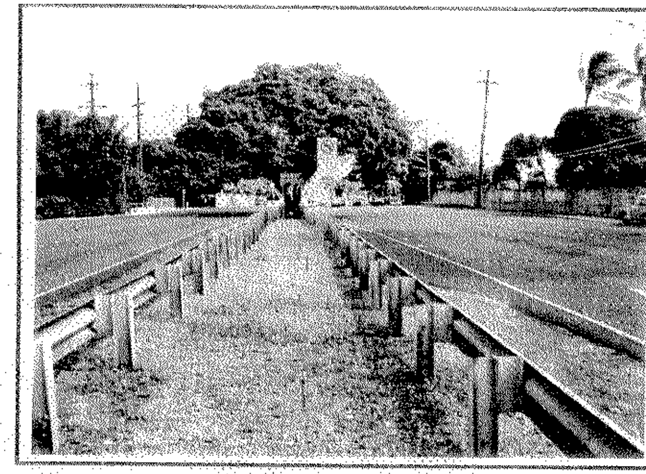
6.3 Modeling Methodology. Due to the present state-of-the-art in air quality modeling, analyses such as this generally focus on estimating concentrations of non-reactive pollutants. For projects involving mobile sources as the principal source, carbon monoxide is normally selected for modeling because it has a relatively long half-life in the atmosphere (ca. 1 month)[19], and it comprises the largest fraction of automotive emissions.

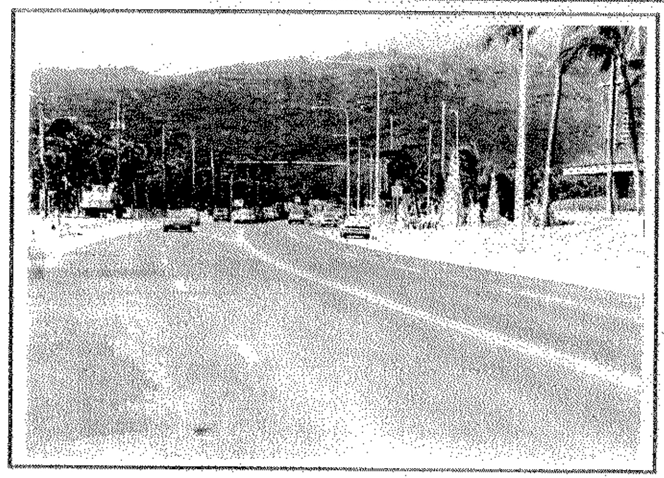
Using the traffic data provided, modeling was performed for the aforementioned intersections for 1996 and 2017 (with and without the project). For 2017, the effects of transportation demand management ("TDM") were also evaluated. Because of the suburban nature of the area, a stable atmosphere (Category "F") was input for the a.m. while neutral atmosphere (Category "D") [20] was input

FIGURE 8

KALANIANAOLE HIGHWAY AT KALANIIKI AND KEAHOLE STREETS
NOVEMBER 1994

Kalanianaole Highway at Kalaniki Street facing east



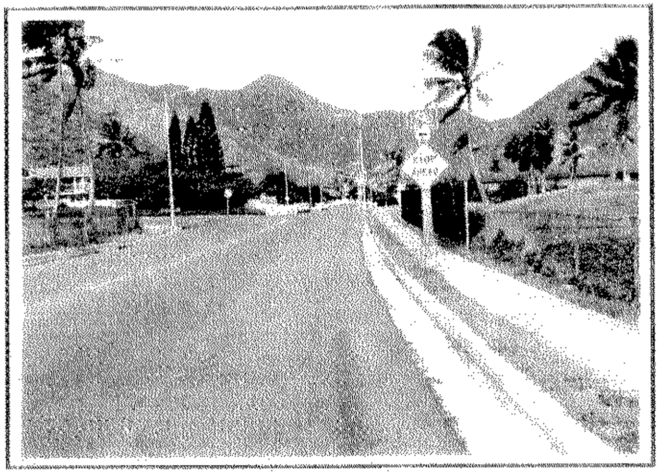


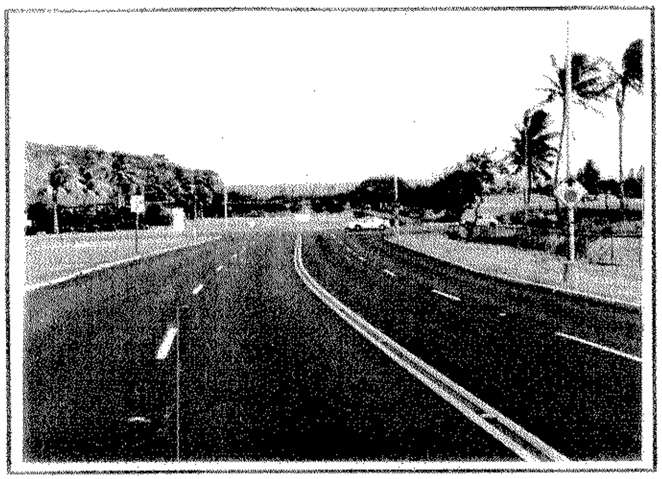
Kalanianaole Highway at Keahole Street facing northwest

FIGURE 9

HAWAII KAI DRIVE AT KEALAHOU STREET
NOVEMBER 1994

Kealahou Street facing north



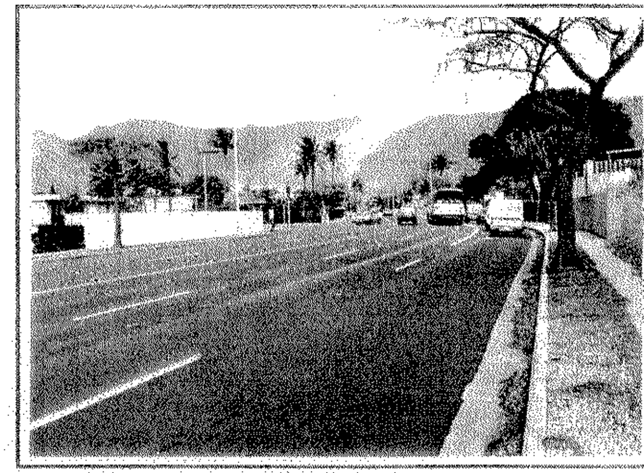


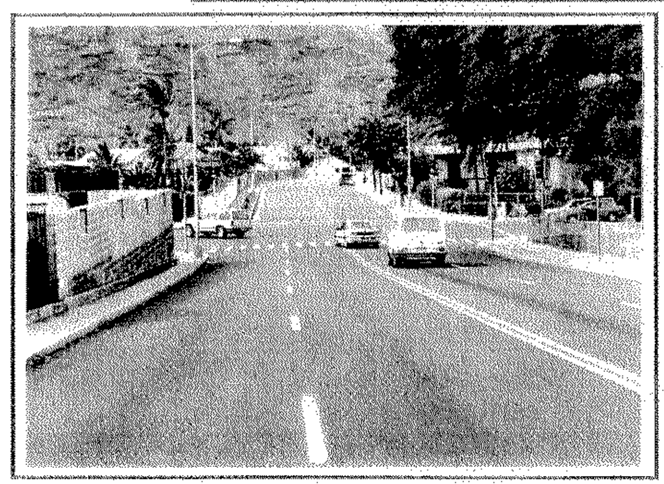
Hawaii Kai Drive approaching Kealahou Street facing southeast

FIGURE 10

HAWAII KAI DRIVE AT LUNALILO HOME ROAD
NOVEMBER 1994

Lunalilo Home Road approaching Hawaii Kai Drive facing northeast





Hawaii Kai Drive approaching Lunalilo Home Road facing northwest

6.4 Results: 1-Hour Concentrations. The results of this modeling are presented in Figures 11 - 14. Each figure depicts the locations of the 48 receptor sites around the respective intersections. Maximum estimated concentrations in milligrams per cubic meter (mg/m^3) for each of the evaluated scenarios are also presented along with the particular receptor location at which they were predicted.

The results suggest that, under worst case conditions of traffic and meteorology, the federal 1-hour CO standard would be met, but the state standard may already be exceeded in close proximity (< 10 meters) to the two Kalanianaole Highway intersections studied during the a.m. peak hour.

The 2017 predictions at the same two intersections exhibited a slight increase over modeled current levels on the order of 1 - 2 milligrams per cubic meter.

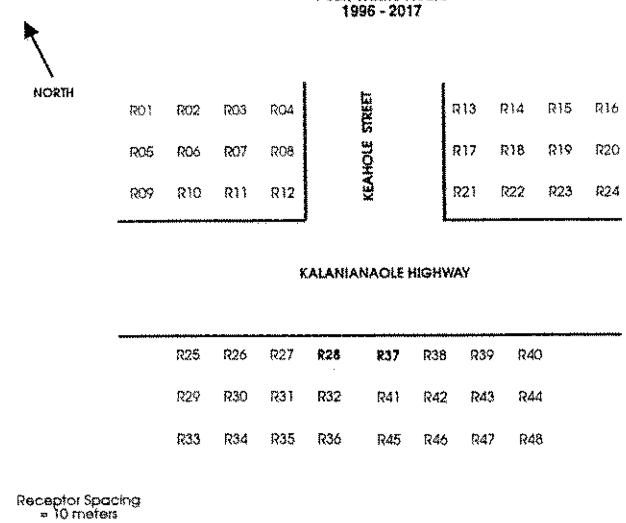
Figure 14 also indicates the effect of instituting transportation demand management (TDM) along Kalanianaole Highway in 2017 with and without the project. The effect of such management on maximum near-roadway CO levels appears to be minimal.

6.5 Results: 8-Hour Concentrations. Estimates of 8-hour concentrations can be derived by applying a "persistence" factor to the maximum 1-hour concentrations. This "persistence" factor accounts for the fact that the worst case 1-hour meteorology and traffic volumes do not persist for 8 hours. EPA recommends calculation of a persistence factor based on actual 1-hour and 8-hour CO measurements. A local persistence factor was computed from Department of Health data for a recent project [23] and used here to estimate 8-hour concentrations. The results are summarized in Table 4.

Not surprisingly, the results parallel the 1-hour findings in that exceedances of the state but not the federal standard are indicated. And, again, TDM does not appear to have a significant effect on the results.

FIGURE 11

ESTIMATES OF MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATIONS
Keahole Street at Kalanianaole Highway
Peak Traffic Hours
1996 - 2017



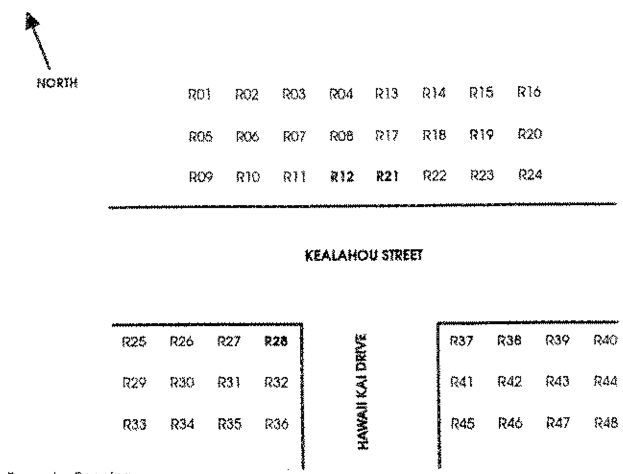
Estimated Maximum Concentrations (mg/m^3)

Period	1996	2017 w/o proj	2017 w/proj
A.M.	10.5	10.3	12.4
P.M.	8.2	9.1	10.1

LOCATION: RECEPTOR #'S 28 & 37

FIGURE 12

ESTIMATES OF MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATIONS
Kealahou Street at Hawaii Kai Drive
Peak Traffic Hours
1996 - 2017



Receptor Spacing = 10 meters

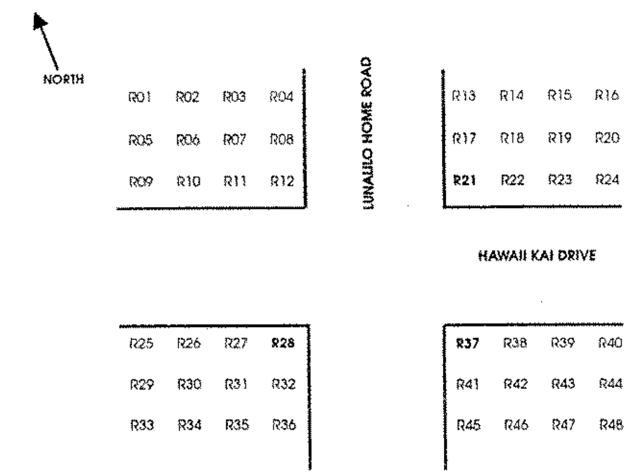
Estimated Maximum Concentrations
(mg/m^3)

Period	1996	2017 w/o proj	2017 w/proj
A.M.	3.5	3.8	5.1
P.M.	2.2	2.4	3.4

LOCATION: RECEPTOR #'S 12, 21, 28

FIGURE 13

ESTIMATES OF MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATIONS
Lunalilo Home Road at Hawaii Kai Drive
Peak Traffic Hours
1996 - 2017



Receptor Spacing = 10 meters

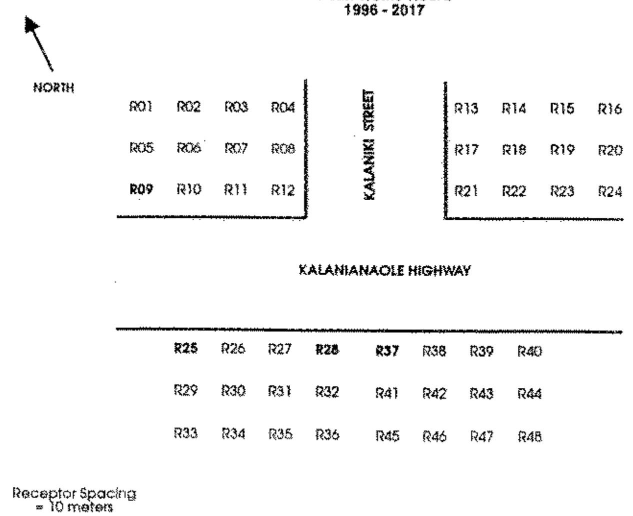
Estimated Maximum Concentrations
(mg/m^3)

Period	1996	2017 w/o proj	2017 w/proj
A.M.	6.3	6.5	7.5
P.M.	4.6	5.2	5.5

LOCATION: RECEPTOR #'S 21, 28, 37

FIGURE 14

ESTIMATES OF MAXIMUM 1-HOUR
CARBON MONOXIDE CONCENTRATIONS
Kalaniki Street at Kalanianaole Highway
Peak Traffic Hours
1996 - 2017



Estimated Maximum Concentrations (mg/m^3)

Period	1996	2017 w/o proj	2017 w/proj
A.M.	18.6	17.3	18.9
w/TDM	n/a	16.6	17.4
P.M.	11.3	10.7	11.5
w/TDM	n/a	10.4	10.6

LOCATION: RECEPTOR #'S 9, 25, 28, 37

TABLE 4

ESTIMATED MAXIMUM 8-HOUR
CARBON MONOXIDE CONCENTRATIONS
1996 - 2017

Intersection	Concentrations (mg/m^3)		
	1996 existing	2017 without project	2017 with project
Kalanianaole Highway at Keahole Street	4.9	4.8	5.8
Hawaii Kai Drive at Kealahou Street	1.7	1.8	2.4
Lunalilo Home Road at Hawaii Kai Drive	2.9	3.0	3.5
Kalanianaole Highway at Kalaniki Street	8.7	8.1 (7.8)	8.8 (8.1)

Note: Values in parentheses are with TDM.

7. OFFSITE STATIONARY SOURCE IMPACTS

7.1 Electrical Generation. The estimated 12.1 million kilowatt hours (kwhrs) of annual electrical demand by the project will necessitate the generation of electricity by power plants. Currently, most of Oahu's electrical energy is generated by Hawaiian Electric Company's oil-fired plants at Kahe Point and Waiau. These units fire low sulfur (0.5%) fuel oil. The estimated emissions resulting from fuel burned to provide the power needed by the project are presented in Table 5.

7.2 Solid Waste Disposal. The refuse generated by the residents of the proposed dwellings will required disposal. Historically, about 80% of Oahu's refuse was being landfilled with the remaining 20% being burned at the Waipahu Incinerator (which was closed down this year). With the opening of the City's resource recovery facility (HPOWER) at Campbell Industrial Park in recent years, most refuse is being pre-processed and burned leaving less mass to be landfilled. This facility was originally designed to handle most of Oahu's domestic refuse (1,800 T/day). Estimates of annual emissions attributable to the combustion of refuse from the proposed Hawaii Kai developments are included in Table 5.

TABLE 5

ESTIMATES OF ANNUAL EMISSIONS FROM OFFSITE SOURCES

Pollutant	Emissions (T/yr)	
	Electrical Generation	Solid Waste Disposal
Nitrogen oxides (NOx)	44.1	9.2
Sulfur oxides (SOx)	33.4	1.9
Particulate matter (PM)	3.4	0.8
Carbon monoxide (CO)	2.1	8.1
Volatile organic compounds (VOC)	0.4	0.5

8. PESTICIDE USE

The use of pesticides is routinely required at golf courses in order to maintain fairways and greens. Typical pesticide use at an 18-hole golf course was obtained from a recent survey of golf course pesticide use [24] and is summarized in Table 6.

An LD-50 value is the dosage of a given toxin that results in 50% mortality in the animals to which it was administered. The herbicides MSMA, metribuzin, dicamba, 2,4-D, MCPP, and oryzalin all have relatively low mammalian toxicities with oral LD-50 values on the order of hundreds or thousands of milligrams active ingredient (a.i.) per kilogram (mg/kg) body weight [25, 26]. MSMA and metribuzin have OSHA air standards of 0.5 mg/m^3 and 5 mg/m^3, respectively [26]. These are 8-hour time-weighted averages.

TABLE 6

TYPICAL PESTICIDE USAGE AT GOLF COURSES IN HAWAII

Pesticide	Applications per Year	Application Rate (lbs active ingredient/acre)
Herbicides		
MSMA	2 - 6	2.0
Metribuzin	1 - 3	0.5
Dicamba	1 - 3	2.0
2,4-D	1 - 3	0.5
MCPP	1 - 3	0.5
Oryzalin	2 - 4	2.0
Fungicides		
Metalaxyl	3 - 6	1.0
Chlorothalonil	3 - 7	7.0
Mancozeb	3 - 7	8.5
Iprodione	1 - 3	5.0
Cupric hydroxide	2 - 4	15.0
Insecticides		
Chlorpyrifos	1 - 3	1.0
Carbaryl	1 -3	4.0

The insecticide chlorpyrifos is a moderately toxic organophosphate which can affect the normal functioning of mammalian nervous systems through its inhibition of the enzyme cholinesterase. It has oral LD-50 values in the range of 60 - 82 mg/kg. The OSHA standard for airborne concentrations of chlorpyrifos is 0.2 mg/m^3 as an 8-hour average [26]. Carbaryl is a less toxic organophosphate with oral LD-50 values in the hundreds of mg/kg range and an OSHA 8-hour standard of 5 mg/m^3 [26].

The fungicides metalaxyl, chlorothalonil, mancozeb, iprodione, and cupric hydroxide have relatively low acute toxicities with oral LD-50 values in the hundreds and thousands of mg/kg [25, 26]. Chlorothalonil, however, at very high dosage, has also demonstrated some tumorigenic potential in rats [26].

If properly used in accordance with label instructions, all of the aforementioned chemicals should present no hazard to the properties or owners of properties adjoining the proposed golf course. In fact, the greatest risk in using such chemicals is generally to the users themselves if they do not strictly follow label instructions. This is because the user may come in contact with the concentrated product while nearby properties and people may only be exposed to the greatly diluted and dispersed application solution.

The potential for significant airborne concentrations of these chemicals is relatively slight when one considers the dilution factor in application solutions, the low level release height, and the coarse spray (droplet size > 100 microns) that is normally used to assure adequate coverage in the desired area and avoidance of drift. Should a user improperly apply these chemicals under wind conditions which would contribute to drift, then there would be an increased possibility of downwind exposure of property and people. In order to assess the possible impact of such an event on people, a "worst case" dispersion modeling analysis was performed for each of the chemicals. The results of this modeling are summarized in Table 7 and indicate low airborne concentrations.

9. DISCUSSION, CONCLUSIONS AND MITIGATION

9.1 Short-Term Impacts. Since portions of the development area are classified as semi-arid thus indicating an increased potential for fugitive dust, it will be important for adequate dust control measures to be employed during the construction period. Dust control could be accomplished through frequent watering of unpaved roads and areas of exposed soil. The EPA estimates that twice daily watering can reduce fugitive dust emissions by as much as 50% [13]. The soonest possible landscaping of completed areas will also help.

9.2 Mobile Source Impacts. As noted in Section 6, a slight increase in carbon monoxide (CO) levels near the intersections studied is projected. Furthermore, under worst case meteorology during peak traffic hours, there appears to be a potential for continued exceedance of the State 1- and 8-hour carbon monoxide standards due to the cumulative impact of traffic at downstream

TABLE 7

ESTIMATED MAXIMUM DOWNWIND CONCENTRATIONS UNDER WORST CASE PESTICIDE DRIFT CONDITIONS

Pesticide	Active Ingredient Concentration (mg/m^3)
MSMA	0.013
Metribuzin	0.003
Dicamba	0.013
2,4-D	0.003
MCPP	0.003
Oryzalin	0.013
Metalaxyl	0.007
Chlorothalonil	0.047
Mancozeb	0.057
Iprodione	0.033
Cupric hydroxide	0.100
Chlorpyrifos	0.007
Carbaryl	0.027

Modeling Conditions

Wind speed:	4.5 m/s
Stability category:	D (neutral)
Downwind distance:	100 m
Exposure duration:	5 - 10 min
Treated area:	1 acre
Application height:	0.5 m
Spray drift:	0.51%

Kalanianaole Highway intersections. This potential is present with or without the proposed development. Factors which mitigate against this being a matter of serious concern for the proposed project are:

- the predicted exceedances were found only close to the intersection (where people would not be expected to remain for 1 or 8 hours) under "worst case" conditions of traffic (weekday peaks) and weather (stable air, low windspeed), and only at particular receptor locations, not all close-in receptors; beyond that all standards are met;
- analysis focused on the worst intersections; all other intersections would have even lower CO concentrations;
- the probability of "worst case" conditions occurring and persisting for 1 to 8 hours is low;
- the predicted exceedances occur with or without the project; the concentration differences between the "with" and "without" scenarios is small;
- the predicted existing exceedances have not been confirmed by actual measurements; what measurement data exists indicate no exceedances;
- the difference between existing and predicted future concentrations is well within the error margin of the models suggesting that there may be no difference between present and future CO levels for the scenarios considered;
- improvements in traffic flow will mitigate the air quality impact; and
- encouragement of van and carpooling and use of public transit (The Bus) can further mitigate the impact.

9.3 Offsite Stationary Source Impacts. The proposed project will increase electrical demand which in turn will cause more fuel to be burned and more pollutants to be emitted into Oahu's air. These impacts can be mitigated by proper design of the proposed dwelling units. The State Department of Business, Economic Development and Tourism has energy conservation design guidelines which should be adhered to. As for HECO's facilities which provide the power, each must continuously demonstrate compliance with all applicable

ambient air quality standards and control regulations in order to retain its operating permit.

Emissions associated with the disposal of solid waste generated by the the project are relatively small compared to the entire county. Nevertheless, they can be reduced by encouragement of and provision of facilities for recycling and composting.

9.4 Pesticide Use. The estimated downwind pesticide concentrations presented in Table 7 indicate the level of human exposure possible under worst case conditions of high wind speed and close proximity to the source. Downwind pesticide concentration estimates were low (microgram quantities versus the miligram quantities in toxic effects studies) and of short duration (5 - 10 minutes per acre treated upwind). Because of the number of variables, e.g., nozzle pressure, spray height, spray volumes, wind speed, etc, these estimates have an error factor of 2 to 3. True concentrations could be up to 3 times greater or 1/3 as much. In either case, the concentrations and duration of exposure suggest low risk. The following measures will help reduce any possible air quality impacts associated with pesticide use:

- full compliance with label use instructions
- use of integrated pest control measures
- minimize pesticide use
- maximize use of non-chemical pest control measures
- use of low-toxicity/nonpersistent chemicals

REFERENCES

1. Clean Air Act, 42 U.S.C.A. § 7409 (CAA § 109), National primary and secondary ambient air quality standards.
2. Code of Federal Regulations, Title 40, Protection of Environment, Part 50, National Primary and Secondary Ambient Air Quality Standards.
3. State of Hawaii. Title 11, Administrative Rules, Chapter 59 Ambient Air Quality Standards, as amended, November 1993.
4. Library of Congress, Congressional Research Service. A Legislative History of the Clean Air Amendments of 1970, Volume 1, p. 411, January 1974.
5. U. S. Environmental Protection Agency. National Ambient Air Quality Standards for Hydrocarbons: Final Rulemaking, Federal Register, Volume 48, No. 3, p. 628, January 1983.
6. U. S. Environmental Protection Agency. National Ambient Air Quality Standards for Photochemical Oxidants: Final Rulemaking, Federal Register, Volume 44, No. 28, p. 8202, February 8, 1979
7. State of Hawaii. Title 11, Administrative Rules, Chapter 60.1, Air Pollution Control, November 1993.
8. Wilbur Smith Associates. Draft traffic impact report (existing conditions) for Hawaii Kai Properties EIR, provided by B. T. Brothers, 30 Sep 94.
9. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, National Climatic Center. Local Climatological Data: Annual Summary with Comparative Data, 1982, Honolulu, Hawaii.
10. Thornwaite, C. W. Climates of North America According to a New Classification, Geog. Rev. 21: 633-655, 1931.
11. U.S. Air Force, Environmental Technical Applications Center Report No. 7461: Stability Wind Roses, Hickam AFB, HI, 0000-2400 LST By Boundary Layer Section, 4 Sep 74.

12. U. S. Environmental Protection Agency. Workbook of Atmospheric Dispersion Estimates, AP-26 (Sixth Edition), 1973.
13. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, Fourth Edition, with Supplements A-F, 1993.
14. Clean Air Act Amendments of 1990, P.L. 101-549, 15 Nov 90.
15. Wilbur Smith Associates. Memorandum from B. T. Brothers to William Wanket, Subject: Preliminary Findings, Traffic Study for Hawaii Kai Properties EIR, November 1994.
16. Wilber Smith Associates. Facsimile transmittal from B. T. Brothers providing existing (1996) and projected (2017) traffic volumes in the Hawaii Kai area, 22 Mar 96.
17. U. S. Environmental Protection Agency. MOBILE-5A (Mobile Source Emission Factor Model), March 1993.
18. City & County of Honolulu, Department of Data Systems. Age Distribution of Registered Vehicles in the City & County of Honolulu (unpublished report), September 1988.
19. Seinfeld, John H. Air Pollution: Physical and Chemical Fundamentals, p. 69, McGraw-Hill Book Company, 1975
20. U. S. Environmental Protection Agency. Workbook of Atmospheric Dispersion Estimates, AP-26 (Sixth Edition), 1973.
21. U.S. Environmental Protection Agency. Guideline on Air Quality Models (Revised) with Supplements A and B, EPA-450/2-78-027R, July 1986.
22. U.S. Environmental Protection Agency. User's Guide to CAL3QHC Version 2.0: A Modeling Methodology for Predicting Pollutant Concentrations Near Roadway Intersections, EPA-450/R-92-006, November 1992.
23. Morrow, J. W. Air Quality Impact Analysis: Hawai'i Convention Center (Revised), 27 Jun 95.

24. Brennan, B. M., A. K. Higaki, and C. L. Murdoch. Estimated Pesticde Use on Golf Courses in Hawaii, College of Tropical Agriculture and Human Resources, University of Hawaii, Research Extension Series 137, 1992.

25. The Royal Society of Chemistry. The Agrochemicals Handbook (Second Edition), April 1988, with Update 5 (June 1990).

26. National Institutes of Occupational Safety and Health, Registery of Toxic Effects of Chemical Substances (RTECS), April 1993.

QUEEN'S BEACH GOLF COURSE

Appendix

J

Environmental Noise Assessment Study

(Darby & Associates)

DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

CONFIDENTIAL
Attorney-Client
Work Product

Project No. 94-30A

ENVIRONMENTAL NOISE ASSESSMENT STUDY
HAWAII KAI PROPERTIES EIR
QUEEN'S BEACH
HONOLULU, OAHU, HAWAII

June, 1996

Prepared for
HAWAII KAI DEVELOPMENT COMPANY
Honolulu, Hawaii

PALI PALMS PLAZA • 970 NO. KALAHEO AVENUE • SUITE A-311
KAILUA, HAWAII 96734 • (808) 254-3318 • FAX (808) 254-5295

CONTENTS

1.0 SUMMARY

1.1 The project site currently experiences equivalent noise levels, L_{eq}, of approximately 57 dBA during the daytime. The dominant noise sources include surf from Queen's Beach, traffic along Kalanianaole Highway and occasional distant aircraft flybys.

1.2 The maximum traffic noise level increase of approximately 3.5 dBA along Kealahou Street near the project due to additional traffic generated by the overall Hawaii Kai Properties Project will be perceptible to most residents near the roadway.

1.3 Results indicate that traffic noise impact on this parcel is insignificant. The clubhouse is "compatible" with the existing outdoor noise environment and does not require special noise attenuation measures according to the Federal Interagency Committee's on Urban Noise and the Acoustical Society of America's land use compatibility guidelines.

1.4 Activities at the project's clubhouse should not significantly impact the proposed residential housing, Queen's Rise due to the greater than 500-foot distance between the housing and the clubhouse.

1.5 The dominant noise source during project construction will probably be earth moving equipment, such as bulldozers and diesel-powered trucks. Any noise impact from such activity on the project site should be relatively short-term and must comply with Hawaii Department of Health (DOH) regulations.

1.6 The day-night equivalent sound levels, L_{dn}, at the project site due to air traffic associated with Honolulu International Airport and Marine Corps Base Hawaii Kaneohe will be less than 55 dBA. Although aircraft flybys will be audible, aircraft noise should not impact the proposed development.

2.0 PROJECT DESCRIPTION

The Hawaii Kai Properties Project consists of 12 parcels of land in Honolulu, Oahu, Hawaii. Queen's Beach, one of the 12 parcels, involves approximately 166 acres of land. The project site abuts Kalanianaole Highway to the west and is east of Hawaii Kai Golf Course as shown in Figure 1. The Kaiwi Channel and preservation land border the eastern part of the project site. Currently, the project area is vacant land. The present conceptual plan [Reference 1] shown in Figure 2 includes an 18-hole golf course and accessory facilities to the golf course such as a driving range, clubhouse/pro shop, restaurant, etc. The existing and proposed zoning is P-2.

3.0 NOISE STANDARDS

Various local and federal agencies have established guidelines and standards for assessing environmental noise impacts and set noise limits as a function of land use. A brief description of common acoustic terminology used in these guidelines and standards is presented in Appendix A.

3.1 State Department of Health - The State Department of Health (DOH) specifies allowable property line noise levels that shall not be exceeded for more than 10% of the time during any 20-minute period [Reference 2]. These are enforced for any location at or beyond the property line. The specified noise limits which apply are dependant on the zoning and time of day as shown in Figure 3. DOH also specifies the following with respect to adjacent zoning and order of precedence.

> "Where the allowable noise level between two adjacent zoning districts differ, the lower allowable noise level shall be used. For example, the allowable noise level for the residential district shall be used at the property line between residential and business districts.
>
> The limits specified in the allowable noise levels table shall apply subject to the order of precedence in which uses were initiated after the effective date of this rule; provided that a new order of precedence is established when any use is discontinued. The initiation of use shall be measured by the date of rezoning. For example, if agricultural or industrial operations are conducted next to a lot used as residence, the agricultural or industrial limits would apply if the building permit for the residence was obtained after the agricultural or industrial operations had been initiated, after the effective date of this rule. Residential limits would apply if the building permit for the residence was obtained before agricultural or industrial operations had been initiated."

3.2 City and County of Honolulu Land Use Ordinance - The Department of Land Utilization (LUO) specifies maximum allowable levels at the property line [Reference 3]. The LUO criteria differ from those of the DOH in that they use octave band sound levels instead of A-weighted levels and no temporal factor is involved. LUO noise regulations are theoretically enforced by the Building Department, however, since they do not have noise measurement capability, noise complaints are usually handled by DOH.

3.3 U.S. Federal Highway Administration - The Federal Highway Administration (FHWA) has established design goals for traffic noise exposure [Reference 4]. The FHWA defines four land use categories and assigns corresponding maximum hourly equivalent sound levels, L_{eq}. For example, Category B, defined as picnic and recreation areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals, has a corresponding maximum exterior L_{eq} of 67 dBA and a maximum interior L_{eq} of 52 dBA. These limits are viewed as design goals, and all projects which are developed to meet these limits are deemed in conformance with the FHWA noise standards.

3.4 U.S. Department of Housing and Urban Development - The U.S. Department of Housing and Urban Development (HUD) has established Site Acceptability Standards for interior and exterior noise for housing [Reference 5]. These standards are based on day-night equivalent sound levels, L_{dn}, and identify the need for noise abatement, either at the site property line or in the building construction. HUD Site Acceptability Criteria rank sites as Acceptable, Normally Unacceptable, or Unacceptable. "Acceptable" sites are those where exterior noise levels do not exceed an L_{dn} of 65 dBA. Housing on Acceptable sites do not require additional noise attenuation other than that provided in customary building techniques. "Normally Unacceptable" sites are those where the L_{dn} is above 65 dBA, but does not exceed 75 dBA. Housing on Normally Unacceptable sites requires some means of noise abatement, either at the property line or in the building construction, to ensure the interior noise levels are acceptable. "Unacceptable" sites are those where the L_{dn} is 75 dBA or higher. The term "unacceptable" does not necessarily mean that housing cannot be built on these sites, but rather that more sophisticated sound attenuation would likely be needed.

3.5 The Federal Interagency Committee on Urban Noise - The Federal Interagency Committee on Urban Noise has established consolidated Federal agency land use compatibility guidelines [Reference 6]. These guidelines assist in the determination of land uses to be allowed at particular sites based on the L_{dn} at those sites. The land use compatibility is expressed as being "compatible", "incompatible" and "compatible with restrictions". "Compatible with restrictions" commonly requires a noise level reduction of 25, 30 or 35 dB to be achieved through noise attenuation in the design or construction of the structure. For example, residential areas are compatible with the outdoor noise environment, if they are exposed to L_{dn} between 55 and 65 dBA, and a minimum of 25 dB attenuation in the design of the building, if they are exposed to L_{dn} between 65 and 70 dBA.

3.6 Acoustical Society of America - Standards of the Acoustical Society of America (ASA) establish day-night equivalent sound levels, L_{dn}, as the preferred acoustical measure to be used in determining compatibility between various land uses and an outdoor noise environment [Reference 7]. The ASA land use compatibility versus L_{dn} is shown in Figure 4.

3.7 State Department of Transportation, Airports Division - The Department of Transportation (DOT) specifies land use compatibility guidelines for aircraft noise exposure [Reference 8]. These guidelines are based on maximum allowable yearly day-night equivalent sound levels, L_{dn}, for various specified land uses. A residential land use, which is specified as single-family homes, apartments, hotels, and resorts, is compatible with an aircraft generated L_{dn} less than or equal to 60 dBA. However, DOT states,

> "Where the community determines that these uses must be allowed, Noise Level Reduction (NLR) measures to achieve interior levels of 45 L_{dn} or less should be incorporated into building codes and be considered in individual approvals. Normal local construction employing natural ventilation can be expected to provide an average NLR of approximately 9 dB. Total closure, plus air conditioning, may be required to provide additional outdoor to indoor NLR, and will not eliminate outdoor noise problems."

The DOT guidelines also specify 60 dBA as the maximum allowable L_{dn} for school, day care center, and church uses without any noise mitigation. Commercial uses such as retail shops, restaurants, shopping centers, etc. are compatible with L_{dn} up to 65 dBA without any noise mitigation. With noise mitigation, such commercial uses are allowed in areas exposed to L_{dn}'s as high as 75 dBA.

3.8 U.S. Environmental Protection Agency - The U.S. Environmental Protection Agency (EPA) has identified a range of yearly day-night equivalent sound levels, L_{dn}, sufficient to protect public health and welfare from the effects of environmental noise [Reference 9]. The EPA has established a goal to reduce exterior environmental noise to an L_{dn} not exceeding 65 dBA and a future goal to further reduce exterior environmental noise to an L_{dn} not exceeding 55 dBA. Additionally, the EPA states that these goals are not intended as regulations as it has no authority to regulate noise levels, but rather they are intended to be viewed as levels below which the general population will not be at risk from any of the identified effects of noise.

4.0 EXISTING ACOUSTICAL ENVIRONMENT

Noise level measurements were conducted on October 28, 1994 from about 8 am to 9 am in order to assess the existing acoustical environment of the project site as shown in Figure 5. Noise level measurements were obtained using a Larson Davis Laboratories, Precision Integrating Sound Level Meter, Model 800B. The measurements are in units of A-weighted decibels (dBA) and are expressed in terms of the equivalent sound levels, L_{eq}.

The project site typically experiences equivalent sound levels, L_{eq}, of approximately 57 dBA during the daytime. The dominant noise sources include surf along Queen's Beach, traffic along Kalanianaole Highway and occasional distant aircraft flybys.

5.0 POTENTIAL NOISE IMPACT DUE TO THE PROJECT AND NOISE MITIGATION

5.1 Additional Traffic Noise - The predicted traffic volumes [Reference 10] were used in conjunction with the Federal Highway Administration (FHWA) Traffic Noise Prediction Model [Reference 11] to estimate the traffic noise increase as a result of the overall Hawaii Kai Properties Project. The day-night equivalent sound levels, L_{dn}, were estimated from the peak hour equivalent noise levels in accordance with the procedures of Reference 5. The traffic noise levels were predicted at the locations shown in Figure 5. The existing, 1996, and projected future, 2017, traffic noise levels during peak traffic hours are summarized in Table 1. In addition, the projected future traffic noise level increases during peak traffic hours are summarized in Table 2. It should be noted that the effects of terrain and roadway elevations and any noise shielding afforded by man-made structures were not included in the calculations and that the referenced traffic study does not provide any truck mix information. The following assumptions of medium truck (MT) and heavy truck (HT) mix and vehicles' operating speeds were used in this analysis.

A. Existing and Future Without the overall Hawaii Kai Properties Project

Location	Roadway	MT (%)	HT (%)	Average Operating Speed (mph)
1	Kealahou Street	2	1	30
2	Kalanianaole Highway	1	4	45

B. Future With the overall Hawaii Kai Properties Project

Location	Roadway	MT (%)	HT (%)	Average Operating Speed (mph)
1	Kealahou Street	2	3	30
2	Kalanianaole Highway	1	4	45

As can be seen in Table 2, the predicted traffic noise level increases at the assessed location due to additional traffic generated by the overall Hawaii Kai Properties Project were less than or equal to 3.5 dBA. A traffic noise level increase greater than 3 dBA will be perceptible by most residents near the roadway.

As cited in Reference 12, the prediction of noise induced annoyance in residential populations is a complex task and research is still presently on-going after many decades of effort. Using the empirical data from one often referenced source [Reference 13], about 11% of the population are "highly annoyed" if they presently experience a traffic L_{dn} of 62 dBA, e.g., at a 50-foot distance from the centerline of Kealahou Street (Location 1) as shown in Table 1. In the future after completion of the overall Hawaii Kai Properties Project, about 17% of the people will be "highly annoyed" if they experience an increase in L_{dn} to 66 dBA.

Projected future traffic noise levels, with the overall Hawaii Kai Properties Project, as shown in Table 1, could place some of the existing residences along Kealahou Street in HUD's "Normally Unacceptable" or "Unacceptable" zones. In accordance with Reference 5, "noise exposure by itself will not result in the denial of HUD support for resale and purchase of otherwise acceptable buildings. However, environmental noise is a marketability factor which HUD will consider in determining the amount of insurance or other assistance that may be given."

Traffic noise mitigation for the existing impacted residences, if warranted, includes:

a) Use of concrete retaining (Jersey) barriers;

b) Construction of roadside noise barriers, i.e., walls, earthen berms or a combination of both;

c) Air-conditioning of impacted dwellings; and

d) A reduction in speed limit.

It should be noted that in order for a barrier to be effective in providing shielding of vehicle tire and exhaust noise, it must block line-of-sight between the noise source and the residences' windows.

5.2 Golf Course - The current conceptual plan for this project involves an 18-hole golf course and accessory facilities to the golf course such as a driving range, clubhouse/pro shop, restaurant, etc. Potential noise sources include the public address system and mechanical equipment at, and near, the clubhouse, as well as mobile equipment associated with the golf course maintenance activities. Stationary mechanical equipment includes refrigeration and air-conditioning units, pumps, exhaust fans, and other stationary equipment. Equipment associated with the ground maintenance activities include lawn mowers, edgers, garden tractors, leaf blowers, chain saws, etc. Typical A-weighted noise levels at a 50-foot distance for these equipment [Reference 14] are listed as follows:

Source	Noise Level (dBA)
Lawn Mower	74
Leaf Blower	76
Lawn Edger	78
Garden Tractor	78
Chain Saw	82

The nearest noise sensitive area is the proposed residential housing, Queen's Rise, west of the project site. Due to the greater than 500-foot distance between the housing and the clubhouse, the noise generated from the clubhouse should not be objectionable. Noise from the ground maintenance equipment, which would be used only during the daytime, would also be attenuated by the long distances and would usually be masked by traffic noise from the intervening highway.

5.3 Construction Noise - Development of the Queen's Beach project will involve excavation, grading, and the construction of infrastructure and buildings. The nearest noise sensitive area is the proposed Queen's Rise residential project. If the proposed Queen's Rise residential project is completed and the units occupied prior to the construction of the proposed Queen's Beach project, construction noise could potentially impact residents in Queen's Rise. The actual noise is dependent upon the methods employed during each stage of the construction process. Typical ranges of construction equipment noise are shown in Figure 6. Earthmoving equipment, such as bulldozers and diesel-powered trucks, will probably be the loudest equipment used during construction assuming that pile driving will not be required.

In cases where construction noise exceeds, or is expected to exceed the DOH's "allowable" property line noise levels [Reference 2], a permit must be obtained from the DOH to allow the operation of vehicles, construction equipment, power tools, etc. which emit noise levels in excess of the "allowable" levels. Required permit conditions for construction activities are:

> "No permit shall allow construction activities creating excessive noise...before 7:00 am and after 6:00 pm of the same day."

> "No permit shall allow construction activities which emit noise in excess of ninety-five dB(A)...except between 9:00 am and 5:30 pm of the same day."

"No permit shall allow construction activities which exceed the allowable noise levels on Sundays and on...[certain] holidays. Activities exceeding ninety-five dB(A) shall [also] be prohibited on Saturdays."

In addition, construction equipment and on-site vehicles or devices whose operations involve the exhausting of gas or air must be equipped with mufflers. Also, construction vehicles using traffic-ways must satisfy the DOH's vehicular noise requirements [Reference 15].

Blasting, if required, could also produce noise impacts. However, blasting at construction sites near populated areas is usually accomplished by using numerous small charges detonated with small time delays. Blast mats can also be used to assist in directing the explosive energy into the rock, controlling flying debris, and muffling the noise. Thus, with the appropriate blast design techniques, the noise from blasting can be controlled within acceptable limits at the closest noise sensitive locations.

6.0 POTENTIAL NOISE IMPACT ON THE PROJECT AND NOISE MITIGATION

6.1 Traffic Noise - The proposed development abuts Kalanianaole Highway to the west. The Federal Highway Administration (FHWA) Traffic Noise Prediction Model has been used with the projected traffic data of Reference 10 to predict the traffic noise level exposures of the clubhouse.

The traffic noise levels were based on the predicted peak hour traffic volumes with the assumptions as previously mentioned in Section 5.1. The predicted peak hour volumes were based on the traffic generated by the overall Hawaii Kai Properties Project. The day-night equivalent sound levels, L_{dn}, were estimated from the peak hour equivalent noise levels in accordance with the procedures of Reference 5. Results indicate the clubhouse will be exposed to L_{dn} less than 65 dBA at the proposed setback distance of approximately 400 feet from the centerline of Kalanianaole Highway. In accordance with Figure 4 and Reference 6, the clubhouse is "compatible" with the existing outdoor noise environment and requires no special attenuation measures.

6.2 Aircraft Noise - The proposed project is approximately 16 miles east of the Honolulu International Airport and 11 miles southeast of the Marine Corps Base Hawaii Kaneohe. In accordance with References 16 and 17, the L_{dn} due to air traffic associated with these airfields will be less than 55 dBA at the project site, which is compatible with DOT noise guidelines. Although aircraft flybys will be audible, aircraft noise should not significantly impact the proposed development.

REFERENCES:

1. Hawaii Kai Environmental Impact Report Preparation Notice, January 1996.

2. *Chapter 43 - Community Noise Control for Oahu,* Department of Health, State of Hawaii, Administrative Rules, Title 11, November 6, 1981.

3. *Section 3.11, Noise Regulations,* Land Use Ordinance, City and County of Honolulu, Oahu October 22, 1986.

4. *Department of Transportation, Federal Highway Administration Procedures for Abatement of Highway Traffic Noise,* Title 23, CFR, Chapter I, Subchapter J, Part 772, 38 FR 15953, June 19, 1973, Revised at 47 FR 29654, July 8, 1982.

5. *Department of Housing and Urban Development Environmental Criteria and Standards,* Title 24, CFR, Park 51, Issued at 44 FR 40860, July 12, 1979, Amended by 49 FR 880, January 6, 1984.

6. *Guidelines for Considering Noise in Land Use Planning and Control,* Federal Interagency Committee on Urban Noise, Washington, DC, June 1980.

7. *American National Standard Sound Level Descriptors for Determination of Compatible Land Use,* American National Standards Committee on Acoustics, Acoustical Society of America, ASA Standard 22-1980.

8. *Study Recommendations for Local Land Use Compatibility with Yearly Day-Night Average Sound Levels,* State of Hawaii Department of Transportation, Airports Division, Received August 1991, Published in Reference 16.

9. *Toward a National Strategy for Noise Control,* U.S. Environmental Protection Agency, April 1977.

10. Transmittals from Terry Brothers of Wilbur Smith Associates to Darby & Associates, March 22, March 27, May 3 and May 6, 1996.

11. *FHWA Highway Traffic Noise Prediction Model,* FHWA - RD - 77 - 108; U.S. Department of Transportation, December 1978.

12. Schultz, T. J., *Synthesis of Social Surveys on Noise Annoyance,* Journal of Acoustical Society of America, 1978.

13. Schultz, T. J., Fidell, S., Green, D. M., *A Theoretical Interpretation of the Prevalence Rates of Noise-Induced Annoyance in Residential Populations,* Journal of Acoustical Society of America, 1988.

14. *Transportation Noise and Noise from Equipment Powered by Internal Combustion Engines,* Environmental Protection Agency, December 1971.

15. *Chapter 42 - Vehicular Noise Control for Oahu*, Department of Health, State of Hawaii, Administrative Rules, Title 11, November 6, 1981.

16. *Honolulu International Airport Master Plan Update & Noise Compatibility Program*, State of Hawaii Department of Transportation, Airports Division, Vol. 2, December 1989.

17. *Air Installation Compatible Use Zones Update for Marine Corps Air Station Kaneohe Bay*, Department of the Navy, Pacific Division, Naval Facilities Engineering Command, November 1990.

TABLE 1
QUEEN'S BEACH
CALCULATED EXISTING (1996) AND PROJECTED FUTURE (2017)
TRAFFIC NOISE LEVELS (L_{dn} in dBA) DURING PEAK TRAFFIC HOURS

	Location*	
	1	2
Existing		
AM	60.3	69.6
PM	61.8	69.1
Future 2017 (Without the overall Hawaii Kai Properties Project)		
AM	60.7	70.2
PM	62.4	69.9
Future 2017 (With the overall Hawaii Kai Properties Project)		
AM	64.2	70.6
PM	65.8	70.4

* See Figure 5

Note: Traffic noise level assessed at an arbitrary 50-foot distance from the centerline of the roadway.

TABLE 2
QUEEN'S BEACH
PROJECTED FUTURE (2017) TRAFFIC NOISE LEVEL
(L_{dn} in dBA) INCREASES DURING PEAK TRAFFIC HOURS

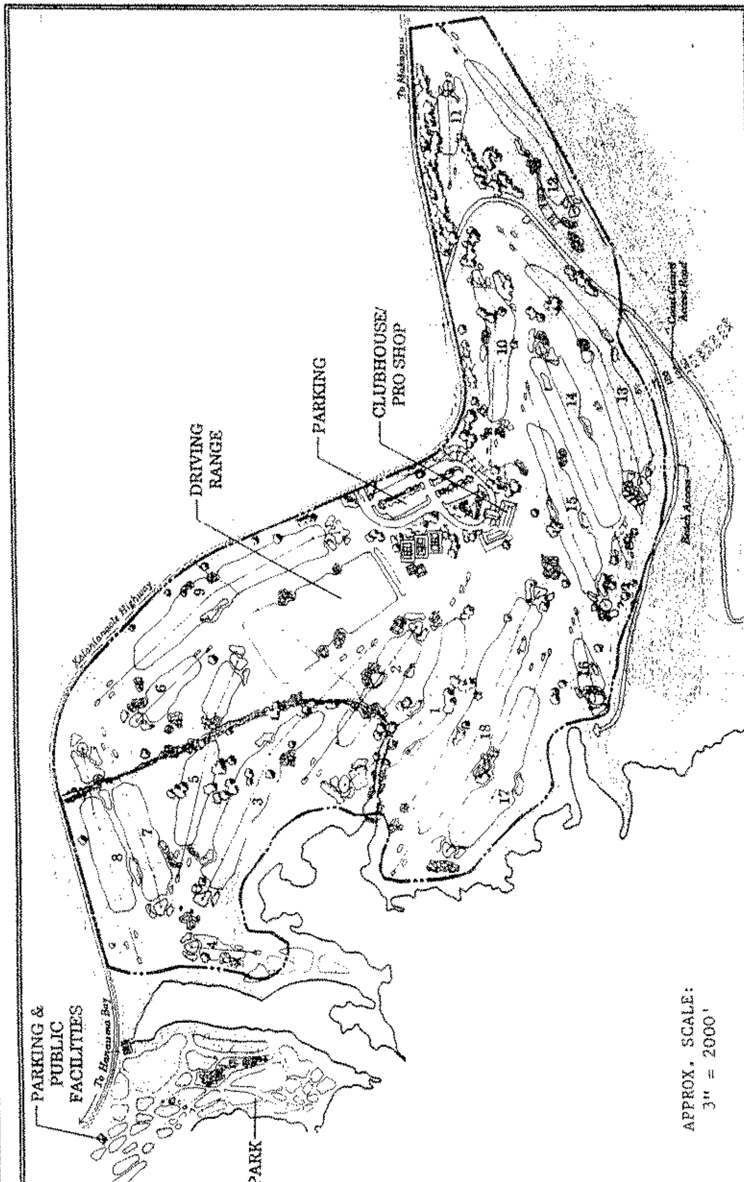
	Location*	
	1	2
Future 2017 Traffic Noise Level Increases (dBA) Without the overall Hawaii Kai Properties Project		
AM	0.4	0.6
PM	0.6	0.8
Future 2017 Traffic Noise Level Increases (dBA) Due to overall Hawaii Kai Properties Project Generated Traffic		
AM	3.5	0.4
PM	3.4	0.5

* See Figure 5

#94-30A

FIGURE 1 - QUEEN'S BEACH PROJECT SITE AND VICINITY

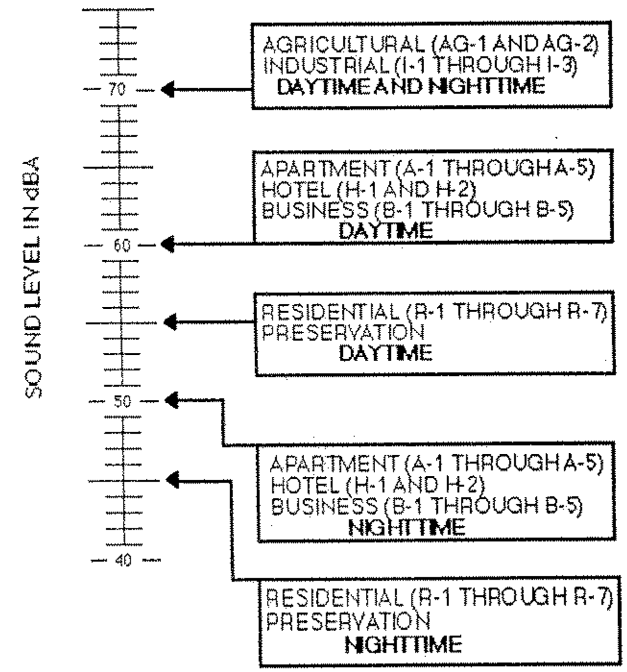
D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS



APPROX. SCALE:
3" = 2000'

D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE 2 - QUEEN'S BEACH CONCEPTUAL PLAN

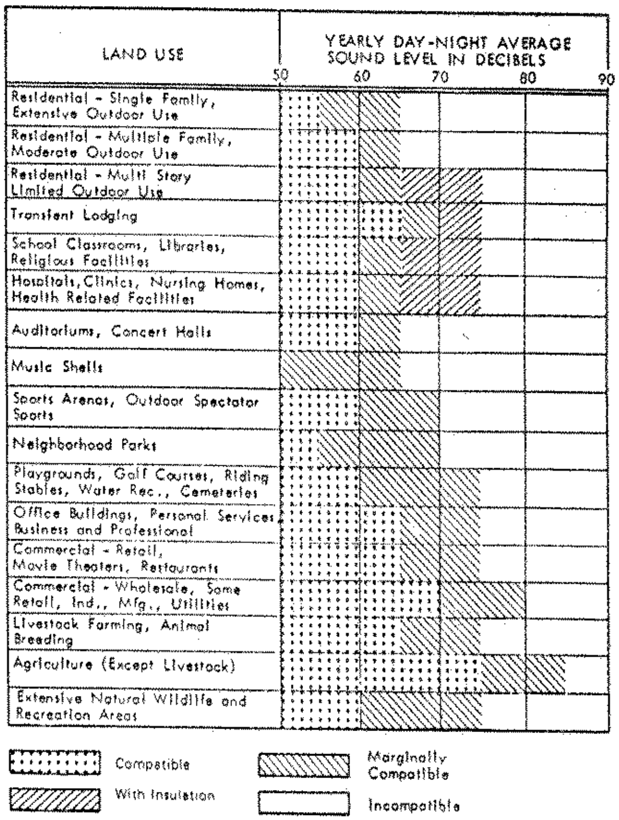


NOTE: LEVELS INDICATED BY ZONING DISTRICT ARE THE "ALLOWABLE" LEVELS THAT SHALL NOT BE EXCEEDED FOR MORE THAN TEN PERCENT OF THE TIME WITHIN ANY TWENTY MINUTE PERIOD DURING THE TIME PERIOD SHOWN (DAYTIME: 7:00 A.M. TO 10:00 P.M., NIGHTTIME: 10:00 P.M. TO 7:00 A.M.)

D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE 3 - ALLOWABLE NOISE LEVELS FOR VARIOUS ZONING DISTRICTS

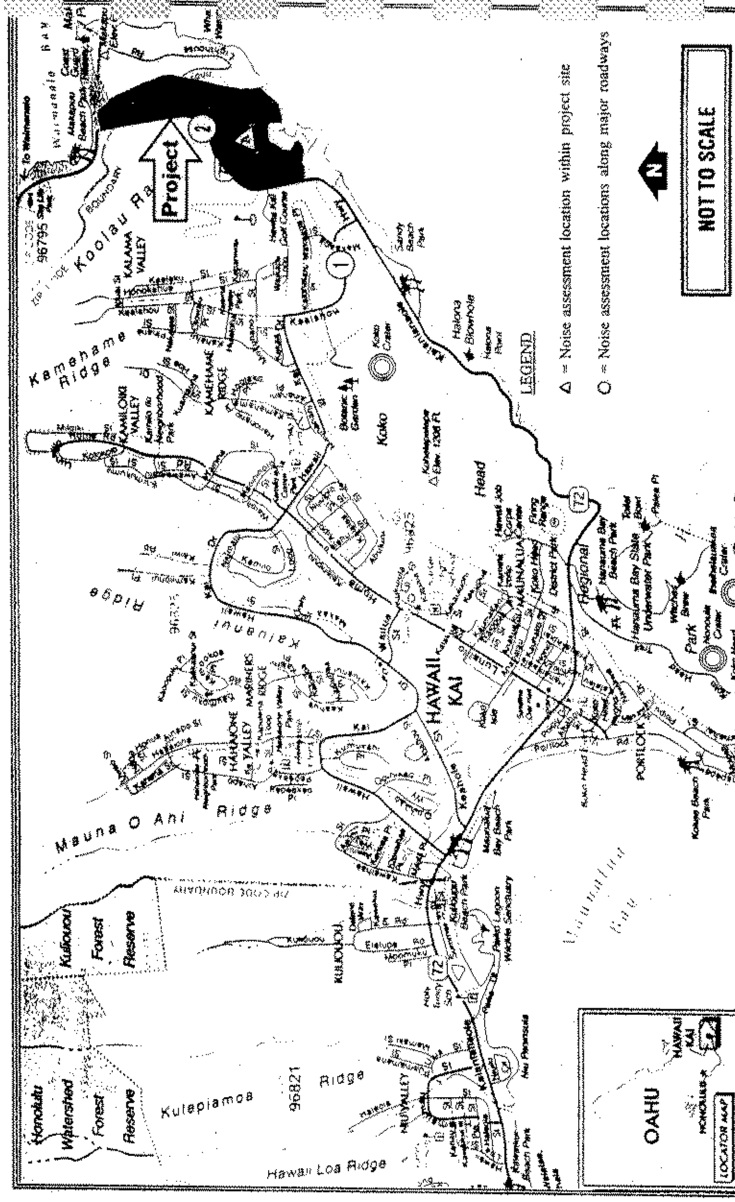
Source: Reference 2



D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

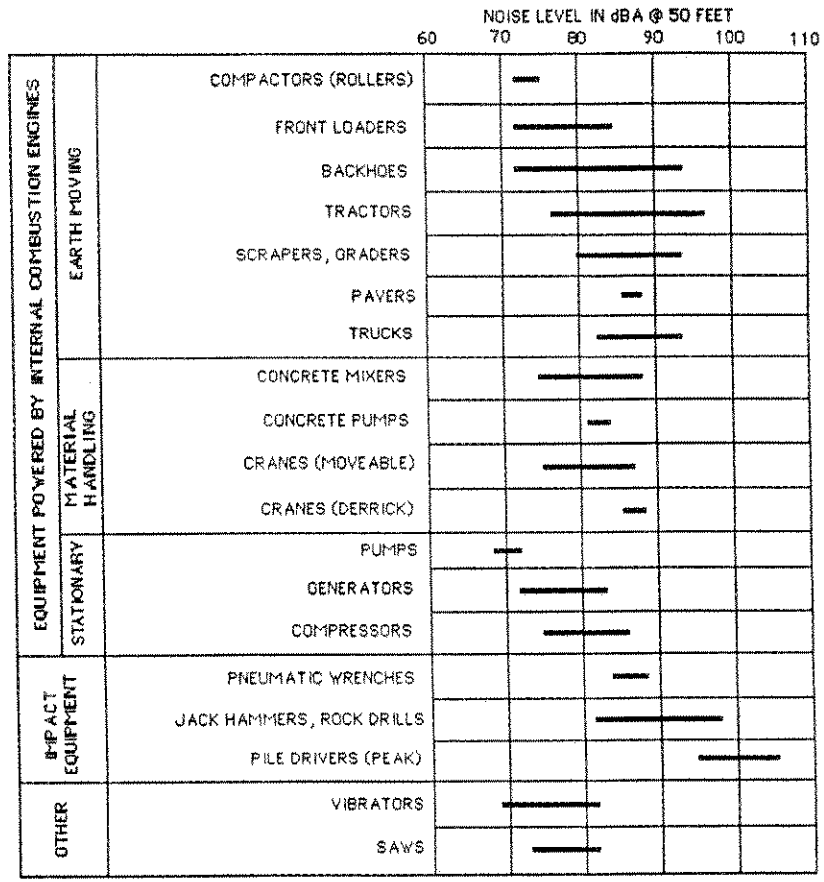
FIGURE 4 - LAND USE COMPATIBILITY FOR COMMONLY CONSTRUCTED BUILDINGS

Source: Reference 7



D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE 5 - QUEEN'S BEACH NOISE LEVEL ASSESSMENT LOCATIONS



NOTE: BASED ON AVAILABLE DATA SAMPLES

D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE 6 - TYPICAL SOUND PRESSURE LEVELS FROM CONSTRUCTION EQUIPMENT

Source: U.S. Environmental Protection Agency

APPENDIX A

ACOUSTICAL TERMINOLOGY

Sound Pressure Level

Sound or noise consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. It is measured in terms of decibels (dB) using precision instruments known as sound level meters. Noise is defined as "unwanted" sound.

Technically, sound pressure level (SPL) is defined as:

$$SPL = 20 \log (P/Pref) \text{ dB}$$

where P is the sound pressure fluctuation (above or below atmospheric pressure) and Pref is the reference pressure, 20 micropascals, which is approximately the lowest sound pressure that can be detected by the human ear. For example, if P is 20 micropascals, then SPL = 0 dB, or if P is 200 micropascals, then SPL = 20 dB. The relation between sound pressure in micropascals and sound pressure level in decibels (dB) is shown in Figure A-1.

The sound pressure level that results from a combination of noise sources is not the arithmetic sum of the individual sound levels, but rather the logarithmic sum. For example, two sound levels of 50 dB produce a combined level of 53 dB, not 100 dB; two sound levels of 40 and 50 dB produce a combined level of 50.4 dB.

Human sensitivity to changes in sound pressure level is highly individualized. Sensitivity to sound depends on frequency content, time of occurrence, duration, and psychological factors such as emotions and expectations. However, in general, a change of 1 or 2 dB in the level of a sound is difficult for most people to detect. A 3 dB change is commonly taken as the smallest perceptible change and a 5 dB change corresponds to a noticeable change in loudness. A 10 dB increase or decrease in sound level corresponds to an approximate doubling or halving of loudness, respectively.

A-Weighted Sound Level

The human ear is more sensitive to sound in the frequency range of 250 Hertz (Hz) and higher, than in frequencies below 250 Hz. Due to this type of frequency response, a frequency weighting system, was developed to emulate the frequency response of the human ear. This system expresses sound levels in units of A-weighted decibels (dBA). A-weighted sound levels de-emphasizes the low frequency portion of the spectrum of a signal. The A-weighted level of a sound is a good measure of the loudness of that sound. Different sounds having the same A-weighted sound level are perceived as being about equally loud. Typical values of the A-weighted sound level of various noise sources are shown in Figure A-1.

Statistical Sound Levels

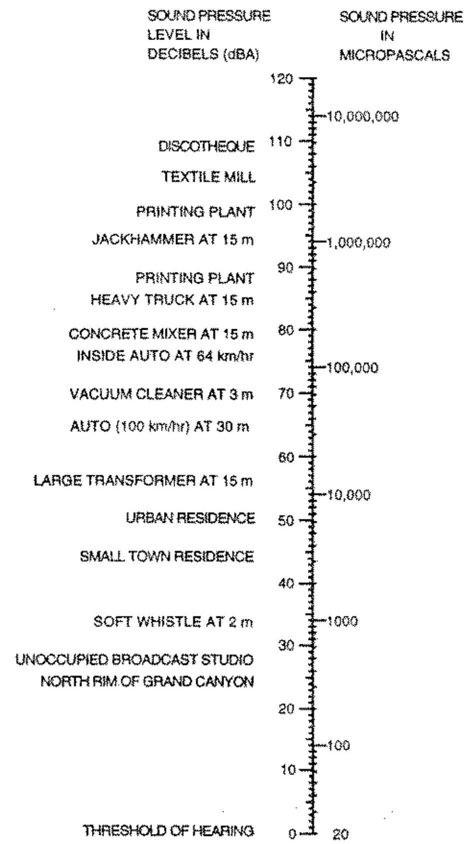
The sound levels of long-term noise producing activities, such as traffic movement, aircraft operations, etc., can vary considerably with time. In order to obtain a single number rating of such a noise source, a statistically-based method of expressing sound or noise levels developed. It is known as the Exceedence Level, L_n. The Exceedence Level, L_n, represents the sound level which is exceeded for n% of the measurement time period. For example, L_{10} = 60 dBA indicates that for the duration at the measurement period, the sound level exceeded 60 dBA 10% of the time. Commonly used Exceedence Levels include L_1, L_{10}, L_{50}, and L_{90}, which are widely used to assess community and environmental noise. Figure A-2 illustrates the relationship between selected statistical noise levels.

Equivalent Sound Level

The Equivalent Sound Level, L_{eq}, represents a constant level of sound having the same total acoustic energy as that contained in the actual time-varying sound being measured over a specific time period. L_{eq} is commonly used to describe community noise, traffic noise, and hearing damage potential. It has units of dBA and is illustrated in Figure A-2.

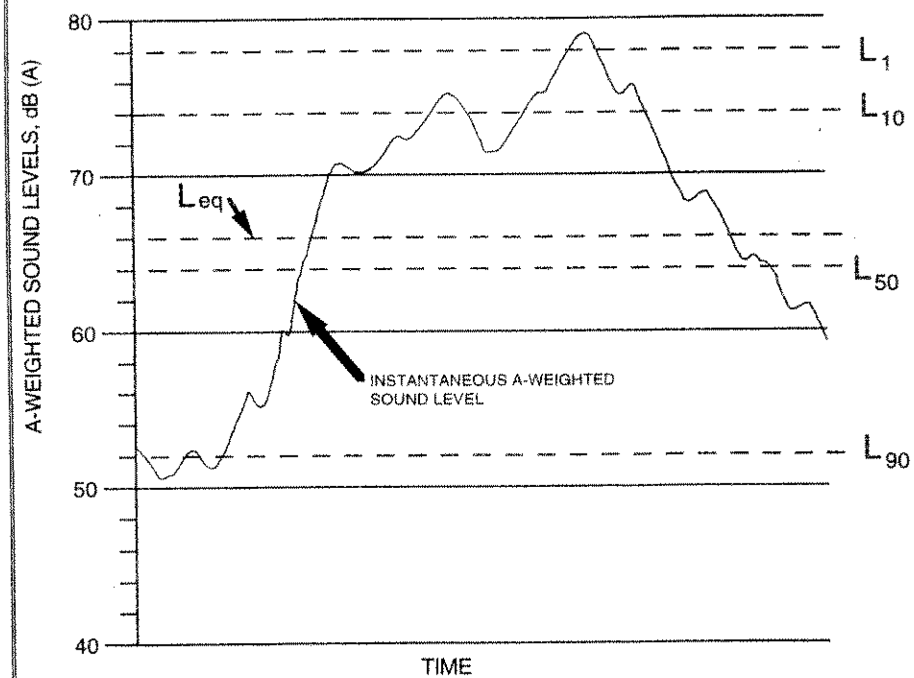
Day-Night Equivalent Sound Level

The Day-Night Equivalent Sound Level, L_{dn}, is the Equivalent Sound Level, L_{eq}, measured over a 24-hour period. However, a 10 dB penalty is added to the noise levels recorded between 10 pm and 7 am to account for people's higher sensitivity to noise at night when the background noise level is typically lower. The L_{dn} is a commonly used noise descriptor in assessing land use compatibility, and is widely used by federal and local agencies and standards organizations. Qualitative descriptions, as well as local examples of L_{dn}, are shown in Figure A-3.



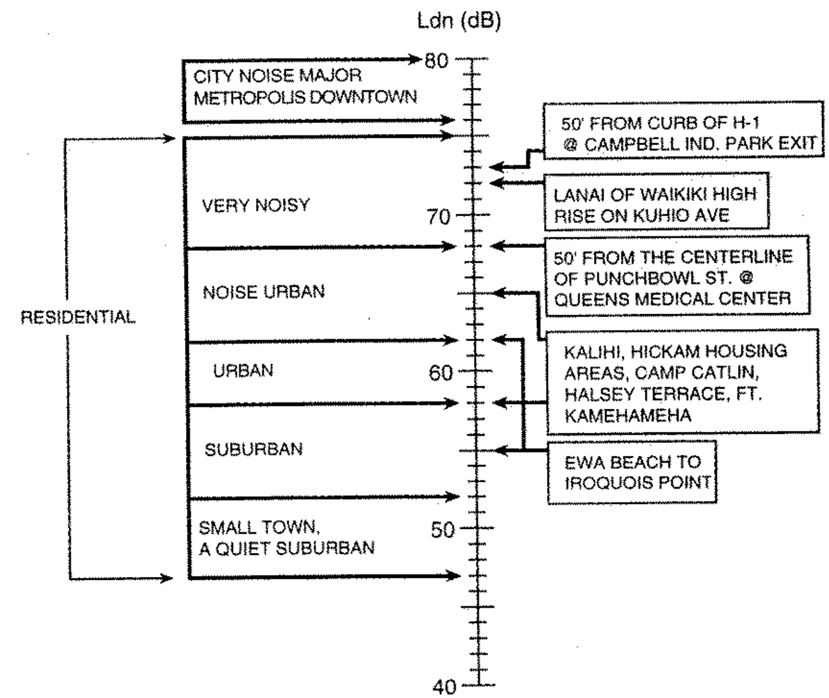
D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE A-1 THE RELATION BETWEEN SOUND PRESSURE, P, AND SOUND PRESSURE LEVEL, SPL. ALSO SHOWN ARE TYPICAL VALUES OF A-WEIGHTED SOUND LEVELS OF VARIOUS NOISE SOURCES.



D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE A-2 COMPARISON OF AN INSTANTANEOUS SOUND LEVEL AND THE CORRESPONDING STATISTICAL SOUND LEVELS



D.L. ADAMS ASSOCIATES, LTD.
dba
DARBY & ASSOCIATES
ACOUSTICAL CONSULTANTS

FIGURE A-3 QUALITATIVE DESCRIPTION OF THE DAY-NIGHT EQUIVALENT SOUND LEVELS (Ldn) AND EXAMPLE Ldn's AT SELECTED LOCATIONS ON OAHU

QUEEN'S BEACH GOLF COURSE

Appendix

K

Fiscal and Economic Impact Assessment

(KPMG Peat Marwick)

The Global Leader

HAWAII KAI
JOINT MASTER PLAN
ECONOMIC AND FISCAL
IMPACT ASSESSMENT

August 1996

Peat Marwick LLP

P.O. Box 4150
Honolulu, HI 96812-4150

Telephone 808 531 7286
Telex 7238615

Telefax 808 541 9321

August 9, 1996

Mr. Steve Silla
Vice President
Maunalua Associates, Inc.
P. O. Box 25007
Honolulu, Hawaii 96825

Mr. Paul Cathcart
Manager for Urban Oahu Division
Kamehameha Schools/Bishop Estate
567 King Street, Suite 200
Honolulu, Hawaii 96813

Kaiser Aluminum and Chemical Corporation
c/o Mr. Scott Ezer
Helber Hastert & Fee
733 Bishop Street, Suite 2590
Honolulu, Hawaii 96813

Mr. William Wanket, President
William E. Wanket, Inc.
Kapolei Building, Suite 320
1001 Kamokila Blvd.
Kapolei, Hawaii 96707

Dear Sirs:

KPMG Peat Marwick LLP (KPMG) is pleased to submit this report which presents our assessment of the economic and fiscal impacts of the Joint Master Plan for Hawaii Kai on the State of Hawaii (State) and the City and County of Honolulu (County).

This letter describes the planned development, the study background and our approach, and provides definitions of key terms used herein. The report attached to this letter is organized in three chapters as follows:

1. **Summary of Study Findings** - Text providing an executive summary of the findings that are detailed in the exhibits (report Chapters 2 and 3), and further explanation of study parameters and assumptions. Readers are encouraged to also refer to Chapters 2 and 3 for a more complete understanding of this study.

2. **Scenario I Exhibits** - Detailed analyses and conclusions for the Hawaii Kai Joint Master Plan areas as petitioned.

3. **Scenario II Exhibits** - Detailed analyses and conclusions for the Hawaii Kai Joint Master Plan areas as allowed under current County Development Plan Approvals.

PROJECT DESCRIPTION

Maunalua Associates, Inc. (MAI), Kamehameha Schools/Bishop Estate (KSBE) and Kaiser Aluminum and Chemical Corporation (KACC) have engaged in a cooperative effort to complete the build-out of Hawaii Kai. The remaining undeveloped land now being master-planned encompasses approximately 546 acres. The three land owners have asked KPMG to prepare this assessment of the economic and fiscal impacts of the master-planned areas on the State and County. This economic and fiscal impact analysis is intended to be included in an Environmental Impact Report (EIR) that is planned to be submitted to the City and County of Honolulu, as part of the process of requesting various entitlements for the subject properties.

The following table summarizes the acreage proposed for the various land uses, as petitioned:

Proposed New Land Uses in Hawaii Kai as Petitioned

Land use	Gross acres	Percent of total area
Residential	326	60%
Retail/Commercial	14	3%
Industrial/ Business Park	11	2%
Inn	29	5%
Golf Course	166	30%
Total	546	100%

STUDY BACKGROUND

KPMG was engaged to estimate the net additional economic and fiscal impacts of the joint master plan areas on the State and the County, based on the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996. Key construction phasing and other assumptions used in this analysis were provided by the various land owners.

The assumptions used are outlined in this text and in the footnotes to its exhibits. Our assessments of the development's economic and fiscal impacts are generally based on the inputs provided by the above sources. Where no guidelines had been previously prepared, our judgment of the "most likely," "typical" or "average" input for any given assumption was applied, unless we felt the most likely outcome could not be projected on a supportable basis.

For purposes of this report, all monetary projections are stated in constant 1995 dollars.

STUDY APPROACH

Any projection of economic and fiscal impacts is necessarily dependent on numerous assumptions and other inputs that cannot be predicted with certainty.

Based on the County's Long Range Development Plan for East Honolulu, portions of the petitioned area are already entitled for development of various types. In order to present a good indication of the economic and fiscal impacts on the State and County, this study presents two scenarios: "Scenario I - Petition," reflecting development of the joint master planned areas as petitioned; and "Scenario II - Development Plan," reflecting development of the joint master planned areas as they are currently classified under the County's long range development plan. The potential economic and fiscal impacts of granting the approvals for the uses petitioned are thus considered to be the difference between the impacts in the two development scenarios.

It should be noted, however, that regardless of the outcome of this petition, there are other zoned lands in Hawaii Kai on which development can be expected to occur.

DEFINITION OF KEY TERMS

This report segregates the projected results into impacts that are "direct," "indirect," and "induced." More specifically:

- **Direct impacts** - Those variables that are affected by the direct expenditure of monies at or on behalf of the development and operations of the various project components. Likewise, the employment of any person in the construction or operation of the various projects is considered a direct impact of the various components' development.

- **Indirect impacts** - These represent expenditures in the State or County by businesses that benefit from the new direct expenditures. For instance, a shopping center would support wholesaling activities on Oahu that may be based elsewhere on the island.

- **Induced impacts** - These represent the re-spending of earned income throughout the State's economy by employees or proprietors of businesses that benefit from direct or indirect expenditures. For instance, a movie theater may experience induced impacts of a development when construction workers take their families to a show after work.

In this manner, indirect and induced impacts become spread geographically throughout the State, as well as through the many sectors of our local economy.

Another less-commonly understood term is "in-migrant." It is used throughout this report to mean the following:

- **In-migrant** - A person who moves his or her principal place of residence across state or county lines. Demographers use this term to distinguish such movers from those who move across international boundaries (the latter are referred to as "immigrants"). However, to simplify discussions in this report, the term "in-migrant" is meant to include those who move across county, state or international boundaries.

* * * * * * *

KPMG appreciates the opportunity to prepare this economic and fiscal impact study for the Hawaii Kai Joint Master Plan.

Very truly yours,

KPMG Peat Marwick LLP

1 - SUMMARY OF STUDY FINDINGS

This chapter explains the study assumptions, parameters and key findings. It references exhibits located in chapters 2 (Scenario I - Petition) and 3 (Scenario II - Development Plan), and readers are encouraged to read those exhibits to gain a better understanding of the study findings.

Based on the County's long range development plan for East Honolulu, portions of the petitioned area are already entitled for development of various types. In order to present an indication of the economic and fiscal impacts on the State and County, this study presents two scenarios: "Scenario I - Petition," reflecting development of the joint master planned areas as petitioned; and "Scenario II - Development Plan," reflecting development of the joint master planned areas as they are currently classified under the County's long range development plan. The potential economic and fiscal impacts of granting the approvals for the uses petitioned are considered to be the difference between the impacts in the two development scenarios.

The respective exhibits for the two scenarios used are numbered identically to facilitate their comparison. Thus, where this text refers to Exhibit 1-A, for instance, the reader may wish to refer both to Exhibit 1-A for Scenario I (Petition) as well as to Exhibit 1-A for Scenario II (Development Plan), or (DP).

EXECUTIVE SUMMARY

Table 1, shown on the next page, summarizes development parameters and key impacts associated with granting of approvals for the petitioned area as of 2010. The year 2010 has been utilized as a benchmark point in the following exhibit and throughout this chapter as it is representative of the activity that is expected to occur. Although 2010 is not the estimated year of build-out, it does incorporate significant construction, sales, population and operational activities that would not be captured if 2013 (estimated year of build-out) was utilized for illustrative purposes.

DEVELOPMENT PARAMETERS

Key development parameters of the study are presented in Exhibits 1-A and 1-B. This section provides further explanation of some of those assumptions.

The proposed developments for the joint master planned areas include residential, retail/commercial, industrial/business, inn, and a golf course. Construction on some of these developments are expected to begin in 1998, when the petitioned entitlements might be obtained. As petitioned, development on the 546 acres included in the joint master planned areas is projected to be completed by the year 2013, as presented in Exhibits 1-A and 1-B.

This is a differential analysis that addresses the impacts of the petitioned areas within the Hawaii Kai joint master planned area only. Even if the petition is not granted, other developments can be expected to occur in Hawaii Kai that will have economic and fiscal impacts within the State and County. Such impacts are not addressed in this study. Examples of some of the types of projects that our analysis does not address are:

- **Zoned, unbuilt projects** - those parcels of land that have received the required entitlements but have not proceeded with construction.
- **Built, yet unoccupied units** - residential units that have been developed but remain unsold or still unoccupied by the new owners.

Table 1

SUMMARY OF DEVELOPMENT PARAMETERS AND KEY IMPACTS ATTRIBUTABLE TO THE SUBJECT PETITION: 2010

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Development parameters:			
Residential units, including lots	1,512	565	947
Retail/Commercial developments (square feet of GLA)	192,000	33,800	158,200
Industrial/Business Park (square feet of GLA)	100,800	137,400	(36,600)
Inn, number of rooms	140	0	140
Golf, number of holes	18	18	0
Total full-time equivalent employment impacts in State (direct, indirect and induced)			
Construction employment average annual, (2006-2010)	850	30	820
Operational employment	1,730	870	860
Population impacts:			
On-site daily population	4,780	1,700	3,080
In-migrant residents -			
County	570	230	340
State	460	190	270
Economic impacts (1995 dollars, in thousands):			
Visitor expenditures (direct, indirect and induced)	$17,580	$0	$17,580
Personal income (direct only)	$35,660	$13,050	$22,610
Fiscal impacts (1995 dollars, in thousands):			
Annual new government revenues -			
County	$3,910	$1,290	$2,620
State	$7,340	$1,430	$5,910
Annual new government expenditures -			
County	$600	$220	$380
State	$2,680	$890	$1,790
Net additional revenues:			
County	$3,310	$1,070	$2,240
State	$4,660	$540	$4,120

- **Projects under construction** - projects that have acquired the necessary entitlements and are under construction and thus unoccupied.

Residential Developments

Based on the petition, a total of eight properties in Hawaii Kai, comprising approximately 326 acres, are proposed for the development of 1,512 residential units. This is equivalent to an average density of approximately 4.6 units per acre. Characteristics of the eight properties vary significantly, ranging from relatively flat parcels with no views, to ridge-top parcels with excellent ocean and mountain views.

In addition, the petitioners have requested entitlements for another 200 residential units. As of the date of this report, the exact location and unit types of this "reserve" have not been determined. Therefore, no reasonable basis is considered to exist to estimate the construction costs, sales prices and development schedules for these units. Thus, we have not addressed these additional 200 residential units within the quantitative analysis.

The various residential unit types and unit counts for Scenarios I (Petition) and II (DP) are shown in the table below:

Potential Residential Units to be Developed - Scenarios I (Petition) and II (DP)

	Scenario I (Petition)	Scenario II (DP)
Multifamily:		
Kalama Valley Remnant	176	(A)
Marina 4B	75	(B)
Kamilonui 2	272	(C)
Kamilonui 1	510	425
Subtotal	1,033	425
Single-family:		
Marina 4B	(D)	50
Golf Course 2/1A	45	(E)
Kamilonui 2	92	(C)
Kamilo Ridge	5	90
Mauuwai	143	(C)
Queen's Rise (lots)	194	(C)
Subtotal	479	140
Total	1,512 (1)	565

(1) Excluding 200 unit "reserve" as described above.
(A) Under the County's current development plan, the area known as "Kalama Valley Remnant" is planned for retail/commercial use.
(B) Under the County's current development plan, the area known as "Marina 4B" is planned for single-family development (see Marina 4B under single-family).
(C) Under the County's current development plan, these parcels are planned for preservation.
(D) Based on the petition, the area known as "Marina 4B" is planned for multifamily development (see Marina 4B under multifamily).
(E) Under the County's current development plan, the land area known as "Golf Course 2/1A" is planned for industrial/commercial use.

- **Scenario I (Petition)** - About 623 multifamily units are projected to be completed by the year 2005 and an additional 410 multifamily units by the year 2010, for a total of 1,033 units. About 142 single-family residential units are expected to be developed by 2005, with an additional 143 by the year 2010, totaling 285 single-family units. In addition to the single-family residential units, 194 lots are assumed to be developed by 2005. The development of homes on these lots are assumed to occur within several years of purchase.

- **Scenario II (DP)** - Currently, the County's development plan indicates that three of the petitioned land areas are designated for residential home development. These are the areas known as "Kamilonui 1," "Marina 4B," and "Kamilo Ridge (lower)." As currently designated under the plan, these areas could be expected to increase the residential home supply by about 357 units by 2000 and another 208 by 2005, for a total of 565 units.

- **Net additional as petitioned** - Based on a comparison of Scenario I (Petition) and Scenario II (DP), the net additional residential units that could be developed under the petition represent about 947 housing units. The net additional residential units due to the petitioned area are shown in the following table:

Additional Residential Development as Petitioned

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Multifamily	1,033	425	608
Single-family (1)	479	140	339
Total	1,512	565	947

(1) Includes single-family units as well as lots.

Retail/Commercial Developments

The proposed retail/commercial site is located approximately 12 miles east of downtown Honolulu, at the intersection of Kalanianaole Highway and Keahole Drive.

- **Scenario I (Petition)** - The subject area consists of 14 acres, of which five are intended to be used for the County's Park and Ride facility. The remaining nine acres would be developed as a 192,000 square foot retail/commercial center. The proposed commercial development is expected to occur in two phases, with 100,000 square feet of gross leaseable area (GLA) put in place by 2005 and another 92,000 square feet by 2010.

- **Scenario II (DP)** - Based on the County's current Development Plan, a different parcel, known as "Kalama Valley Remnant," is proposed for a retail/commercial development. The designation allows for approximately 33,800 square feet of GLA on a portion of nearly 11 acres of land. It is expected that the total 33,800 square feet of GLA could be absorbed by 2005. Under Scenario I (Petition), development on this site would be multifamily residential.

- **Net additional as petitioned** - Based on a comparison of the Scenario I (Petition) and Scenario II (DP), over 158,000 more square feet of GLA could be built in Hawaii Kai under the current petition.

Net Additional Retail/Commercial Development as Petitioned

	Scenario I (Petition)	Scenario II (DP)	Net additional/(deficit) as petitioned
GLA (sq. ft.)	192,000	33,800 (1)	158,200
Area (acres)	14	11	3

(1) Presumes build-out of only a portion of the development plan approved area, since the approved density would not require the entire site.

Industrial/Business Park

Kamehameha Schools/Bishop Estate (KSBE) owns an 11-acre site known as "Golf Course 2/1A - Industrial" (Parcel 2/1A). Both the current development plan approvals and the entitlements being petitioned would permit the property to be utilized as a light industrial/business park, which could meet the demands of service businesses, wholesalers, and others catering to the Hawaii Kai region. However, the petition would result in less total GLA than currently entitled.

- **Scenario I (Petition)** - The proposed development is expected to consist of 100,800 square feet of GLA by the year 2010, which is to be developed on 11 acres of land.
- **Scenario II (DP)** - Current entitlements on the site, under the County's development plan, allow for the development of a light industrial/business park. The plan allows for about 137,400 square feet of GLA to be built on about 15 acres of land.
- **Net deficit as petitioned** - Based on the two scenarios, development of the area as petitioned would generate less light industrial/business development than if development were to be maximized based on the County's current development plan.

Net Deficit Industrial/Business Park Development as Petitioned

	Scenario I (Petition)	Scenario II (DP)	Net additional/(deficit) as petitioned
GLA (sq. ft.)	100,800	137,400	(36,600)
Area (acres)	11	15	(4)

Inn

The petition includes the development of an inn. The proposed site is situated about 1/4-mile mauka of Sandy Beach, below the Koko Crater Botanical Garden and Stables. The development concept is for a mid-sized inn of 140 rooms to cater to the demand for accommodations outside of Waikiki from Hawaii residents, as well as foreign tourists.

As stated in the market study, the location, as well as the ambiance of the proposed inn would provide a secluded and relaxing atmosphere that would provide a unique lodging experience, unlike those typical of a hotel/inn located in Waikiki. Thus, if the site of the proposed inn were changed, its development costs and user markets would have to be reconsidered.

Currently, County development plans do not have any areas designated for the purpose of an inn within the joint master planned area. Therefore, the net economic and fiscal impacts due to the inn can be based solely on Scenario I.

Net Additional Inn Development as Petitioned

	Scenario I (Petition)	Scenario II (DP)	Net additional/(deficit) as petitioned
Rooms	140	0	140
Area (acres)	29	0	29

Golf Course

The proposed golf course would be located on the east shore of Oahu in an area known as Queen's Beach. The golf course site consists of about 166 acres of oceanfront land with a gradual slope to the ocean. Due to its oceanfront location, the course could provide a picturesque and memorable golf experience that is available at very few daily fee courses on Oahu. Adjacent and nearby properties consist of undeveloped lands and two daily fee courses, the 18-hole Hawaii Kai Championship Course and the 18-hole par-3 Hawaii Kai Executive Course.

Currently, the County's Development Plan and the Petition designate a "preservation use," on which a golf course is developable. Plans are for its development to occur between 1998 and 2000. Since the current development plan allows for this particular usage, granting of the landowners' petition would have no net effect on County and State economic and fiscal impacts.

No Change in Golf Development as Petitioned

	Scenario I (Petition)	Scenario II (DP)	Net additional/(deficit) as petitioned
Number of holes	18	18	0
Area (acres)	166	166	0

EMPLOYMENT IMPACTS

The development of the joint master planned areas under either scenario will generate short-term employment during the construction and sales/lease up of the various project components, and long-term employment in the operation and support of retail/commercial, industrial/business park, inn (Scenario I only), and golf course.

Construction Employment (Exhibit 2-A)

- **Direct Construction Employment**

Direct construction employment due to the development of the joint master planned areas would include on-site laborers, operators and craftsmen, as well as professional, managerial, sales, and clerical workers whose usual place of employment may be elsewhere in the County or State. Other types of direct employment include professional consultants such as architects, engineers, and a variety of technical consultants.

Direct construction employment has been projected based on the budgeted development costs, as provided by the various land owners and their consultants. To estimate direct construction employment due to the joint master planned development, each project component's construction budget allocated to labor (estimated at 40%) is divided by the estimated wages (approximately $46,400 in 1995 dollars as published by the Department of Labor and Industrial Relations for 1994 wages and inflated to 1995 dollars based on inflation rates furnished by Bank of Hawaii) and benefits (estimated at about 35% of wages) for an average construction worker in Honolulu. Thus, the total estimated 1995 wages and benefits of a construction worker in the City and County of Honolulu is estimated at $62,640. This results in estimated total employment that is measured in full-time equivalent (FTE) positions.

An example of the calculation of FTE construction positions for a multifamily unit is as follows:

- The estimated development cost of a multifamily unit is $152,420.
- $60,970, or 40% of the estimated development cost, is considered to be the estimated construction labor cost associated with the unit.
- The estimated construction labor cost is then divided by the average construction worker's wages and benefits, estimated at $62,640 in 1995.
- The resulting number, 0.97 is thus the estimated number of full-time-equivalent positions associated with the construction of one multifamily unit.

– **Scenario I (Petition)**

Direct construction employment from development of the areas as petitioned is estimated to range dramatically in the years between commencement of the development and completion, as shown in Exhibit 2-A. The most employment, or about 270 FTE positions annually, can be expected to occur during the initial development period (1998 to 2000). This is due in most part to the major infrastructure construction that must occur prior to the development of any of the project components. Thereafter, direct construction employment is expected to drop to about 180 to 250 FTE positions annually.

– **Scenario II (DP)**

Direct construction employment from the various project components as they are designated by the County's Development Plan is estimated to range from an average of about 10 to 200 FTE positions annually. As in Scenario I (Petition), Scenario II (DP) will generate the majority of construction employment during the initial development period (1998 to 2000). Thereafter, direct construction employment is estimated to range from 10 to 60 FTE positions annually.

– **Net additional as petitioned** - The net additional direct construction employment generated by the development of the petitioned area totals about 2,030 FTE positions and continues through the year 2013.

Net Additional Direct Construction Employment as Petitioned (FTE person-years) (Rounded)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
1998 - 2000	270	200	70
2001 - 2005	180	60	120
2006 - 2010	250	10	240
2011 - 2013	10	0	10
Total	3,010	980	2,030

- **Indirect and Induced Construction Employment**

Indirect and induced construction employment within other industries on the island and within the State are expected to be stimulated by the direct employment of construction workers. Indirect and induced employment are estimated based on findings from the "1987 Hawaii State Input-Output Model," as provided by the Department of Business, Economic Development and Tourism (DBEDT). The model provides a basis to calculate the indirect and induced jobs created by one direct construction job within Hawaii.

– **Scenario I (Petition)**

Total indirect and induced FTE person-years attributable to the construction of the petitioned area are projected to range from an average of about 30 to 630 FTE person-years annually during the respective periods, as also shown in Exhibit 2-A. During the initial three-year period, an average of about 630 FTE person-years annually are projected. Thereafter, this figure is expected to fluctuate from about 420 to 600 FTE person-years annually in the period from 2001 to 2010, to about 30 FTE person-years annually over the final projection period. Overall, indirect and induced construction employment is projected to account for over 7,040 FTE person-years over the term of the project.

- **Scenario II (DP)**

  Indirect and induced FTE person-years based on the County's development plan are projected to range from an average of about 20 to 480 FTE person-years annually during the respective periods, as also shown in Exhibit 2-A.

- **Net additional as petitioned** - The net additional indirect and induced construction employment generated by the development of the area as petitioned totals 4,760 FTE person-years.

■ **Total direct, indirect and induced construction employment** for Scenarios I and II is summarized as shown below (see Exhibit 2-A of the respective scenarios):

Projected Total (Direct, Indirect and Induced) Construction Employment as Petitioned (FTE person-years) (Rounded)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
1998 - 2000	900	680	220
2001 - 2005	600	210	390
2006 - 2010	850	30	820
2011 - 2013	40	0	40
Total	10,050	3,260	6,790

Operational Employment - Statewide (Exhibit 2-B)

■ **Direct operational employment due to the development of the joint master planned areas of Hawaii Kai** is projected to be created by sales and management of the residential developments, residential maintenance and operational staff, staff of the retail/commercial space and industrial/business park developments, and by the operations of the inn, golf course and clubhouse.

- **Residential**

  Based on the marketing experience reported by developers of similar projects, property management and sales attributable to the developer are estimated to require an average of 1.0 FTE positions for every 25 units sold in a year. Once all of the residential units have been sold, these positions would not be required.

  The residential development will also require on-going maintenance and operational staff. Such employment is typically supported by a homeowners or community association. Through discussions with industry representatives, an average of 1.0 FTE positions for every 100 units developed is estimated to be required.

- **Retail/commercial space**

  Operational employment at the various commercial/retail facilities have been projected based on the Urban Land Institute's (ULI) "Development Impact Assessment Handbook," 1994. ULI estimates an average of 2.5 workers per 1,000 square feet of GLA for retail space and 3.0 workers per 1,000 square feet of office space. For this analysis, we have used a blended ratio of 2.75 workers per 1,000 square feet of GLA.

- **Industrial/business park**

  Operational employment at the industrial/business park has been estimated to represent 2.27 FTE positions per 1,000 square feet of GLA, based on estimates of employment at industrial parks as published in "Business and Industrial Park Development Handbook," published by the ULI.

- **Inn**

  As petitioned, Hawaii Kai would include a 140 room inn. Based on a Hawaii hotel industry staffing survey prepared by KPMG in 1995, staffing requirements at a property such as the one being petitioned could be expected to represent about 1.0 FTE positions per room.

- **Golf course and clubhouse**

  Operational employment at the golf course and clubhouse has been estimated at about 30 and 15 FTE positions per year, respectively. These employment multipliers are based on interviews with several representatives of daily-fee and municipal courses on Oahu. Both the petition and the County's development plan allow for the development of a golf course.

Thus, direct operational employment increases over the study period range from about 50 to 960 FTE positions in Scenario I (Petition) and from 60 to 460 FTE positions in Scenario II (DP).

■ **Indirect and induced operational employment** within other industries on the island and elsewhere in the State is projected to occur during the sales/lease-up and facility operations at the various developments within Hawaii Kai. Analysis of the economic impacts of direct, indirect and induced employment by DBEDT have been used to estimate the indirect and induced operational employment. A blending of the multipliers relevant to the various operational positions lead to multipliers that have been applied to the direct operational employment created by each project component, as shown in Exhibit 2-B.

Thus, indirect and induced operational employment increases over the study period range from about 40 to 770 FTE positions in Scenario I (Petition) and from 50 to 410 FTE positions in Scenario II (DP).

- **Total direct, indirect and induced operational employment**

  - **Scenario I (Petition)** - Based on the foregoing assumptions, total direct, indirect and induced operational employment is projected at 90 FTE positions in the year 2000, 1,070 FTE positions by 2005, and about 1,720 to 1,730 FTE positions by 2010 and thereafter.

  - **Scenario II (DP)** - Since the development plan allows for less development, total operational employment can also be expected to be less than indicated in Scenario I (Petition). Based on the development plan, total Statewide operational employment could stabilize by the year 2010 at 870 FTE positions.

  - **Net additional employment due to the petitioned areas** - By 2010, it is expected that nearly 500 FTE direct operational positions and about 360 indirect and induced FTE positions could be created if the current petition were approved. In total, by the year 2010, approximately 860 FTE positions could be attributable to the development of the petitioned area:

The table below summarizes the net impacts on direct, indirect and induced operational employment under the petition.

Projected Full-Time Equivalent Direct, Indirect and Induced Operational Employment as Petitioned: 2010 (FTE person-years)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Direct	960	460	500
Indirect and induced	770	410	360
Total (rounded)	1,730	870	860

POPULATION IMPACTS ·

On-Site Daily Population (Exhibit 2-C & 2-D)

Development of any type within Hawaii Kai is expected to lead to an increase in households and daily population in the area. On-site residential population is projected based on the number of homes planned to be developed at the project, and occupancy rates and average household sizes as projected in Exhibit 2-C. On-site visitor population is projected based on the occupancy levels at the inn, visitors who are expected to stop at the retail/commercial developments, and the number of golf rounds attributable to non-Oahu residents.

The projected increase in the number of households and population is presented in Exhibit 2-D and a summary of the two scenarios is presented on the following page:

Projected On-Site Daily Population (cumulative) as Petitioned

	Residents		Visitors		
	Scenario I (Petition)	Scenario II (DP)	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
2000	950	860	60	60	90
2005	2,030	1,520	590	180	920
2010	3,830	1,520	950	180	3,080
2013	4,020	1,520	980	180	3,300

In-migrant Resident Population to the County and State (Exhibit 2-E)

In-migrants are those individuals and their respective dependents that move into the County or State because of development of the project. In-migrants to the County and State consist of on-site and off-site community residents but most are likely to settle off-site.

Based on sales at other Oahu projects, the majority of the residents (approximately 87%) at the new residential developments within Hawaii Kai are projected to be current residents living elsewhere on the island, with the remaining approximately 13% coming from the other islands or out-of-State.

Off-site in-migrant residents consist of construction and operational employees and their respective dependents. The analyses assumed that Oahu's construction labor force would be sufficient to accommodate the development of the petitioned areas, as well as the development of the areas as they are currently specified in the development plan. Therefore, there are no off-site in-migrant resident impacts due to construction employment. However, operational employees and their dependents are expected to contribute towards the off-site in-migrant resident population.

The projected in-migrant residents to the County and State attributable to the development in Hawaii Kai are presented in Exhibit 2-E and summarized below:

- **New Residents for the County of Honolulu**

  On-site community residents would consist of those who move within the island of Oahu, in-migrant residents to the County who are currently living on another island, and in-migrant residents from out-of-State. Under Scenario I (Petition), on-site community residents who are new to the County are estimated to represent 13% of the total or a cumulative total of about 124 individuals by 2000, 264 by 2005, 498 by 2010, and stabilize at about 523 by 2013. Under Scenario II (DP), the increase in on-site community residents who are new to the County will approximate about 112 individuals by 2000 and stabilize at about 198 by 2010.

  Off-site residents include new County residents (and their dependents) involved in the operations of the various project components in Hawaii Kai. In Scenario I (Petition), these new residents stabilize at about 72 by about 2010. In Scenario II (DP), the off-site in-migrant community is relatively small, consisting of about 35 persons by 2010.

Comparing the two scenarios, net in-migrant residents to the County due to the various projects as petitioned are relatively few. Thus, the net impact of approving the petition could represent a cumulative total of about 10 new County residents by 2000, 90 by 2005, 340 by 2010, and 360 by 2013.

- **New Residents for the State of Hawaii**

On-site community residents who are new to the State are estimated to comprise approximately 10% of the total on-site population. Compared to the 13% figure used for the County, this implies that 10% are in-migrant from other states or countries, while 3% move inter-island.

Off-site residents include operational employees (and their dependents) for the various project components within Hawaii Kai. Due to the relative inactivity in the construction industry and the sizable in-state trained labor market, no construction workers from out-of-State are projected.

- **Net additional in-migrants due to the petition**

Comparing the two scenarios, net new in-migrant residents to the County and State due to the petition by the year 2010 amount to approximately 340 persons (County) and 270 persons (State), as shown in the following table:

Projected In-Migrant Population to the State and County as Petitioned: 2010

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
In-migrants to the County:			
On-site	498	198	300
Off-site	72	35	37
Total (rounded)	570	230	340
In-migrants to the State:			
On-site	383	152	231
Off-site	72	35	37
Total (rounded)	460	190	270

ECONOMIC IMPACTS

Visitor Expenditures (Exhibit 2-F)

The petition calls for an inn, which would directly impact visitor expenditures within the County and State, while the County's Development Plan does not provide for such a use. Other visitor expenditures at the various projects, including the golf course, the shopping center and possibly the business park, are assumed to occur elsewhere on the island if these facilities are not developed in Hawaii Kai. Therefore, the net visitor spending impact between the two scenarios is approximated based on visitor spending at the proposed inn only.

Based on occupancy levels and average daily room rates at the proposed inn (as shown in Exhibit 1-A), it is estimated that guests of the inn could spend over $3.9 million by 2010 and $4.5 million by 2013. However, based on the market study prepared for the inn, only about 75% of these expenditures are considered to be new to the State, as the other 25% could be from Hawaii residents. In addition, the new out-of-State visitors will make other expenditures in the State. Hawaii Visitors Bureau (HVB) data estimates these expenditures at $83 per day for westbound visitors and $257 per day for eastbound visitors in 1994. Based on this information and the estimated 75%/25% mix of westbound and eastbound out-of-State visitors staying at the inn, these other expenditures are projected at $130 per out-of-State visitor per day in 1995.

Indirect and induced spending adds another $0.77 to the economy per direct dollar spent by each visitor, according to DBEDT. Thus, in total, annual expenditures due to out-of-State visitors staying at the inn are expected to approximate $3.0 million in 2010, and nearly $3.4 million per year by 2013 and thereafter.

The total effect of direct, indirect and induced spending attributable to the inn is projected to be as follows in the year 2010:

Projected Annual Visitor Expenditures Attributable to the Inn as Petitioned: 2010 (1995 dollars, in thousands)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Direct expenditures	$9,930	$0	$9,930
Indirect and induced	7,646	0	7,646
Total (rounded)	$17,580	$0	$17,580

Personal Income (Exhibit 2-G)

The developments within Hawaii Kai would generate additional personal income for residents of the County and the State. For purposes of this assessment, personal income is defined as the wages paid to the direct construction and operational employees associated with the various project components. Personal income is projected on the basis of average industry wages, as published in "1994 Employment and Payrolls in Hawaii" by the Department of Labor and Industrial Relations, and inflated to 1995 dollars for the various anticipated categories of employment and on the projected future employment demands of the project as presented in Exhibit 2-G. The following table depicts the net additional income paid to Oahu residents due to the development of the petitioned area.

- **Net personal income paid to Oahu residents employed in the construction of the various project components of the petitioned area** could be expected to average approximately $3.3 million annually in the initial three-year period. In the subsequent 5-year periods, net new personal income due to the petitioned area is projected to average about $5.6 million, $11.1 million, and $460,000 annually, respectively.

- **Net personal income paid to Hawaii residents employed in the operations of the various project components as petitioned,** could represent about $7.9 million in 2005, $11.5 million in 2010, and $11.4 million in 2013. Personal income has been estimated based on 1994 average wages inflated to 1995 dollars, as published by the Department of Labor and Industrial Relations for the various types of operational positions expected due to the petitioned area. As a whole, these wages may be conservative as they are based on averages of wages throughout the County, whereas the landowners report higher current wages for some comparable existing employees in Hawaii Kai.

The following table summarizes the net impacts on direct personal income from direct employment under the petition.

Direct Personal Income from Direct Employment as Petitioned: 2010 (1995 dollars, in thousands)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Construction	$11,600	$460	$11,140
Operational	24,060	12,590	11,470
Total	$35,660	$13,050	$22,610

FISCAL IMPACTS

Fiscal impacts are evaluated by comparing the operating tax revenues with the new operating expenditures that are projected to be incurred by the State and County governments.

Further development within Hawaii Kai would bring additional tax revenues to both the County and the State governments. Tax revenues come from many sources, including general excise taxes on goods and services; collections from residents and visitors for special taxes such as fuel, vehicle, public safety, highways and the like; transient accommodation taxes on hotel rooms; and real property taxes.

New residents attracted to the County and State by the development or operations of the various project components would also necessitate additional expenditures of State and County public resources. In-migrant residents would require additional public expenditures for public safety, maintenance of highways, recreational facilities, preservation and management of natural resources, health and sanitation measures, special cash capital improvements, education, mass transportation, retirement and pension funds, public welfare and other government functions. All of these government expenditures are allocated to residents who benefit from these services. Visitors, however, do not require government tax resources for items like education, retirement and pension funds and certain other services. Therefore, these other expenses are not allocated to visitors.

County Government Revenues (Exhibits 3-A and 3-B)

For the County, there are three main sources of revenue: real property taxes, government service taxes, and the allocated portion of Transient Accommodations Tax (TAT) collected by the State.

- **Net increase in property tax revenues to the County (Exhibit 3-A)**

  Real property taxes are based on tax assessed building and land values and current taxation rates. New property taxes are based on the development timing of each project component. These new taxes, less the current real property taxes being paid, are used to estimate the net new real property taxes that are attributable to the proposed development under each scenario.

  The calculation of net new property tax, as shown in Exhibit 3-A, is considered conservative because it is based on the development timing of each individual component. However, it is likely that upon rezoning of lands as petitioned, their assessed values and taxation rates would be raised to be consistent with each new zoning designation, even without any building development. In addition, the projections are considered to be conservative since not all of the estimated $200,000 in current property taxes that are being subtracted from both scenarios would be immediately lost. This is because some of the lands unaffected by the requested zoning changes would continue to be assessed for property taxes at the current rates.

  Scenario I (Petition) - Annual new property taxes based on the various developments are estimated at $680,000 in 2000, $2.3 million in 2005, $3.9 million in 2010, and $4.2 million in 2013.

  Scenario II (DP) - Based on this scenario, annual new property taxes are estimated at $568,000 in 2000 and are estimated to stabilize at about $1.4 million by 2010.

  Net new real property taxes attributable to the petition - Comparing the two scenarios, the new real property tax revenues to the County are approximately $110,000 by 2000, $1.1 million by 2005, $2.4 million by 2010, and $2.8 million by 2013.

- **Government service tax revenues** include fuel, utility, motor vehicle and other non-grant taxes. When evaluated on a per capita basis, collections of such taxes amount to about $280 per person in 1995 dollars, whether that person is a resident or a "full-time equivalent" tourist.

  Government service tax revenues have been estimated based on the increased direct, indirect and induced County population levels projected previously. However, for visitor population they are attributed only to those staying at the inn and originating from out-of-State. This is because the other on-site visitors noted in Exhibit 2-D are not considered to be attracted to the island solely by the development. In Scenario I (Petition), such taxes are estimated to be about $200,000 annually by 2010. Based on Scenario II (DP), these taxes could generate an additional $60,000 annually, by 2010, representing net new revenues attributable to the petition of about $140,000 annually by 2010.

- **TAT** - The County's allocation of the State transient TAT collections has also been calculated to estimate the total new revenues receivable to the County. As of July 1994, the State is required to distribute its TAT collections as follows:

16.7%	to the State's Convention Center Capital and Operations Special Fund
4.2%	to the State
34.9%	to Honolulu County
44.2%	to the other Neighbor Island counties
100.0%	Total

The only generator of TAT is the proposed inn. Thus, there are no TAT's under Scenario II (DP). The calculation of total TAT collections attributable to the development of the inn is shown in Exhibit 3-D. The impact of the inn on the State TAT revenues is estimated based on the assumption that 75% of the rooms are expected to be filled by out-of-State visitors. Honolulu County's 34.9% share of the statewide collections could amount to about $62,000 annually by 2010 and increase to about $71,000 by 2013.

The total increase in revenues to the County attributable to the development under the petition is projected at about $1.2 million by 2005, escalating to about $2.6 million in 2010, and about $3.0 million in the year 2013.

Total New Tax Revenues to Honolulu County as Petitioned: 2010 (1995 dollars, in thousands)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Real property taxes	$3,650	$1,230	$2,420
Non-real property tax revenues	200	60	140
TAT revenues	62	0	62
Total new County revenue	$3,910	$1,290	$2,620

State Government Revenues (Exhibits 3-D, 3-E & 3-F)

Tax revenue sources for the State government are composed primarily of general excise taxes (GET) on development costs, construction materials and visitor expenditures; personal income taxes paid by new State residents; and the TAT paid on the additional hotel earnings attributable to visitors at the inn. In addition, GET taxes on indirect and induced spending stimulated by direct spending are also included in determining total new revenues to the State.

- **General excise taxes (GET)**

New revenues to the State are projected to be generated by general excise taxes related to construction spending. A 0.5% tax is payable to the State from contractors on all wholesale materials purchased, while an additional 4% general excise tax is also payable on the total development costs.

General excise taxes from visitor spending is estimated at 4.0% for every direct dollar spent by an out-of-State inn visitor on accommodations or other purchases in Hawaii.

State tax revenues from indirect and induced expenditures are also projected to be generated as a result of the direct construction expenditures associated with the development in Hawaii Kai. Based on the DBEDT's Input-Output Model and Hawaii Econometric Model, the indirect and induced effect is estimated at $0.77 per direct tax dollar.

A summary of the projected annual new general excise tax revenues to the State is presented in the table below:

Total GET to the State as Petitioned: 1998 to 2013 (1995 dollars, in thousands)

Source of GET	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
Development costs	$18,730	$6,050	$12,680
Wholesale tax on construction materials	960	320	640
Visitor spending	3,534	0	3,534
Indirect and induced spending	17,882	4,905	12,977
Total GET attributable to the project	$41,110	$11,270	$29,840

- **Income and other individual taxes** assessed to new residents employed in the construction and operation of the various project components constitute a growing source of revenue to the State.

- **The State's retained share of the TAT** amounts to 20.9% of total collections, representing 16.7% that would be allocated to the Convention Center Capital and Operations Special Fund, and 4.2% to the general fund. The additional hotel room expenditures created by the inn are projected to generate from $32,000 to $42,000 in net additional TAT for the State.

The net total increase in State tax revenues attributable to the various developments as petitioned is projected at about $1.2 million in the year 2000, about $3.4 million in 2005, $5.9 million in 2010, and $2.1 million by 2013.

Projected Total New Revenues to the State as Petitioned (1995 dollars, in thousands)

	GET		Income and other individual taxes		TAT		Net additional/ (deficit) as petitioned
	Scenario I (Petition)	Scenario II (DP)	Scenario I (Petition)	Scenario II (DP)	Scenario I (Petition)	Scenario II (DP)	
2000	$3,130	$2,340	$1,530	$1,170	$0	$0	$1,150
2005	2,710	710	2,380	980	32	0	3,432
2010	3,640	120	3,660	1,310	37	0	5,907
2013	930	0	2,380	1,260	42	0	2,092

County Government Expenditures (Exhibits 4-A and 4-B)

Annual County government expenditures per capita are estimated at $960 for residents, and about $310 for visitors, as shown in Exhibit 4-A. This assumption does not vary between the two scenarios. Net new expenditures by the County attributable to obtaining the petitioned entitlements are projected to be about $380,000 to $400,000 per year after the year 2010, as shown in the following table:

Projected Annual New County Expenditure as Petitioned (1995 dollars, in thousands)

	In-migrant residents		Visitors		Net additional/ (deficit) as petitioned
	Scenario I (Petition)	Scenario II (DP)	Scenario I (Petition)	Scenario II (DP)	
2000	$120	$120	$0	$0	$0
2005	300	210	40	0	130
2010	550	220	50	0	380
2013	570	220	50	0'	400

State Government Expenditures (Exhibits 4-C and 4-D)

A similar analysis shows that State government operating expenditures per capita are significantly greater than for the County, at $4,670 per FTE resident, and $3,580 per visitor per year in 1995, as shown in Exhibit 4-C. Like the County expenditure basis, this would not vary between the two scenarios. During the initial construction period, net State expenditures attributable to granting the petitioned entitlements are projected to be relatively low at about $50,000 per year. However, by 2010, additional State operating expenditures from the increase in population under the petition scenario could average about $1.8 million per year, as shown in Exhibit 4-D.

Projected Annual New State Expenditure as Petitioned (1995 dollars, in thousands)

	In-migrant residents		Visitors		Net additional/ (deficit) as petitioned
	Scenario I (Petition)	Scenario II (DP)	Scenario I (Petition)	Scenario II (DP)	
2000	$470	$420	$0	$0	$50
2005	1,170	790	450	0	380
2010	2,150	890	530	0	1,790
2013	2,190	890	600	0	1,900

County Revenue and Expenditure Analysis (Exhibit 4-E)

The new fiscal impacts of the proposed developments to the County are estimated by comparing the projected operating revenues and expenditures for the County. Financially, the County experiences negligible operating expenses through the construction period. The analysis indicates that additional County government revenues projected to be generated by the various project components are above the additional operating expenses. The net impact to the County is shown in the table below:

Summary of Annual Net Additional County Revenues as Petitioned (1995 dollars, in thousands)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
2000	$400	$280	$120
2005	1,970	870	1,100
2010	3,310	1,070	2,240
2013	3,700	1,070	2,630

State Revenue and Expenditure Analysis (Exhibit 4-F)

The State could also benefit fiscally from the proposed Hawaii Kai developments. As projected, the State's revenues exceed its expenditures, as shown in Exhibit 4-F. A summary of the net impact to the State is shown below:

Summary of Annual Net Additional State Revenues as Petitioned (1995 dollars, in thousands)

	Scenario I (Petition)	Scenario II (DP)	Net additional/ (deficit) as petitioned
2000	$4,190	$3,090	$1,100
2005	3,500	900	2,600
2010	4,660	540	4,120
2013	560	370	190

Exhibit 1-A

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

HAWAII KAI JOINT MASTER PLAN DEVELOPMENT AND OPERATIONAL ASSUMPTIONS:
DEVELOPMENT AND SALES WITHIN PROJECT PERIODS (1)

	Assumptions	Project period ending 2000	2005	2010	2013	Total
Residential development (units) -	Based on market study					
Multifamily		251	372	410	0	1,033
Single-family		137	5	143	0	285
Single-family lots		0	194	0	0	194
Total residential units		**388**	**571**	**553**	**0**	**1,512**
Residential sales (units) -	10% less than developed in each period					
Multifamily		226	357	405	45	1,033
Single-family		123	17	130	14	285
Single-family lots		0	175	17	2	194
Total sold residential units		**349**	**549**	**553**	**61**	**1,512**
Custom home development on above lots (cumulative) -						
Homes completed	Development w/in 5 yrs	0	35	178	192	192
Unimproved lots		0	140	14	2	2
Total lots sold	As shown above	0	175	192	194	194
Retail/Commercial developments (cumulative) -						
Land area (acres)		0.0	14.0	14.0	14.0	14.0
Gross leasable area (sq. ft.)		0	100,000	192,000	192,000	192,000
Industrial/Business Park (cumulative) -						
Land area (acres)		0	11	11	11	11
Gross leasable area (sq. ft.)		0	50,000	100,800	100,800	100,800
Inn (cumulative) -						
Number of rooms		0	140	140	140	140
Projected occupancy rate		0%	60%	70%	80%	--
Estimated total number of guests, daily	2 persons per room	0	168	196	224	--
Estimated number of out-of-state visitors, daily	75% of above	0	126	147	168	--
Acres		0	29	29	29	--
Golf (cumulative) -						
Number of holes		18	18	18	18	18
Total acreage		166	166	166	166	166
Average golf rounds per year		80,000	80,000	80,000	80,000	80,000
Clubhouse		1	1	1	1	1

(1) Based on information provided in the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996

Exhibit 1-B

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

HAWAII KAI JOINT MASTER PLAN DEVELOPMENT AND OPERATIONAL ASSUMPTIONS:
CUMULATIVE DEVELOPMENT AND SALES

	Assumptions	2000	2005	2010	2013
Residential development (units) -	Based on Exhibit 1-A				
Multifamily		251	623	1,033	1,033
Single-family		137	142	285	285
Single-family lots		0	194	194	194
Total developed residential units		**388**	**959**	**1,512**	**1,512**
Residential sales (units) -	Based on Exhibit 1-A				
Multifamily		226	583	988	1,033
Single-family		123	140	271	285
Single-family lots		0	175	192	194
Total sold residential units		**349**	**898**	**1,451**	**1,512**
Custom home development -	Based on Exhibit 1-A				
Homes completed		0	35	178	192
Unbuilt lots		0	140	14	2
Total lots sold		0	175	192	194
Retail/Commercial developments -	Based on Exhibit 1-A				
Land area (acres)		0.0	14.0	14.0	14.0
Gross leasable area (sq. ft.)		0	100,000	192,000	192,000
Industrial/Business Park -	Based on Exhibit 1-A				
Land area (acres)		0	11	11	11
Gross leasable area (sq. ft.)		0	50,000	100,800	100,800
Inn -	Based on Exhibit 1-A				
Number of rooms		0	140	140	140
Projected occupancy rate		0%	60%	70%	80%
Land area (acres)		29	29	29	29
Golf -	Based on Exhibit 1-A				
Number of holes		18	18	18	18
Average golf rounds per year		80,000	80,000	80,000	80,000
Clubhouse		1	1	1	1

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED DIRECT, INDIRECT AND INDUCED CONSTRUCTION EMPLOYMENT
(Full-Time Equivalent Person Years)

	Development cost assumptions	Average annual full-time equivalent person years (1) 1996 - 2000	2001 - 2005	2006 - 2010	2011 - 2013	Total FTE person-years
Direct construction employment:						
Residential development (units) (2) -						
Multifamily	$152,420	81	72	80	0	1,008
Single-family	$407,480	119	3	74	0	744
Lots:						
Lots	$107,520	0	27	0	0	136
Homes	$375,000	0	17	69	11	438
Retail/Commercial	$192 per sq. ft GLA	0	24	23	0	238
Industrial/Business Park	$97 per sq. ft GLA	0	6	6	0	66
Inn	$173,900 per room	0	31	0	0	158
Golf	$141,420 per acre	50	0	0	0	153
Clubhouse	$4,200,000 total	9	0	0	0	30
Infrastructure	$5,907,000 total	11	1	0	0	41
Subtotal, direct construction employment (rounded)		270	180	250	10	3,010
Indirect and induced construction employment:	Indirect and induced jobs multiplier (3)					
Residential development -						
Multifamily	2.92 per direct	238	212	233	0	2,942
Single-family	2.24 per direct	266	6	166	0	1,660
Lots:						
Lots	2.24 per direct	0	60	0	0	301
Homes	2.24 per direct	0	37	153	26	978
Retail/Commercial	1.60 per direct	0	39	38	0	379
Industrial/Business Park	1.60 per direct	0	10	10	0	103
Inn	1.83 per direct	0	57	0	0	288
Golf	1.82 per direct	91	0	0	0	276
Clubhouse	1.60 per direct	14	0	0	0	46
Infrastructure	1.82 per direct	20	2	0	0	72
Subtotal, indirect and induced construction employment (rounded)		630	420	600	30	7,040
Total, direct, indirect and induced employment (rounded) (3)		900	600	850	40	10,050

(1) Based upon the number of units developed (as shown in Exhibit 1-A) and construction costs per unit; with 40% dedicated to labor wages and benefits that average about $62,640 per full-time equivalent worker. This is assuming an average construction worker's annual wages (estimated at about $46,400 based on information from the Department of Labor and Industrial Relations) and benefits (estimated at about 35% of wages to determine full-time equivalent positions).
(2) Estimated construction costs are based on a weighted average of the various construction costs associated with each of the multifamily and single-family residential projects, as calculated based on information provided by Kemper Real Estate Management Company.
(3) Based on the "1987 Hawaii State Input-Output Model," by Department of Business, Economic Development, and Tourism.

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED DIRECT, INDIRECT AND INDUCED OPERATIONAL EMPLOYMENT
(Full-Time Equivalent Positions)

Employment type	Full-time equivalent assumptions	2000	2005	2010	2013
Direct operational employment:					
Residential property management and sales (1)	1.0 FTE / 25 units sold/ per yr	5	4	4	1
Residential property maintenance and operations (1)	1.0 FTE / 100 cumulative units	4	10	15	15
Retail/Commercial space (2)	2.75 FTE per 1,000 sq.ft. GLA	0	275	528	528
Industrial/Business Park	2.27 FTE/1,000 GLA	0	114	229	229
Inn	1.0 FTE /rm./ per yr.	0	140	140	140
Golf Course	30 FTE/ per yr.	30	30	30	30
Golf Course Clubhouse	15 FTE/ per yr.	15	15	15	15
Subtotal direct operational employment (rounded)		50	590	960	960
Indirect and induced operational employment:	Indirect and induced jobs multiplier (3)				
Property management and sales	1.11 per direct	5	5	5	1
Residential property maintenance and operations	1.26 per direct	5	12	19	19
Retail/Commercial space	0.64 per direct	0	176	338	338
Industrial/Business Park	1.00 per direct	0	114	230	230
Inn	1.01 per direct	0	142	142	142
Golf Course	0.88 per direct	26	26	26	26
Golf Course Clubhouse	0.51 per direct	8	8	8	8
Subtotal, indirect and induced operational employment (rounded)		40	480	770	760
Total (rounded)		90	1,070	1,730	1,720

(1) Property management and sales operational employment estimated at 1.0 persons for every 25 residential home sales. Based on interviews with other residential developers on Oahu.
(2) Estimated based on an average of 2.5 retail workers and 3.0 office workers per 1,000 square feet, as published in "Development Impact," ULI - the Urban Land Institute, 1994.
(3) Based on the "1987 Hawaii State Input-Output Model," by Department of Business, Economic Development, and Tourism

Exhibit 2-C

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

UNIT USAGE ASSUMPTIONS FOR ON-SITE POPULATION PROJECTIONS (FOR SOLD UNITS)

	Projected occupancy rate	Persons per unit (1)
Completed multifamily units	95%	2.78
Completed single-family units	95%	2.98
Completed single-family lots with homes	85%	3.0

(1) Estimated based upon the projected 1995 to 2013 average household size for the Hawaii Kai area, adjusted for unit type.

Exhibit 2-D

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED NUMBER OF HOUSEHOLDS AND ON-SITE DAILY POPULATION

	Assumptions	Project period 2000	2005	2010	2013
Incremental:					
Projected number of households (1) -					
Multifamily		215	340	385	43
Single-family		117	16	124	14
Single-family lots (with custom homes built)		0	30	122	12
Total households (rounded)		330	390	630	70
Projected on-site population (2) -					
Multifamily		597	944	1,069	119
Single-family		349	48	369	41
Single-family lots (with custom homes built)		0	88	363	36
Total residents (rounded)		950	1,080	1,800	200
Visitors -					
Inn (total number of guests)	Based on Exhibit 1-A	0	168	196	224
Retail/Commercial developments (3)		0	360	690	690
Golf Course (4)		61	61	61	61
Total daily visitors (rounded)		60	590	950	980
Cumulative:					
Projected number of households -	Based on above				
Multifamily		215	554	939	981
Single-family		117	133	257	271
Single-family lots (with custom homes built)		0	30	151	164
Total households (rounded)		330	720	1,350	1,420
Projected on-site population -	Based on above				
Multifamily		597	1,540	2,609	2,728
Single-family		349	397	766	807
Single-family lots (with custom homes built)		0	88	451	487
Total residents (rounded)		950	2,030	3,830	4,020
Visitors	Based on above	60	590	950	980

(1) Based upon the projected number of housing units sold, as shown in Exhibit 1-A, and occupancy rates, as shown in Exhibit 2-C.
(2) Based upon the number of households and average household size, as shown in Exhibit 2-C.
(3) Estimate based on total retail sales of $225 per gross leasable area and visitors representing 12% of expenditures, at about $12.00 per visit. Based on information provided in the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996.
(4) Estimated annual rounds of 80,000 with visitor play estimated at 28% of the total. Based on information provided in the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996.

Exhibit 2-E

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

TOTAL PROJECTED ADDITIONAL IN-MIGRANT RESIDENT POPULATION
TO THE CITY AND COUNTY OF HONOLULU AND THE STATE OF HAWAII (CUMULATIVE)

	Assumptions	2000	2005	2010	2013
City and County of Honolulu:					
On-site community residents	13% of daily resident population	124	264	498	523
Off-site community residents:					
Construction employees	100% assumed to be from Oahu	0	0	0	0
Construction employees' dependents	100% assumed to be from Oahu	0	0	0	0
Operational employees	5% of direct operational employees	3	30	48	48
Operational employees' dependents	50% of above	1	15	24	24
Total in-migrant population to the City and County of Honolulu (rounded)		**130**	**310**	**570**	**590**
State of Hawaii:					
On-site community residents	10% of daily resident population	95	203	383	402
Off-site community residents:					
Construction employees	100% assumed to be from Oahu	0	0	0	0
Construction employees' dependents	100% assumed to be from Oahu	0	0	0	0
Operational employees	5% of direct operational employees	3	30	48	48
Operational employees' dependents	50% of above	1	15	24	24
Total in-migrant population to the State of Hawaii		**100**	**250**	**460**	**470**

Exhibit 2-F

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED ANNUAL OAHU VISITOR EXPENDITURES ATTRIBUTABLE TO THE PROJECT,
FROM OUT-OF-STATE VISITORS ONLY
(1995 Dollars, $000's)

	Assumptions	2000	2005	2010	2013
Direct annual visitor expenditures:					
Accommodations (1)	For out-of-state visitors (75% of total room revenue)	$0	$2,529	$2,951	$3,373
Other spending (2)	$130/out-of-state visitor/day	$0	$5,979	$6,975	$7,972
Total direct annual visitor expenditures		$0	$8,510	$9,930	$11,340
Indirect and induced expenditures (3)	$0.77 per direct	$0	$6,553	$7,646	$8,732
Total annual expenditures (rounded)		$0	$15,060	$17,580	$20,070

(1) Based on an average room rate of $110 and occupancy at levels as shown in Exhibit 1-A. Applied only to 75% of room revenue, based on estimated guest mix of about 25% Hawaii residents and 75% out-of-state visitors, as stated in the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996.
(2) Estimated at $130 per out-of-state visitor per day, based on a weighted average guest mix and 1994 non-lodging expenditures of $83 for westbound visitors and $257 for eastbound visitors.
(3) Based on the "1987 Hawaii State Input-Output Model," by Department of Business, Economic Development, and Tourism

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED DIRECT PERSONAL INCOME FROM DIRECT EMPLOYMENT ASSOCIATED WITH THE PROJECT
(1995 Dollars, $000's)

	Assumptions	2000	2005	2010	2013
Direct employment (persons):					
Construction	Based on Exhibit 2-A	270	180	250	10
Operational -	Based on Exhibit 2-B				
Property management & sales		5	4	4	1
Property maintenance & operations		4	10	15	15
Retail/Commercial space		0	275	528	528
Industrial/Business Park		0	114	229	229
Inn		0	140	140	140
Golf Course		30	30	30	30
Golf Course Clubhouse		15	15	15	15
Total direct employment (rounded)		320	770	1,210	970
	Full-time equivalent wages (1)				
Direct personal income (rounded):					
Construction	$46,410	$12,530	$8,350	$11,600	$460
Operational -					
Property management & sales	$27,660	130	120	120	20
Property maintenance & operations	$27,980	110	270	420	420
Retail/Commercial space	$22,590	0	6,210	11,930	11,930
Industrial/Business Park	$30,570	0	3,470	6,990	6,990
Inn	$27,160	0	3,800	3,800	3,800
Golf Course	$20,000	600	600	600	600
Golf Course Clubhouse	$13,190	200	200	200	200
Total annual personal income (rounded)		$13,570	$23,020	$35,660	$24,420

(1) Sources: 1994 Honolulu County wages as reported in "1994 Employment and Payrolls in Hawaii," Department of Labor and Industrial Relations, and inflated to 1995 dollars (inflation rates as provided by the Bank of Hawaii Economics Department); interviews with management at 2 daily fee courses and a representative of the City's golf courses.

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED ADDITIONAL PROPERTY TAX REVENUES TO THE COUNTY GOVERNMENT
(1995 Dollars, $000's)

Source of tax revenue	Property tax rate per $1,000 value (building/land)	2000	2005	2010	2013
Projected property taxes (1):					
Multifamily (2)	$3.52 / $3.52	$203	$586	$964	$984
Single-family (2)	$3.92 / $3.12	285	364	1,160	1,556
Single-family unimproved lots (3)	$3.92	0	102	10	1
Retail/Commercial (4)	$8.51 / $8.51	0	297	580	580
Industrial/Business Park (5)	$8.51 / $8.51	0	143	287	287
Inn (6)	$9.64 / $9.64	0	661	661	661
Golf Course and clubhouse (7)	$9.00 / $9.00	187	187	187	187
Total new property tax revenues (rounded)		680	2,340	3,850	4,240
Less: Current property taxes (rounded)		200	200	200	200
Net new County property tax revenues (rounded) (1)		$480	$2,140	$3,650	$4,040

(1) Conservative estimate of future real property taxes. See text for further explanation.
(2) Estimated building values have been based on each individual project's estimated development cost per unit, as provided by the landowner
Estimated land values have been based on each individual project's estimated sales price per unit less the respective estimated development cost per unit
(3) Real property taxes shown are based the project's estimated sales price.
(4) Real property taxes shown are based on a building value equal to the development cost, as provided by the landowner, and land value has been estimated at $40 per sq. ft.
Real property taxes on the land is based on 9 acres. This is based on information provided by the landowners indicating that of the total 14 acres, five will be allocated to the City's Park and Ride Program. Therefore, it has been assumed that the City will be exempt from paying real property taxes on the five acre parcel.
(5) Real property taxes shown are based on a building value equal to the development cost, as provided by the landowner, and land value has been estimated at $25 per sq. ft.
(6) Real property taxes shown are based on a building value equal to the development cost, as provided by the landowner, and land value has been estimated at $35 per sq. ft.
(7) Estimated assessed value of $100,000 per acre for land, plus $4.2 million for building.

Exhibit 3-B

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED NEW GOVERNMENT SERVICE TAX REVENUES COLLECTED BY HONOLULU COUNTY
(1995 Dollars, $000's)

City and County of Honolulu per capita non-real property tax collections:

Collection sources	Total collections FY'93 (000's) (1)	Source population (rounded) (2)	Annual revenue Per resident	Annual revenue Per visitor
Liquid fuel	$44,334	914,800	$48	$48
Utility franchise	14,857	914,800	16	16
Motor vehicle weight	20,065	914,800	22	22
Other (non-grant) sources	160,934	914,800	176	176
Total 1993 dollars	$240,190		$263	$263
Total 1995 dollars, rounded (3)			$280	$280

Total County tax collections associated with the Hawaii Kai Joint Master Plan Development areas:

	Assumptions	2000	2005	2010	2013
Increase in resident and visitor population due to the project:					
Additional in-migrants to the County	Based on Exhibit 2-E	130	310	570	590
Average daily visitor population	Based on Exhibit 1-A (inc out-of-state visitors only)	0	126	147	168
Total increase in daily population (rounded)		130	440	720	760
Projected non-RPT revenue:					
Resident generated revenue	$280 per in-migrant resident	$36	$87	$160	$165
Visitor generated revenue	$280 per daily out-of-state visitor	0	35	41	47
Total new non-real property taxes to the County, attributable to the project (rounded)		$40	$120	$200	$210

(1) County government operating revenues for fiscal year ended June 30, 1993 as reported by the Tax Foundation of Hawaii.
(2) Estimated de facto population for the County as of January 1, 1993, based upon the estimated de facto population for July 1, 1992 and 1993.
(3) Adjusted to 1995 dollars based upon CPI increases from 1994 to 1995, as reported by the Bank of Hawaii.

Exhibit 3-C

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED TOTAL NEW TAX REVENUES TO HONOLULU COUNTY
(1995 Dollars, $000's)

Source of tax revenue	Assumptions	2000	2005	2010	2013
Real property taxes	Based on Exhibit 3-A	$480	$2,140	$3,650	$4,040
Non-real property tax revenues	Based on Exhibit 3-B	40	120	200	210
TAT revenues	Based on Exhibit 3-D	0	53	62	71
Total new County revenue (rounded)		$520	$2,310	$3,910	$4,320

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED REVENUES FROM TRANSIENT ACCOMMODATIONS TAX (TAT)
(1995 Dollars)

	Assumptions	2000	2005	2010	2013
Calculation of total TAT revenues due to out-of-state visitors staying at the Inn collected by the State:					
Revenue from hotel occupancy (1)	See note (1)	$0	$2,529,450	$2,951,025	$3,372,600
Total TAT (rounded)	6.0% of inn rooms revenue	0	151,770	177,060	202,360
Allocation of TAT revenues:					
State of Hawaii -	20.9% of TAT rev.	0	31,720	37,010	42,290
City and County of Honolulu (rounded)	34.9% of TAT rev.	0	52,970	61,790	70,620
Neighbor Island Counties (rounded)	44.3% of TAT rev.	0	67,230	78,440	89,650
Total TAT revenue (rounded) (2)		$0	$151,920	$177,240	$202,560

(1) Based on an average room rate of $110 and occupancy levels as shown in Exhibit 1-A. Applied to only 75% of room revenue, based on an estimated guest mix of about 25% Hawaii residents and 75% out-of-state visitors, as stated in the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996.
(2) Total TAT revenues, as shown, will not equal "Total TAT" as shown above due to rounding.

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED ANNUAL NEW GENERAL EXCISE TAX (GET) REVENUES TO THE STATE GOVERNMENT
(1995 Dollars, $000's)

	Development costs per unit, as shown in Ex. 2-A	Average annual revenue 1998 - 2000	2001 - 2005	2006 - 2010	2011 - 2013	Total
GET on development (1) -						
Residential development (units):						
Multifamily	$152,420	$510	$454	$500	$0	$6,301
Single-family	$407,480	744	16	466	0	4,648
Lots:						
Lots	$107,520	0	167	0	0	837
Homes	$375,000	0	105	430	72	2,743
Retail/Commercial	$192 per sq. ft GLA	0	153	141	0	1,476
Industrial/Business Park	$97 per sq. ft GLA	0	39	39	0	395
Inn	$173,900 per room	0	195	0	0	977
Golf	$141,420 per acre	313	0	0	0	942
Clubhouse	$4,200,000 total	56	0	0	0	171
Infrastructure (2)	$5,907,000 total	70	5	0	0	239
Total annual GET on construction (rounded)		$1,690	$1,130	$1,580	$70	$18,730
GET on wholesale construction materials (3) -						
Residential development (units):						
Multifamily	$152,420	$26	$23	$25	$0	$318
Single-family	$407,480	37	1	23	0	235
Lots:						
Lots	$107,520	0	6	0	0	45
Homes	$375,000	0	5	21	4	137
Retail/Commercial	$192 per sq. ft GLA	0	8	7	0	77
Industrial/Business Park	$97 per sq. ft GLA	0	2	2	0	23
Inn	$173,900 per room	0	10	0	0	52
Golf	$141,420 per acre	16	0	0	0	50
Clubhouse	$4,200,000 total	3	0	0	0	11
Infrastructure	$5,907,000 total	3	0	0	0	15
Total annual GET on construction materials (rounded)		$80	$60	$80	$0	$960
Direct visitor spending (out-of-state visitors):						
For accommodations (4)	Based on Exhibit 2-F	$0	$2,529	$2,951	$3,373	$37,520
For "other" visitor expenditures (5)	Based on Exhibit 2-F	0	5,979	6,975	7,972	$50,819
Total (rounded)		$0	$8,510	$9,930	$11,340	$88,340
GET on direct visitor spending	4.0% per direct dollar	$0	$340	$397	$454	$3,534
GET on indirect and induced spending (6)	$0.77 per direct dollar	$1,363	$1,178	$1,584	$403	$17,882
Total GET attributable to the project (rounded)		$3,130	$2,710	$3,640	$930	$41,110

(1) Based on General Excise Tax of 4.0% the total development costs.
(2) Estimated infrastructure cost breakdown by period is $5.2 million from 1998 - 2000 and $675,000 from 2001 - 2005. Based on information provided by Kamper Real Estate Management Company.
(3) Based on a wholesale construction material tax of 0.5% charged to contractors for materials, assumed to be 40% of off-site, on-site, residential development and commercial/retail costs.
(4) Applied only to 75% of room revenue, based on estimated guest mix of about 25% Hawaii residents and 75% out-of-state visitors.
(5) Based on 1994 non-lodging expenditures of $93 for westbound visitors and $257 for eastbound visitors.
(6) Based on the "1987 Hawaii State Input-Output Model," by the Department of Business, Economic Development, and Tourism.

Exhibit 3-F

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED ANNUAL TOTAL NEW REVENUES TO THE STATE GOVERNMENT
(1995 Dollars, $000's)

Revenue source	Assumptions	2000	2005	2010	2013
General Excise Tax	Based on Exhibit 3-E	**$3,130**	**$2,710**	**$3,640**	**$930**
Income and other individual taxes:					
Direct personal income -	Based on Exhibit 2-G				
Construction		$12,530	$8,350	$11,600	$460
Operational -					
Property management & sales		130	120	120	20
Property maintenance & operations		110	270	420	420
Retail/Commercial space		0	6,210	11,930	11,930
Industrial/Business Park		0	3,470	6,990	6,990
Inn		0	3,800	3,800	3,800
Golf Course		600	600	600	600
Golf Course Clubhouse		200	200	200	200
Taxes (1) -					
Construction	11.4% of pers. inc.	1,431	954	1,325	53
Operational -					
Property management & sales	10.0% of pers. inc.	13	12	12	2
Property maintenance & operations	10.0% of pers. inc.	11	27	42	42
Retail/Commercial space	9.4% of pers. inc.	0	584	1,122	1,122
Industrial/Business Park	10.2% of pers. inc	0	354	713	713
Inn	9.9% of pers. inc.	0	377	377	377
Golf Course	9.1% of pers. inc.	54	54	54	54
Golf Course Clubhouse	7.8% of pers. inc.	16	16	16	16
Income and other individual taxes (rounded)		**1,530**	**2,360**	**3,660**	**2,380**
Transient Accommodations Tax	Based on Exhibit 3-D	**0**	**32**	**37**	**42**
Total State revenues (rounded)		**$4,660**	**$5,120**	**$7,340**	**$3,350**

(1) Includes state income, general excise, auto weight, gas and specific excise taxes; based on typical tax burdens for households utilizing the direct personal income as stated above based on state income tax rates, and the ratio of income to other state taxes paid as shown for "The Tax Burden of The Average Aloha Family," by the Tax Foundation of Hawaii.

Exhibit 4-A

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

CITY AND COUNTY OF HONOLULU AVERAGE PER CAPITA GOVERNMENT OPERATING EXPENSES

Function	Total expenditures FY'93 ($000's) (1)	Service population (2)	Annual expenditure Per resident	Annual expenditure Per visitor
General government	$91,318	914,800	$100	$100
Public safety	181,038	875,600	207	--
Highways	26,498	875,600	30	--
Health and sanitation	107,080	875,600	122	--
Recreation	54,310	875,600	62	--
Interest	63,297	875,600	72	--
Bond redemption	42,016	914,800	46	46
Retirement and pension	57,693	914,800	63	63
Economic and urban development	25,358	914,800	28	28
Mass transit	79,640	875,600	91	--
Cash capital improvements	23,670	875,600	27	--
Miscellaneous	57,741	914,800	63	63
Total 1993 dollars	$809,659		$911	$300
Total 1995 dollars (rounded) (3)			**$960**	**$310**

(1) County government operating expenditures for fiscal year ended June 30, 1993, as reported in Tax Foundation of Hawaii, "Government in Hawaii," 1994.
(2) Resident and de facto population estimates for the County as of January 1, 1993, based on estimated de facto population for July 1, 1992 and 1993
(3) Adjusted to 1995 dollars based on estimated increases as reported by Bank of Hawaii Information Center

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED ANNUAL COUNTY GOVERNMENT EXPENDITURES
(1995 Dollars, $000's)

	Assumptions	Project period 2000	2005	2010	2013
Average daily population:					
Visitor population (1)	See note (1)	0	126	147	168
In-migrant residents to the County	Based on Exhibit 2-E	130	310	570	590
New County expenditure (rounded):					
Visitor population	$310 per visitor, based on Exhibit 4-A	$0	$40	$50	$50
In-migrant residents to the County	$960 per resident based on Exhibit 4-A	120	300	550	570
New County expenditure		**$120**	**$340**	**$600**	**$620**

(1) Based on 75% of the daily inn visitors, as shown in Exhibit 2-D, due to an estimated guest mix of about 25% Hawaii residents and 75% out-of-state visitors, as stated in the report entitled, "Hawaii Kai Joint Master Plan Market Assessment," dated May 1996

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

STATE OF HAWAII AVERAGE PER CAPITA GOVERNMENT OPERATING EXPENSES

Function	Total expenditures FY'93 ($000's) (1)	Service population (2)	Annual expenditure Per resident	Per visitor
General government	$447,606	1,182,500	$379	$379
Public safety	177,055	1,276,400	139	--
Highways	109,069	1,276,400	85	--
Natural resources	43,042	1,276,400	34	--
Health and sanitation	193,085	1,276,400	151	--
Hospitals and institutions	282,110	1,182,500	239	239
Public welfare	777,641	1,182,500	658	658
Education	1,399,442	1,182,500	1,183	1,183
Recreation	42,256	1,276,400	33	--
Utilities and other enterprises	312,462	1,276,400	245	--
Debt service	436,795	1,276,400	342	--
Retirement and pension	219,055	1,182,500	185	185
Employees' health insurance	744	1,182,500	1	1
Unemployment compensation	236,596	1,182,500	200	200
Grants-in-aid to counties	1,725	1,276,400	1	--
Urban redevelopment and housing	108,174	1,182,500	91	91
Cash capital improvements	449,834	1,182,500	380	380
Miscellaneous	117,342	1,182,500	99	99
Total 1993 dollars	$5,354,055		$4,446	$3,415
Total 1995 dollars (rounded) (3)			**$4,670**	**$3,580**

(1) State government operating expenditures for fiscal year ended June 30, 1993, as reported in Tax Foundation of Hawaii, "Government in Hawaii," 1994.
(2) Resident and de facto population estimates for the State as of January 1, 1993, based on estimated de facto population for July 1, 1992 and 1993
(3) Adjusted to 1995 dollars based on estimated increases as reported by Bank of Hawaii Information Center.

Exhibit 4-D

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

PROJECTED ANNUAL STATE GOVERNMENT EXPENDITURES
(1995 Dollars, $000's)

	Assumptions	2000	2005	2010	2013
Average daily population:					
Visitor population	Based on Exhibit 4-B	0	128	147	168
In-migrant residents to the State	Based on Exhibit 2-E	100	250	460	470
New State expenditure (rounded):					
Visitor population	$3,580 per visitor based on Exhibit 4-C	$0	$450	$530	$600
In-migrant residents to the State	$4,670 per resident based on Exhibit 4-C	470	1,170	2,150	2,190
New State expenditures		**$470**	**$1,620**	**$2,680**	**$2,790**

Exhibit 4-E

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

SUMMARY OF COUNTY GOVERNMENT REVENUES AND EXPENDITURES
(1995 Dollars, $000's)

		Project period			
	Assumptions	2000	2005	2010	2013
New County revenues	Based on Exhibit 3-C	$520	$2,310	$3,910	$4,320
New County expenditures	Based on Exhibit 4-B	120	340	600	620
Net additional revenues		**$400**	**$1,970**	**$3,310**	**$3,700**
Revenue/expenditure ratio (1)		**4.3**	**6.8**	**6.5**	**7.0**

(1) New revenues divided by new expenditures.

Scenario I: Development On Hawaii Kai Joint Master Plan Areas As Petitioned

SUMMARY OF STATE GOVERNMENT REVENUES AND EXPENDITURES
(1995 Dollars, $000's)

	Assumptions	Project period 2000	2005	2010	2013
New State revenues	Based on Exhibit 3-F	$4,660	$5,120	$7,340	$3,350
New State expenditures	Based on Exhibit 4-D	470	1,620	2,680	2,790
Net additional revenues		**$4,190**	**$3,500**	**$4,660**	**$560**
Revenue/expenditure ratio (1)		**9.9**	**3.2**	**2.7**	**1.2**

(1) New revenues divided by new expenditures.

Appendix

L

Market Analysis

(KPMG Peat Marwick)

1 - EXECUTIVE SUMMARY

BACKGROUND

Maunalua Associates, Inc. (MAI), Kamehameha Schools/Bishop Estate (KSBE) and Kaiser Aluminum and Chemical Corporation (KACC) have engaged in a cooperative effort to complete the originally intended buildout of Hawaii Kai. The remaining undeveloped land now being master-planned encompasses approximately 546 acres. The three land owners have asked KPMG Peat Marwick LLP (KPMG) to prepare this market assessment for the subject properties. This market assessment is intended to be included in an Environmental Impact Report (EIR) that is planned to be submitted to the City and County of Honolulu, requesting a zoning amendment for the subject properties.

STUDY OBJECTIVES

The objectives of KPMG's assistance were as follows:

- To review relevant residential, retail/commercial, industrial/business park, inn and golf course market conditions.
- Based upon the above, to assess the anticipated market support for the proposed residential, retail/commercial, industrial/business park, inn and golf course uses on the subject properties.

PROJECT DESCRIPTION

The following table summarizes the acreages proposed for the various land uses:

Proposed New Land Uses in Hawaii Kai

Land use	Number of sites	Gross acres	Percent of total area
Residential	8	326	60%
Retail/Commercial	1	14	3%
Industrial/ Business Park	1	11	2%
Inn	1	29	5%
Golf Course	1	166	30%
Total	12	546	100%

The projects planned for the subject properties are summarized below:

- **Residential** - Eight sites, comprising about 326 acres, are proposed for development of about 1,500 residential units. This is equivalent to an average gross unit density of approximately 4.6 units per acre. The residential developments are proposed to include a broad range of product types to appeal to a wide spectrum of housing demand. Products offered could include low-rise townhouse developments, mid-rise condominium units, duplex and zero-lot-line developments, single-family homes, and custom house lots.
- **Retail/Commercial** - Retail/commercial development is proposed for a 14-acre property located at the mauka corner of Kalanianaole Highway and Keahole Street. The property has excellent road frontage, access, and visibility and is adjacent to the current location of a Park & Ride facility, which will be relocated to the east end of the development. A waterfront commercial center consisting of approximately 192,000 square feet of retail and office space is proposed for the site.
- **Industrial/Business Park** - A business park with limited industrial uses is planned to be located on approximately 11 acres in the Kalama Valley area, adjacent to an existing sewage treatment plant. The property is currently vacant. Approximately 100,000 square feet of space are proposed for the site and the development is intended to address a shortage of service commercial space within East Honolulu.
- **Inn** - An inn with 140 rooms is planned to be located on a site of approximately 29 acres in Kalama Valley, adjacent to Koko Crater and the proposed business park. The inn is intended to target markets such as specialty/repeat visitors to the islands, those visiting family and friends in East Honolulu, and corporate and other group retreats.
- **Golf** - Development of a golf course is proposed to address the strong demand for golf within urban Honolulu generated by both residents and visitors. The course would be developed on a 166-acre oceanfront site that will provide a memorable golf experience.

SUMMARY OF THE MARKET ASSESSMENT

A summary of the major findings regarding the market assessment for the subject properties in Hawaii Kai is presented in the following sections. An approximate development phasing schedule under the joint master-plan also follows. This schedule incorporates KPMG's findings regarding the market support for each use. It should be noted, however, that much of the non-residential projects are proposed to be developed in the years 2001 to 2005 although market demand could support the projects earlier. This schedule is considered to be preliminary, and future adjustments in the timing of the developments may become necessary as dictated by the market.

Projected Supportable Development Schedule for the Subject Properties

Land use	Total cumulative development 1996-2000	2001-2005	2006-2013
Residential (units)			
Multifamily	251	623	1,033
Single-family	137	336	479
Cumulative total	388	959	1,512
Retail/Commercial (square feet)	--	100,000	192,000
Industrial/Business Park (square feet)	--	50,000	100,800
Inn (rooms)	--	140	140
Golf Course (holes)	18	18	18

Note: Shaded areas indicate construction periods.

As shown in the table above, by the year 2000, about 390 residential units are projected to be developed. In the subsequent period (2001 to 2005), an additional 570 residential units are expected to be completed, along with the first phase of the retail/commercial center (approximately 100,000 square feet), the first phase of the industrial/business park (approximately 50,000 square feet), the inn and the golf course. In the final period (2006 to 2013), an additional 550 residential units and the second phases of the retail/commercial center (approximately 92,000 square feet) and industrial/business park (approximately 50,800 square feet) are expected to be completed.

Residential Market Assessment (Maunalua Associates, Inc.)

Given an adequate supply of new housing units, the population of the Hawaii Kai community is projected to continue to grow as a result of its high quality of development, comprehensive community facilities, convenient location relative to downtown and Waikiki employment areas and its scenic and highly desirable reputation. In the past, demand appears to have been constrained by the number of new homes that could be constructed in the area.

Based upon the projected increase in population and households in Hawaii Kai, the demand for housing units is projected to exceed the supply through the year 2013. Thus, even if all of the currently entitled projects were to be developed, as well as the subject properties, there would still be a shortage of over 1,900 housing units in Hawaii Kai.

By the year 2000, about 390 residential units are projected to be constructed at the subject properties; an additional 570 units are projected during the subsequent five-year period; and another 550 units are projected during the years 2006 to 2013, as shown in the table above.

Retail/Commercial Market Assessment (Kamehameha Schools/Bishop Estate)

Future retail space demand in Hawaii Kai has been projected based upon the anticipated population growth and demonstrated historical expenditure estimates for Hawaii Kai and other East Oahu residents. In addition, visitors to the East Oahu area are projected to generate incremental spending at the center. Office space demand is estimated based upon the projected growth in Hawaii Kai's population and the historical relationship of the demand for office space in other similar growing communities.

Based upon projected resident and visitor retail expenditure estimates for Hawaii Kai, approximately 70,000 to 80,000 square feet of additional retail space could be expected to be supportable by the year 2000; 100,000 to 120,000 square feet by the year 2005; and about 130,000 to 150,000 square feet could be supported by the year 2010.

On the other hand, Hawaii Kai's office market currently has an ample supply of space. However, based upon the projected future increase in households, approximately 35,000 to 45,000 square feet of office space could be supported by the year 2010.

The retail/commercial center (192,000 square feet) is projected to be developed in two phases, with the initial phase planned to be completed by the year 2005, containing about 100,000 square feet. The second phase would contain approximately 92,000 square feet and is projected for completion by the year 2010, as shown previously.

Industrial Market Assessment (Kamehameha Schools/Bishop Estate)

Demand for industrial space in Hawaii Kai is created by the growing need to serve local residents, service businesses, wholesalers and other business park users at a location that is convenient to the community.

Two market indicators which are drawn from similar communities were utilized to project industrial demand in Hawaii Kai, including an analysis of the average population per industrial acre demonstrated at other comparable communities and the aggregate household income per industrial acre. The analysis indicates that the primary market area alone could be expected to support 16 to 22 acres of industrial lands, or up to two times the area proposed in Hawaii Kai.

Based upon the high demand for smaller industrial bays in the Windward area reported by local brokers, the existing demand for industrial space in East Oahu, and relatively small building area planned for development, between 20,000 to 35,000 square feet of space is projected to be absorbed annually at the subject site.

Similar to the retail/commercial center, the industrial/business park is projected to be developed in two phases, comprising about 100,800 square feet. The initial phase is expected to comprise about 50,000 square feet and be completed by the year 2005. The second phase, consisting of approximately 50,800 square feet, is projected to be completed by the year 2010.

Inn Market Assessment (Kamehameha Schools/Bishop Estate)

The demand for visitor accommodations at the proposed Inn is based upon an identification of specific target hotel submarkets and an estimation of the projected room night demand that could be captured in East Oahu.

In assessing the market demand for the proposed Inn, the facilities and demand characteristics of existing boutique hotels and lodging accommodations in Hawaii were reviewed. Boutique hotels are generally smaller facilities, which through their reputation, location and unique orientation have created a distinct market niche for their properties.

The target markets for the proposed Inn include Hawaii residents, U.S. Mainland visitors, and foreign visitors. Within these broad markets, three potential submarket groups were identified: visiting family and friends, specialty visitor, and the corporate or group retreat market.

The proposed Inn is expected to capture about 31,200 room nights annually by the year 2000, increasing to about 39,400 room nights annually by the year 2010. On a daily basis, this translates to a need for about 110 to 120 rooms by the year 2000; 120 to 140 rooms by the year 2005; and 130 to 150 rooms by the year 2010.

The 140 rooms planned for the Inn are estimated to be developed by the year 2005.

Golf Course Market Assessment (Kaiser Aluminum and Chemical Corporation)

The demand for golf rounds within the area is based upon anticipated play by both local residents and visitors to the island. Resident demand for golf is based upon the area's projected population and an estimated number of golf rounds per resident; visitor golf demand is based upon the projected number of visitors and an estimated number of golf rounds typically averaged per visitor.

In assessing the market demand for the proposed golf course, the facilities and demand characteristics of existing golf courses on Oahu were reviewed. Demand for golf rounds in urban Honolulu is projected to increase as the population base increases; however, no new golf courses are planned for this area.

Thus, the proposed golf course is expected to help meet the projected increase in demand for golf rounds primarily from residents of urban Honolulu. Secondarily, the course could be utilized to serve the recreational needs of visitors of nearby Waikiki.

The proposed 18-hole golf course is projected to be completed by the year 2000.

8 - GOLF COURSE MARKET ASSESSMENT

PROJECT AND SITE DESCRIPTION

The proposed golf course would be located on the east shore of Oahu in an area known as Queen's Beach. The golf course site consists of about 166-acres of oceanfront land with a gradual slope to the ocean. Due to its oceanfront location, the course would provide a picturesque and memorable golf experience that is available at very few daily fee courses. Adjacent properties consist of undeveloped lands and two daily fee courses including the 18-hole Hawaii Kai Championship Course and the 18-hole par-3 Hawaii Kai Executive Course.

The proposed golf development is planned to address the strong demand for golf within urban Honolulu from both residents and visitors. The greatest golf patronage is expected to come from residents of Oahu's East Honolulu area and Primary Urban Center (P.U.C.). This region includes communities from Hawaii Kai to Pearl City and is within a 45-minute drive from the site.

OAHU GOLF MARKET OVERVIEW

Golfer Characteristics

Golfers are generally young professionals with relatively high household incomes and some college education, based on demographic statistics reported by the National Golf Foundation (NGF), as shown in Exhibit 8-A.

- **Wide age appeal** - Over 50% of golfers are between the ages of 18 and 39; those 65 years of age and older produce the highest percentage of rounds.
- **High household income** - 46% of the U.S. golf market represents households with incomes greater than $50,000, as compared to only 28% of the U.S. population at large.
- **Higher level occupations** - Golfers tend to have professional/managerial occupations, as over 40% of those surveyed by the NGF fall into this category. Golfers with professional/managerial occupations also produce the highest percentage of golf rounds.
- **High educational attainment** - Golfers tend to be well educated, as 71% show some college education.

Oahu Resident Profile

Oahu's population mix and national statistics on golfer characteristics indicate that Oahu residents have a high propensity towards golf, as summarized below and shown in Exhibit 8-B.

- **Age** - Nationally, golfers are generally young, between the ages of 18 and 39; over 30% of Oahu's population is within this category.

Exhibit 8-A

Golfers are generally professionals with higher household incomes and some college education

CHARACTERISTICS OF GOLFERS IN THE UNITED STATES

Description	Percentage of golfers	Percentage of rounds
Age profile:		
12 to 17 years	7%	4%
18 to 29 years	25%	16%
30 to 39 years	26%	17%
40 to 49 years	18%	16%
50 to 59 years	11%	15%
60 to 64 years	4%	8%
65 years and over	10%	24%
Total	100%	100%
Household income:		
Less than $50,000	54%	53%
$50,000 - $ 74,999	28%	28%
$75,000 and over	18%	19%
Total	100%	100%
Occupation (1):		
Professional/managerial	41%	35%
Clerical/sales	17%	13%
Blue collar	24%	21%
Other	8%	7%
Retired/not employed	10%	25%
Total	100%	100%
Educational attainment:		
Less than high school	3%	3%
High school graduate	25%	30%
Some college	27%	25%
College graduate	44%	42%
Total	100%	100%

Source: National Golf Foundation, Golf Participation in the United States, 1993 Edition.

Exhibit 8-B

Oahu's residents have a high propensity to golf due to the higher household incomes, greater proportion of professionals and high educational levels

DEMOGRAPHICS OF UNITED STATES AND OAHU RESIDENTS

Description	United States	Oahu
Age profile:		
13 years and under	20%	20%
14 to 17 years	5%	5%
18 to 24 years	11%	11%
25 to 34 years	17%	18%
35 to 44 years	15%	16%
45 to 54 years	11%	11%
55 to 64 years	8%	8%
65 years and over	13%	12%
Total	100%	100%
Household income(2):		
Less than $65,099	72%	61%
$65,100 - $98,099	16%	22%
$98,100 and over	12%	18%
Total	100%	100%
Occupation (1):		
Professional/managerial	16%	24%
Clerical/sales	19%	24%
Blue collar	16%	15%
Other	9%	14%
Other/retired/not employed	40%	23%
Total	100%	100%
Educational attainment:		
Less than high school	25%	19%
High school graduate	30%	28%
Some college	19%	20%
College graduate	26%	33%
Total	100%	100%

(1) Excludes military population.
(2) Estimated 1994 income distribution as shown in Exhibit 3-D.
Source: Donnelley Marketing Information Services; 1990 Census Data.

- **High household incomes** - Golfers tend to have high household incomes; nearly 44% of Oahu's households have incomes greater than $50,000.
- **Occupation** - Golfers tend to have professional careers; nearly a quarter of Oahu's population are professionals and/or managers.
- **Educational attainment** - Golfers are generally well educated. The majority of Oahu's population has had some college education and nearly 35% of the adult population has obtained a college degree.

Coupled with the fact that Oahu's golf season is year-round and that nearby Waikiki is host to most of Oahu's estimated 4.8 million visitors annually, Oahu residents and visitors generate high levels of demand for golf in the East Honolulu and P.U.C. areas.

Market Overview

Hawaii's golf market is comprised of both local residents and visitors to the state. The local resident golf market can also be segmented into two main categories:

- **Local recreational** - Local recreational players utilize daily fee and municipal courses, usually as small social golfing clubs or foursomes. These players tend to be flexible in time of play and also tend to be price sensitive.
- **Country club** - Country club players consist of upper income residents that hold golf memberships at private clubs. Golfers in this segment have demonstrated a willingness to pay a premium for memberships at private golf country clubs with their various amenities, associated prestige, and playing privileges.

The visitor golf market in Hawaii can be categorized into the following sub-market segments:

- **Golf resort guests** - Golf resort guests can be defined as visitors from out-of-state and local residents staying at resorts that offer hotel or condominium accommodations located around/or associated with a golf course. Access to the course is typically offered along with room accommodations, and green and cart fees are charged according to usage. The Hawaii Prince, Turtle Bay, and Ko Olina resorts comprise this segment of Oahu's resort golf market.
- **Free and independent travel golfers (FIT)** - FIT golfers are visitors who are not staying at golf resorts but who independently arrange their own recreational itinerary. FIT golfers generally reserve tee times through guest services at their hotel or through a local golf tour operator.
- **Group travel** - Group travel golfers make their recreational, as well as travel and tour arrangements at their point of origin. The majority of group travelers consist of Japanese who book their golf tee times with one of several golf tour operators. This market is less price sensitive than others, and sometimes book reservations several months ahead. Although the golf courses have seen a decline in eastbound visitor players, they remain a frequent demand generator for the Oahu golf market.

EXISTING OAHU GOLF COURSE OVERVIEW

Oahu currently has 37 golf courses, as shown in Exhibit 8-C. However, of the 37 courses one, the Royal Kunia Country Club, has never opened. The Club was completed in 1995 and is currently under receivership

Daily Fee Courses

Daily fee golf courses are typically owned by individuals, partnerships or corporations on a "for-profit" basis and are accessible to the general public. Oahu currently has 11 daily fee courses. Daily fee golf courses are characterized as follows:

- Open to the general public with starting times on a first-come, first-served or a telephone reservation basis.
- Generally designed to be more challenging than municipal courses.
- Landscaping and maintenance are superior to municipal courses.
- Levels of play are lower than at municipal courses.
- Overall quality, appearance and maintenance of the golf course, clubhouse and related facilities allow for higher green fees.

Municipal Courses

Municipal golf courses are owned and operated by the county in which they are located on a "non-profit" basis. Oahu has five municipal golf courses, of which the Ala Wai Golf Course is said to be the busiest golf course in the nation. The County of Honolulu is planning to open a new 18-hole course, Ewa Villages, in the summer of 1996.

Municipal golf courses are characterized as follows:

- Open to the general public with starting times on a first-come, first-served or a telephone reservation basis.
- Generally designed to facilitate a quick pace, yet provide a continued challenge for the repeat golfer.
- Landscaping and maintenance are limited, although some municipal courses have direct ocean frontage and scenic views.
- Average rounds played are very high, often exceeding 100,000 per year. Groups of up to six are not uncommon on busy days during the peak season. The average number of members per group is 5.
- Clubhouse facilities and the golf course layout are usually simple and often outdated.
- Municipal courses are predominantly geared towards local play, with inexpensive green fees and monthly rates that are subsidized by the county.

Exhibit 8-C

There are 37 existing golf courses on Oahu

HAWAII GOLF COURSE INVENTORY - FEBRUARY 1996

	Location	Number of holes	Year founded	Course architect	Course operator
Daily fee:					
Hawaii Kai Championship Course	Hawaii Kai	18	1973	William Bell	Independent
Hawaii Kai Executive Course (Par 3)	Hawaii Kai	18	1973	Robert Trent Jones Jr.	Independent
Olomana Golf Links	Waimanalo	18	1967	Bob Baldock	Independent
Bayview Golf Links (Par 3)	Kaneohe	18	1963	Jimmy Ukauka	Independent
Koolau Golf Course	Kaneohe	18	1992	Dick Nugent	Independent
Pearl Country Club	Pearl City	18	1967	Akira Sato	Independent
Waikele Golf Course	Waikele	18	1993	Ted Robinson	Independent
Hawaii Country Club	Kunia	18	1957	Red Aldrick	Independent
Kapolei Golf Course	Kapolei	18	1994	Ted Robinson	Independent
Mililani Golf Club	Mililani	18	1966	Bob Baldock	Independent
Makaha Valley Country Club	Makaha Valley	18	1967	William P. Bell	Independent
Royal Kunia Country Club	Kunia	18	1995	Nelson & Wright	Independent
Municipal:					
Ala Wai Golf Course	Waikiki	18	1931	Nelson & Wright	City & County
Kahuku Golf Course	Kahuku	9	1937	Built by Kahuku Sugar Plantation workers	City & County
Pali Golf Course	Kaneohe	18	1953	Willard G. Wilkinson	City & County
Ted Makalena Golf Course	Waipio/Waipahu	18	1971	Bob Baldock	City & County
West Loch Golf Course	Ewa Beach	18	1990	Nelson & Wright	City & County
Resort:					
Hawaii Prince Golf Club	Ewa	27	1992	Arnold Palmer/Ed Seay	Independent
Ko Olina Club	Kapolei	18	1990	Ted Robinson	Independent
Sheraton Makaha Golf Club(1)	Makaha Valley	18	1967	William P. Bell	
The Links at Kuilima	Kahuku	18	1992	Arnold Palmer	Arnold Palmer Management
Turtle Bay Golf Course	Kahuku	9	1971	George Fazio	Arnold Palmer Management
Military:					
Barbers Point Golf Course	Barbers Point	18	1965	William Bell	Military
Hickam (Par 3)	Hickam AFB	9	1966	Built by civil engineers	Military
Hickam Mamala Bay Golf Course	Hickam AFB	18	1966	Bob Baldock	Military
Kalakaua Golf Course	Schofield Barracks	18	1918	Army	Military
Kaneohe Klipper Golf Course	Kaneohe	18	1939	William Bell	Military
Leilehua Golf Course	Wahiawa	18	1948	Willard G. Wilkinson	Military
Navy Marine Golf Course	Salt Lake	18	1948	William Bell	Military
Walter Nagorski Golf Course	Fort Shafter	9	1919	Willard G. Wilkinson	Military
Private clubs:					
Ewa Beach International Golf Club	Ewa Beach	18	1992	Nelson & Wright	Independent
Honolulu Country Club	Salt Lake	18	1977	Francis Dunne	Independent
Mid-Pacific Country Club	Kailua	18	1926	Seth Raynor/Alex Bell	Independent
Moanalua Golf Club(2)	Moanalua	9	1898	Samuel Damon	Independent
Oahu Country Club	Nuuanu Valley	18	1906	Alex Bell	Independent
Luana Hills	Maunawili	18	1992	Pete Dye	Independent
Waialae Country Club	Waialae-Kahala	18	1927	Seth Raynor	Independent
Total golf holes(3)		612			

(1) The hotel previously associated with the course has been closed and there is no immediate re-opening date scheduled. Due to course play and the availability of a hotel re-opening, this course has been classified as a "resort course."

(2) Course is open for public Mondays through Fridays only.

(3) The Royal Kunia Country Club has been deleted from the total golf hole inventory, as the course is currently closed and under receivership.

Source: Discussions with project representatives and published information.

Resort Courses

Resort golf courses are a special category of daily fee courses utilized as recreational facilities. They are primarily for visitors and residents of resorts, and on a secondary basis are available to local residents and the general public. There are five resort courses on Oahu that cater to the visitor market.

Resort golf course characteristics include:

- Primary use by resort guests and residents, and secondary use by the general public.
- Design characteristics of resort courses typically include:

  Well-known course architect for the design and layout.
  Natural ocean and mountain views are maximized.
  Extensive landscaping.
  Oceanfront holes are built where feasible.
  May feature original artwork or other aesthetic amenities.

- Resort golf courses are typically owned and managed by a subsidiary of the master landowner/developer of the entire resort. Course management generally features:

  Multiple tee boxes to accommodate a wide range of skills.

  Tee times typically set 8 to 9 minutes apart, compared to 7 minutes at non-resort golf courses.

  Green fees are the most expensive among the daily-fee courses due to the high quality and name recognition of resort courses.

Military Courses

The military has eight courses operating primarily for military personnel use. Military golf courses are owned and operated by the military on a "non-profit" basis.

Military golf courses are characterized as follows:

- Open to the military personnel and retired military personnel with starting times on a first-come, first-served basis.
- Average rounds played are very high, averaging about 80,000 per year.
- Offer inexpensive green fees and monthly rates.

Private Golf Club Courses

Oahu has seven private golf clubs. Private courses and clubs are generally member-owned "non-profit" entities. Course use is generally restricted to members and their guests. The private clubs on Oahu continue to attract the professional and managerial resident population.

Several types of memberships are generally available, ranging from regular memberships with unrestricted privileges to social memberships with limited or no golfing privileges. Characteristics of these courses include:

- Designed to promote challenging and exciting play.
- Emphasis on natural viewpoints and extensive landscaping.
- Restricted membership, with club acceptance determined by existing members.
- Local resident members are charged initiation fees, monthly dues, and in some cases mini-charges to cover operational expenses in the food and beverage department.
- Attractive clubhouse facilities.

Golf club membership is attractive for a number of reasons, including:

- Access to a well-designed, well-maintained golf course.
- Availability of tee times and ability to reserve tee times in advance.
- Presence of outstanding facilities and amenities.
- Prestige, social and business aspects associated with membership.

Golf Courses in the Primary Market Area

The primary market area for the proposed golf course at Queen's Beach is encompassed by the area from Hawaii Kai to Pearl City. These communities span nearly 25 miles and contain about 55% of the island's population. However, despite the large population base, only 31% of Oahu's golf holes, or an equivalent of 10.5 courses are located in the area, as shown in Exhibit 8-D. Only four of these courses are open to public play, while the others are military courses or private clubs. The following are the four courses open to the general public:

- Hawaii Kai Championship Course
- Hawaii Kai Executive Course (Par 3)
- Pearl Country Club
- Ala Wai Golf Course

Thus, there is an apparent undersupply of courses in the area spanning from Oahu's East Honolulu area through its P.U.C. given the area's residents and proximity to Waikiki's visitor population.

PLANNED OAHU GOLF COURSES

Sixteen new golf courses or golf course additions were currently planned for Oahu, as reported by the City and County of Honolulu's Planning Department and shown in Exhibit 8-E. In addition to the 16 new courses, the daily fee Royal Kunia Country Club was recently completed but has never been opened. The course is currently in receivership and course representatives do not have an opening date.

Exhibit 8-D

The area from Hawaii Kai to Pearl City contains only 31% of Oahu's golf holes while it includes 56% of Oahu's population

NUMBER OF GOLF HOLES IN EAST HONOLULU AND THE P.U.C. AREAS OF OAHU

Name of course	Type of course	P.U.C. and East Honolulu	Oahu	Percent of Oahu
Hawaii Kai Championship Course	Daily fee	18		
Hawaii Kai Executive Course (Par 3)	Daily fee	18		
Pearl Country Club	Daily fee	18		
Ala Wai Golf Course	Municipal	18		
Hickam (Par 3)	Military	9		
Hickam Mamala Bay Golf Course	Military	18		
Navy Marine Golf Course	Military	18		
Walter Nagorski Golf Course	Military	9		
Honolulu Country Club	Private	18		
Moanalua Golf Club	Private	9		
Oahu Country Club	Private	18		
Waialae Country Club	Private	18		
Total golf holes		189	612	31%
1996 resident population, rounded(1)		501,000	893,000	56%

(1) Population projections based upon the City & County Planning Department's "Development Plan Annual Report Fiscal Year 1995," September 1, 1995.

Oahu has 16 golf courses proposed for development

PROPOSED GOLF COURSE DEVELOPMENT FOR OAHU: 1995

		Location	Estimated Start	Estimated Finish	Estimated Open	Number of Holes	Status
1	Ewa by Gentry Golf Course	Ewa	1997	1998	1998	18	All approvals granted
2	Ewa Marina Golf Course	Ewa	1997	1999	1999	27	All approvals granted
3	Ewa Villages Golf Course	Ewa	1993	1995	1996	18	All approvals granted
4	Ko Olina Phase II Golf Course	Ewa	NAV	NAV	NAV	18	All approvals granted
5	Lualualei Golf Course	Waianae	1997	1998	1998	18	Rezoning or PRU or SMP pending
6	Makaha Challenge Par-3	Waianae	1997	1998	1998	18	DPLUM Ordinance or Alternate needed
7	Makaha Valley Golf Course (Expansion)	Waianae	NAV	NAV	NAV	+9	All approvals granted
8	Makakilo Golf Course	Makakilo	1990	NAV	NAV	18	Approved as CUP
9	Royal Hawaiian Country Club 2	Maunawili	NAV	NAV	NAV	18	Approved as CUP
10	Royal Kunia #1 (Koei Hawaii)	Central	NAV	NAV	NAV	18	PRU required
11	Royal Kunia #3 (Halekua)	Central	NAV	NAV	NAV	18	Rezoning required
12	Waianae Kai Golf Course	Waianae	1996	1997	NAV	27	Rezoning required
13	Waiawa Golf Course #1	Central	1996	1997	1998	18	Rezoning or PRU or SMP pending
14	Waiawa Golf Course #2	Central	1996	1997	1998	18	Rezoning or PRU or SMP pending
15	Waikane Golf Course #1	Windward	NAV	NAV	NAV	18	Rezoning and SMP required
16	Waikane Golf Course #2	Windward	NAV	NAV	NAV	18	CDUA required

NAV = Not available.
PRU = Planned Review Use.
SMP = Shoreline Management Permit.
DPLUM = Department of Planning Land Use Map.
CUP = Conditional Use Permit
CDUA = Conservation District Use (State designation).
Source: "Development Plan Annual Report Fiscal Year 1995," Planning Department, September 1, 1995.

The development of the additional 16 planned courses is uncertain, due to the following reasons:

- Most of the proposed courses need additional permits.
- Financing is limited or unavailable for construction of new golf courses, especially in less desirable locations.

MIX OF PLAY

Within Oahu's East Honolulu to P.U.C. area, residents generate the majority of golf rounds, representing over 80% of the rounds. At golf courses throughout Oahu, the mix of play is also predominantly resident oriented, consisting of 72% residents, as shown in Exhibit 8-F.

- **Daily fee courses** - At golf courses throughout Oahu's East Honolulu to P.U.C. area, residents generate the majority of rounds at daily fee courses, about 75%, while visitors generate the remaining 25%.
- **Municipal course** - About 97% of the rounds are generated by residents.
- **Military courses** - Rounds are generated by active and retired military personnel and are estimated to represent about 70% residents and about 30% visitors.
- **Private** - Members play about 81% of the rounds, with the remaining 19% being generated by their guests.

Overall, Oahu residents account for about 72% of all golf rounds played at Oahu courses.

SUPPLY OF GOLF ROUNDS

Course capacity is a function of the desired intervals between tee times, the average size of the golf parties (usually 4 to 6 people), hours of play and the desired quality of play targeted by course management. The average number of desired rounds by type of course range from 78,000 to 131,000 rounds, as shown in Exhibit 8-G.

- **Daily fee courses** average about 88,000 rounds annually. Play on these courses are generally slower than at municipal golf courses, as the interval between tee times is about 7 minutes.
- **Municipal courses** generate the highest average number of rounds per course at nearly 131,000 rounds per year. Oahu residents are price sensitive and have found the facilities and green fees at municipal courses to be the most attractive on the island. To accommodate this demand, these courses have tee intervals of about six minutes and are geared towards high volumes of play with an average of about five members per group.
- **Resort courses** average about 78,000 rounds annually, emphasizing the quality and challenge of play. Course play is geared towards a more leisurely pace, with longer intervals of about 8 minutes, resulting in a lower volume of play.

Exhibit 8-F

Over 80% of all golf rounds generated at golf courses within the P.U.C. to Hawaii Kai area are done by Hawaii residents; however islandwide, residents account for only 70% of the play

MIX OF PLAY AT GOLF COURSES

	Residents	Visitors
P.U.C. to Hawaii Kai(1)		
Daily-fee:		
Hawaii Kai Championship Course	80%	20%
Hawaii Kai Executive Course	65%	35%
Pearl Country Club	80%	20%
Average	**75%**	**25%**
Municipal:		
Ala Wai Golf Course	**97%**	**3%**
Military(2)	**70%**	**30%**
Private:		
Honolulu Country Club	NAV	NAV
Moanalua Golf Course	90%	10%
Oahu Country Club	80%	20%
Waialae Country Club	74%	26%
Average	**81%**	**19%**
Average all P.U.C. to Hawaii Kai courses	**81%**	**19%**
Island of Oahu(3)	**72%**	**28%**

(1) Based on statistical information provided by golf course representatives for 1995.
(2) Estimated by military golf course representative.
(3) Based on an island-wide survey completed in 1993 and updated to 1995 for P.U.C. to Hawaii Kai courses.
Source: Interviews with golf course representatives.

Exhibit 8-G

The 12 existing golf courses from Hawaii Kai to Pearl City are able to accommodate nearly 925,000 rounds annually

SUPPLY OF GOLF ROUNDS FROM HAWAII KAI TO OAHU'S P.U.C.: 1995

Type of course	Number of courses(1)	Tee-time intervals (minutes)	Estimated course capacity, rounds Daily(2)	Annually(3)	Estimated total annual rounds
Daily fee	2.5	7.0	270	88,200	220,500
Municipal(4)	1.0	6.0	400	130,700	130,700
Resort	0.0	8.0	240	78,400	0
Military	3.0	7.0	270	88,200	264,600
Private	3.5	7.0	270	88,200	308,700
Total, (rounded)					924,500

(1) Nine hole courses and par-3 courses counted as a half a course.
(2) Based on 8 hours of available tee time and one four-some teeing off at the specified intervals.
(3) Estimated at 90% capacity for tournaments, course maintenance, closures, and rain out days.
(4) Based on 8 hours of available tee time and one five-some teeing off at the specified intervals.
Source: Discussions with golf course representatives.

- **Military courses** have levels of play similar to daily fee courses, at about 88,000 rounds annually.
- **Private club** members enjoy a relaxed pace of play, with an average about 88,000 rounds annually.

The existing 12 courses within the Hawaii Kai to Pearl City area can supply nearly 925,000 rounds of golf annually, as also shown in Exhibit 8-G.

DEMAND FOR GOLF ROUNDS

Oahu golf courses typically generate about 2.6 million rounds of golf, as shown in Exhibit 8-H. Residents represent the largest producers of these golf rounds, with nearly 1.9 million rounds. Based on an estimated population of 893,000 residents, this is equal to about 2,100 golf rounds per 1,000 Oahu residents, as also shown in Exhibit 8-H.

Resident play on Oahu's East Honolulu to P.U.C. area courses represent approximately 1,200 rounds of golf per 1,000 East Honolulu and P.U.C. residents annually, as shown in Exhibit 8-I. Over half of Oahu's population reside within this area encompassed by Hawaii Kai and Pearl City. As stated earlier, Oahu's residents have a high propensity towards golf. Throughout the island, a wide range of courses are available for golfers to choose from. However, within Oahu's urban area, there exists a very limited supply: 2.5 daily fee; 1.0 municipal, no resort, 3.0 military, and 3.5 private courses. Of these, only 3.5 courses are open to the general public. Therefore, much of urban Oahu's golfing population must travel outside their immediate area in order to vary their course play. This is believed to particularly explain the higher resident rate of play at courses islandwide (2,100 rounds per 1,000 residents) as compared to those within the East Honolulu to P.U.C. area (1,200 resident rounds per 1,000 area residents).

Future resident demand for golf throughout Oahu's East Honolulu to P.U.C. area is based on the area's projected population and an estimated range of rounds per 1,000 resident. Due to the common occurrence of area residents golfing outside of the subject area, a reasonable range could be between the 2,000 resident rounds per 1,000 residents noted islandwide, and the 1,200 noted in the East Honolulu to P.U.C. area. For purposes of this study, a range of 1,400 to 1,500 resident golf rounds per 1,000 area residents has been used.

Visitor demand for golf is conservatively estimated to represent an additional 28% of total rounds based on the historical mix of play at Oahu's golf courses, or nearly 266,000 to 285,000 rounds in 1996, as also shown in Exhibit 8-J.

Thus, in total, projected demand for golf rounds within the market area is estimated to range from 970,000 to 1.1 million rounds by the end of 1996, as shown in Exhibit 8-J. The popularity of the game is expected to remain high and thus, with over 55% of the island's population living within the primary market area, there could continue to be a strong demand for golf rounds.

An average of about 2,100 golf rounds were generated for very 1,000 residents on Oahu

HISTORICAL GOLF DEMAND FOR THE ISLAND OF OAHU

Type of course	Number of courses(1)	Annual rounds per course(2) Range (rounded)	Typical	Estimated total number of rounds
Daily fee	10.0	46,000 - 105,000	72,900	729,000
Municipal	4.5	60,000 - 190,000	131,000	590,000
Resort	5.0	45,000 - 65,000	53,600	268,000
Military	7.0	50,000 - 95,000	80,400	563,000
Private	6.5	44,000 - 80,000	65,300	424,000
Total, rounded				2,574,000

Estimated resident golf rounds per 1,000 residents:

Total golf rounds	2,574,000
Percentage of resident play(3)	72%
Estimated resident rounds	1,865,457
Total estimated Oahu residents(4)	893,000
Golf rounds per 1,000 island residents, rounded	**2,100**

(1) Nine hole courses and par-3 courses counted as half courses.
(2) Discussions with project representatives.
(3) As shown in Exhibit 8-F.
(4) As shown in Exhibit 8-D.

Exhibit 8-I

An average of about 1,200 golf rounds at Hawaii Kai to P.U.C. courses were generated for every 1,000 residents of the area

HISTORICAL GOLF DEMAND FROM HAWAII KAI TO OAHU'S P.U.C.

Type of course	Number of courses(1)	Annual rounds per course(2) Range (rounded)	Annual rounds per course(2) Typical	Estimated total number of rounds
Daily fee	2.5	46,000 - 72,000	63,000	158,000
Municipal	1.0	189,000	189,000	189,000
Resort	0.0	0 - 0	0	0
Military	3.0	36,000 - 85,000	70,000	210,000
Private	3.5	44,000 - 70,000	61,000	214,000
Total, rounded				771,000

Estimated resident golf rounds per 1,000 residents:

Total golf rounds	771,000
Percentage of resident play(3)	81%
Estimated resident rounds, rounded	623,000
Total Hawaii Kai to Oahu's P.U.C. residents, rounded(4)	501,000
Golf rounds per 1,000 area residents, rounded	**1,200**

(1) Nine hole courses and par-3 courses counted as half courses.
(2) Discussions with project representatives.
(3) As shown in Exhibit 8-F.
(4) As shown in Exhibit 8-D.

Exhibit 8-J

Demand for golf rounds within East Honolulu to Oahu's East Honolulu to P.U.C. area is estimated to range from nearly 970,000 to 1 million rounds annually in 1996

PROJECTED GOLF COURSE ROUNDS WITHIN OAHU'S EAST HONOLULU TO P.U.C.: 1996 TO 2000

	Projected P.U.C. and East Honolulu population(1)	Resident golf demand: Estimated golf round per 1,000 residents(2)	Resident golf demand: Annual resident rounds, rounded	Visitor demand(3)	Total demand
1996	501,000	1,400 - 1,500	701,400 - 751,500	266,400 - 285,400	967,800 - 1,036,900
1997	503,000	1,400 - 1,500	704,200 - 754,500	267,500 - 286,600	971,700 - 1,041,100
1998	506,000	1,400 - 1,500	708,400 - 759,000	269,000 - 288,300	977,400 - 1,047,300
1999	508,000	1,400 - 1,500	711,200 - 762,000	270,100 - 289,400	981,300 - 1,051,400
2000	511,000	1,400 - 1,500	715,400 - 766,500	271,700 - 291,100	987,100 - 1,057,600

(1) Population projections based upon the City & County Planning Department's "Development Plan Annual Report Fiscal Year 1995," September 1, 1995
(2) Estimated based on Oahu and Hawaii Kai to P.U.C. average golf demand per 1,000 residents, as shown in Exhibit 8-H and 8-I.
(3) Estimated at 28% of total golf rounds based on the historical experiences of Oahu courses, as shown in Exhibit 8-F.

PROJECTED NEED FOR ADDITIONAL GOLF COURSES

With no new planned additions to the supply of golf courses within Oahu's East Honolulu to P.U.C. area, the region has a limited supply of only about 925,000 rounds available. At the same time, demand for golf rounds within the region is expected to increase as the population base increases. Thus, the primary market area is projected to have an undersupply of rounds, as shown in Exhibit 8-K.

GOLF MARKET ASSESSMENT FOR THE SUBJECT SITE

The high levels of utilization of golf courses within Oahu's East Honolulu to P.U.C. area and the expected growth in the area's resident population suggests that there is considerable demand for golf within Oahu's urban communities.

Thus, demand for golf rounds within the area is expected to continue to exceeded the supply of golf rounds available. This analysis indicates that the demand could more than support the addition of the proposed golf course at Queen's Beach due to the following reasons:

- Residents represent a significant portion of the rounds generated and are the most likely market for generating golf rounds at the site. The site is conveniently accessible to nearly 55% of Oahu's population.
- There are no other golf course developments planned for the region.
- There are only four courses open to public play from Hawaii Kai to Pearl City.
    - Three daily-fee golf courses open to the public in the primary market area, one of which one is an executive par-3 course.
    - One municipal golf course, the Ala Wai Golf Course, which is extremely busy and is also known as the nation's busiest course.
- The existing courses within the region have generated golf rounds comparable to other daily-fee courses.
- Newly completed and planned courses on Oahu are concentrated in Central Oahu and within the Ewa Plain. These areas are not conveniently located to urban Honolulu residents.
- The demographics of Oahu's population, and Hawaii Kai residents in particular, support a strong demand for golf. Residents in the primary market are generally older residents with higher household incomes and have a higher participation rate for golf.
- Oahu visitors generate nearly 30% of all golf rounds. The proposed golf course's proximity to Waikiki and its oceanfront location could make it very popular with Oahu visitors.

Thus, the proposed golf course is projected to be played primarily by local residents. The golf facilities at Queen's Beach would be similar to those found at comparable Oahu daily fee courses which typically include a driving range, putting green, and chipping green. In addition, a clubhouse and pro shop would be included to oversee golf operations and for sales of food and beverage and related golf accessories.

Exhibit 8-K

Demand for golf within the area encompassed by Hawaii and Pearl City exceeds the supply of the area

PROJECTED GOLF COURSE SUPPLY AND DEMAND ANALYSIS

Year	Estimated supply of golf rounds(1)	Estimated golf demand: Demand for golf rounds(2)	Estimated golf demand: Average annual golf rounds (3)	Cumulative golf shortage: Rounds	Cumulative golf shortage: Courses (3)
1996	924,500	967,800 - 1,036,900	80,000	43,300 - 112,400	1 - 1
1997	924,500	971,700 - 1,041,100	80,000	47,200 - 116,600	1 - 1
1998	924,500	977,400 - 1,047,300	80,000	52,900 - 122,800	1 - 2
1999	924,500	981,300 - 1,051,400	80,000	56,800 - 126,900	1 - 2
2000	924,500	987,100 - 1,057,600	80,000	62,600 - 133,100	1 - 2

(1) As shown in Exhibit 8-G.
(2) As shown in Exhibit 8-J.
(3) Estimated based on the current mix of golf courses, and an average of 80,000 rounds per course annually played in area golf courses.
Source: Compiled by KPMG Peat Marwick LLP.

QUEEN'S BEACH GOLF COURSE

Appendix

M

Traffic Impact Study

(Wilbur Smith Associates)

HAWAII KAI PROPERTIES

TRAFFIC IMPACT STUDY

Prepared for

Maunalua Associates, Inc.

by

WSA

June 1996

TABLE OF CONTENTS

ILLUSTRATIONS

TABULATIONS

WSA

EXECUTIVE SUMMARY

This traffic study assesses the potential impacts from the development of 12 parcels located within the Hawaii Kai area. These 12 parcels, which have not yet received necessary approvals by the City and County of Honolulu, herein referred to as the *Project*.

The traffic impact study identifies the future travel increases that would likely occur with the proposed development of these 12 *Project* parcels. The study assesses the effects of the *Project* on traffic conditions on Hawaii Kai roadways, and on the Kalanianaole Highway between the H-1 Freeway and Makapuu Point. The traffic assessment also reflects travel increases from approved, but not yet occupied development in Hawaii Kai, development in other areas of East Honolulu, and "background" travel increases.

PROJECT DESCRIPTION

The *Project* includes development of 12 parcels that have not received City approvals. Development is expected by Year 2017. The parcels and proposed uses are as follows:

Parcel	Acres	Proposed Use	Access
Kalama Valley	8.3	176 Low Rise Condo Units	Mokuhana St.
Kamilo Ridge	36.5	5 Single Family Houses	Hawaii Kai Dr. Ext.
Kamilonui 1	17.4	510 Mid-Rise Condo Units	Hawaii Kai Dr. Ext.
Kamilonui 2	62.8	92 Single Family Houses 272 Townhouses	Hawaii Kai Dr. Ext.
Marina 4B	5.1	75 Townhouses	Ainahou St.
Mauuwai	82.7	143 Single Family Houses	Kealahou St. (Alternate is Kalanianaole Hwy.)
Queen's Rise	101.9	194 Single Family Houses	Kalanianaole Hwy.
Golf Course 2/1A	9.8	45 Single Family Houses	Kealahou St.
Golf Course 2/1A	10.9	Business Park	Kealahou St.
Golf Course 2/1A	29.1	140-Room Inn	Kealahou St.
Marina 1 Strip 1	6.6	192,000 sq. ft. of Office and Retail Uses	Keahole St. Hawaii Kai Dr. Kalanianaole Hwy.
Queen's Beach	166.0	Golf Course	Kalanianaole Hwy.

STUDY METHODOLOGY AND ASSUMPTIONS

The study includes analyses of existing traffic conditions, 2017 conditions without the *Project*, and 2017 with the *Project*. The 2017 analyses are made for a "Baseline" condition, which includes planned near-term roadway improvements but not those transit and travel demand management (TDM) programs and longer-term roadway improvements set forth in the Oahu Regional Transportation Plan (Oahu RTP). A second analyses of 2017 conditions are also made to reflect the Oahu RTP plans and programs. The Oahu RTP analysis assessed conditions only along Kalanianaole Highway, where the planned programs would have the most effect.

Key elements of the study methodology and assumptions include the following:

- **Existing Conditions** - Existing peak hour traffic volumes and conditions are primarily based on counts made between January 25 and February 15, 1996.

- **Without *Project* Travel Forecasts (Baseline)** - The assessment reflects future travel increases from:

  1. Completion and occupancy of 10 developments in Hawaii Kai, that are already approved, but unoccupied by February 1996. These include approximately 1,750 housing units and 68,000 sq. ft. of floor area in commercial projects to be occupied.

  2. Construction of 605 additional residential units in East Honolulu areas outside of Hawaii Kai.

  3. An areawide growth factor (0.35 percent increase per year) to reflect increased travel to/from existing uses.

- ***Without Project* Roadway Modifications (Baseline)** - The analyses reflect two roadway modifications:

  1. Installation of a traffic signal at the intersection of Kalanianaole Highway with Kealahou Street, and addition of an eastbound left-turn lane.

  2. Extension of the morning contraflow high occupancy vehicle (HOV) lane from Niu Valley to Keahole Street in Hawaii Kai.

- ***With Project* Travel Forecasts (Baseline)** - The *Project* baseline forecasts reflect existing trip-making characteristics, such as travel mode usage and distribution of trip origins/destination within/outside of Hawaii Kai.

- ***With Project* Roadway Modifications (Baseline)** - The *Project* would include construction of the missing segment of Hawaii Kai Drive around the mauka end of Kuapa Pond. The roadway would provide one travel lane in each direction plus left-turn lanes at cross streets.

- **Oahu RTP Assessment** - The analyses of 2017 traffic conditions along Kalanianaole Highway reflect two changes from the "Baseline" analyses. These are:

  1. Traffic reductions as a result of transit improvements and TDM programs. Based on the Oahu RTP forecasts, the Baseline traffic forecasts were reduced by 6.9 and 5.0 percent in the peak travel directions for the morning and afternoon peak hours, respectively. The off-peak direction traffic was reduced by half these amounts.

  2. Addition of a fourth ewabound through lane on Kalanianaole Highway from Laukahi Street to the Kilauea Avenue off-ramp.

EXISTING CONDITIONS

Existing conditions at key intersections are summarized in Tables 1 and 2 for morning and afternoon peak hours, respectively. For traffic signal-controlled intersections, the tables indicate the proportion of estimated intersection capacity used by existing traffic. At STOP sign-controlled intersections, the level-of-service (LOS) is indicated for the stopped vehicles, with conditions ranging from LOS A (short delay, less than 5 seconds) to LOS F (long delay of more than 45 seconds).

The analyses indicate that overall conditions for each intersection are currently at acceptable levels. Along Kalanianaole Highway, present morning commute peak hour traffic uses about 80 percent of the estimated capacity at each intersection; overall traffic delay times generally are at LOS B (not shown in tables). Traffic on the cross streets experience very long delays, typically equivalent to LOS F, due to the long signal cycle length and the small portion of green time allocated to the cross streets. However, the overall intersection conditions reflect the LOS A or B conditions afforded the much larger volumes of through traffic on Kalanianaole Highway.

In the afternoon commute peak hour, traffic at the Kalanianaole Highway intersection with Kalaniiki and Laukahi Streets operate at over 80 percent of capacity. However, the other intersections operate at 50 to 69 percent of capacity.

Within Hawaii Kai, traffic at the Wailua Street intersection with Hawaii Kai Drive uses 85 percent of capacity during the afternoon peak hour. This is due to the high volume of traffic turning right from the single turn lane on maukabound Hawaii Kai Drive.

2017 BASELINE CONDITIONS WITHOUT THE *PROJECT*

In the morning peak hour, peak direction traffic along Kalanianaole Highway is projected to increase by 21.4 percent at Kawaihae Street, and 18.0 percent at Kalaniiki Street. The afternoon peak hour increases are estimated as 24.6 and 17.2 percent at Kawaihae and Kalaniiki Streets, respectively. Traffic increases on major roadways in Hawaii Kai are estimated to range between 12 and 30 percent, dependent upon the locations relative to approved project sites.

Forecast traffic volumes at the Kalanianaole Highway intersections with Kalaniiki and Laukahi Streets would use about 90 percent or more of the estimated capacity during both peak hours (Tables 1 and 2). Laukahi Street conditions would worsen relative to Kalaniiki Street.

The volume-to-capacity ratios for intersections along Kalanianaole Highway between East Halemaumau Street and Hawaii Kai is projected to improve (decrease). This occurs since the

Table 2

AFTERNOON PEAK HOUR TRAFFIC CONDITIONS AT KEY INTERSECTION[1]
Hawaii Kai Properties Transportation Study

Intersection	Existing	Baseline[2]		With Oahu RTP[3]		With[2] Mitigation
		Without Project	With Project	Without Project	With Project	
Kalanianaole Hwy./Kalaniiki St.	0.879	0.896	0.951	0.852	0.905	---
Kalanianaole Hwy./Laukahi St.	0.839	0.928	1.016	0.888	0.962	0.957
Kalanianaole Hwy./West Hind St.	0.687	0.828	0.900	0.787	0.855	---
Kalanianaole Hwy./East Halamaumau St.	0.636	0.777	0.858	0.740	0.817	---
Kalanianaole Hwy./Kawaihae St.	0.578	0.698	0.781	0.664	0.742	---
Kalanianaole Hwy./Hawaii Kai Dr.	0.495	0.601	0.668	0.572	0.636	---
Kalanianaole Hwy./Keahole St.	0.630	0.779	0.910	0.750	0.878	0.814
Kalanianaole Hwy./Lunalilo Home Rd.	0.618	0.796	0.845	---	---	---
Kalanianaole Hwy./Kealahou St.	C	0.390	0.491	---	---	---
Hawaii Kai Dr./Kawaihae St.	C	C	C	---	---	---
Hawaii Kai Dr./Keahole St.	0.562	0.728	0.865	---	---	---
Hawaii Kai Dr./Wailua St.	0.852	0.963	0.917	---	---	0.917
Hawaii Kai Dr./Kaluanui Rd.	B	B	D	---	---	B
Lunalilo Home Rd./Wailua St.	0.650	0.742	0.818	---	---	---
Lunalilo Home Rd./Hawaii Kai Dr.	0.619	0.785	0.949	---	---	0.795
Hawaii Kai Dr./Kealahou St.	B	C	E	---	---	---

(1) = Portion of estimated intersection capacity used by peak hour traffic is provided for traffic signals. Level-of-service (delay to minor street traffic) is provided for STOP sign controls.
(2) = Year 2017 conditions without longer-range Oahu Regional Transportation Plan improvements and programs.
(3) = Year 2017 conditions with longer-range Oahu Regional Transportation Plan improvements and programs.

Wilbur Smith Associates; June 1996

HAWAII KAI PROPERTIES EIR
WSA WILBUR SMITH ASSOCIATES

Table 1

MORNING PEAK HOUR TRAFFIC CONDITIONS AT KEY INTERSECTION[1]
Hawaii Kai Properties Transportation Study

Intersection	Existing	Baseline[2]		With Oahu RTP[3]		With[2] Mitigation
		Without Project	With Project	Without Project	With Project	
Kalanianaole Hwy./Kalaniiki St.	0.802	0.916	0.970	0.704	0.746	---
Kalanianaole Hwy./Laukahi St.	0.772	0.946	1.008	0.791	0.855	0.995
Kalanianaole Hwy./West Hind St.	0.767	0.885	0.922	0.804	0.906	---
Kalanianaole Hwy./East Halamaumau St.	0.818	0.776	0.894	0.714	0.823	---
Kalanianaole Hwy./Kawaihae St.	0.792	0.742	0.858	0.678	0.785	---
Kalanianaole Hwy./Hawaii Kai Dr.	0.818	0.791	0.881	0.726	0.809	---
Kalanianaole Hwy./Keahole St.	0.806	0.878	0.959	0.804	0.907	0.810
Kalanianaole Hwy./Lunalilo Home Rd.	0.453	0.519	0.619	---	---	---
Kalanianaole Hwy./Kealahou St.	C	0.365	0.482	---	---	---
Hawaii Kai Dr./Kawaihae St.	C	D	E	---	---	---
Hawaii Kai Dr./Keahole St.	0.378	0.501	0.586	---	---	---
Hawaii Kai Dr./Wailua St.	0.472	0.534	0.658	---	---	0.658
Hawaii Kai Dr./Kaluanui Rd.	A	B	B	---	---	B
Lunalilo Home Rd./Wailua St.	0.634	0.721	0.687	---	---	---
Lunalilo Home Rd./Hawaii Kai Dr.	0.741	0.891	0.943	---	---	0.633
Hawaii Kai Dr./Kealahou St.	B	B	C	---	---	---

(1) = Portion of estimated intersection capacity used by peak hour traffic is provided for traffic signals. Level-of-service (delay to minor street traffic) is provided for STOP sign controls.
(2) = Year 2017 conditions without longer-range Oahu Regional Transportation Plan improvements and programs.
(3) = Year 2017 conditions with longer-range Oahu Regional Transportation Plan improvements and programs.

Wilbur Smith Associates; June 1996

estimated number of vehicles using the HOV lane extension slightly exceeds the forecast traffic increase through this segment of the roadway.

Within the Hawaii Kai area, the highest volume-to-capacity ratios in the morning peak hour are estimated for the intersections of Lunalilo Home Road with Hawaii Kai Drive (0.891) and Kalanianaole Highway with Keahole Street (0.878). In the afternoon peak hour, the highest volume-to-capacity ratio is estimated for the intersection of Hawaii Kai Drive with Wailua Street (0.963) due to the high volume of vehicles turning right onto Wailua Street.

PROJECT TRIP GENERATION

The total numbers of vehicle trip origins or destinations generated by the 12 *Project* parcels on a typical weekday are estimated as follows:

Parcels	Morning Peak Hour		Afternoon Peak Hour	
	Destination	Origin	Destination	Origin
Residential Parcels	156	600	618	346
Commercial Parcels	306	129	568	612
Combined	**462**	**729**	**1,186**	**958**

The 12 *Project* parcels represent an increase of about 15 to 16 percent in Hawaii Kai vehicle trip ends. The much higher afternoon traffic generation results from the Marina 1 commercial development, which would account for almost one-half of the *Project* trips.

The *Project* is estimated to add 460 and 395 vehicles to peak direction traffic volumes on Kalanianaole Highway in the morning and afternoon peak hours, respectively. This would amount to a 10.4 and 12.3 percent increase at Kawaihae Street during the two peak hours, respectively. The increase at Kalaniiki Street would approximate 6 percent in each peak hour.

2017 BASELINE CONDITIONS WITH THE PROJECT

Traffic analyses indicate several significant changes in conditions at key intersections with the *Project*:

- At the Kalanianaole Highway intersection with Kalaniiki Street, the increased traffic would amount to 95 percent or more of existing intersection capacity in both peak hours.
- At the Kalanianaole Highway intersection with Laukahi Street, the forecast traffic volumes would exceed existing capacity in both peak hours.
- At the Kalanianaole Highway intersection with Keahole Street, morning peak hour traffic would approximate 96 percent of capacity.

- At the Lunalilo Home Road - Hawaii Kai Drive intersection, the increased traffic would approximate 94-95 percent of existing capacity in both peak hours.
- At STOP sign-controlled intersections, LOS E conditions are projected for:
  - Kawaihae Street at Hawaii Kai Drive, morning peak hour; and
  - Hawaii Kai Drive at Kealahou Street, afternoon peak hour, if the Mauuwai access road connects to this intersection.

The extension of Hawaii Kai Drive is anticipated to improve conditions at the Hawaii Kai Drive intersection with Wailua Street in the afternoon peak hour, since some traffic would likely use the extension, in lieu of Wailua Street, to travel to the upper Lunalilo Home Road area or the Kalama Valley area.

Along Kalanianaole Highway, the overall effect of the *Project* traffic increase would be to increase travel time between Hawaii Kai and the H-1 Freeway by about one minute during both peak hours. Travel times would also increase by less than one minute between other East Honolulu communities and the freeway. Figure 1 summarizes travel time increases for the Niu Valley and Waialae Iki areas, as well as Hawaii Kai.

TRANSIT AND BICYCLE IMPACTS

The *Project* would increase public transportation ridership in the Hawaii Kai area:

- The *Project* would add about 105 riders to TheBus routes during each peak period. About 70 of these would use express bus routes, which could necessitate one or two additional bus trips in each peak period.
- The *Project* would generate an estimated 273 passenger trips on TheHandi-Van each month. This would require about 105 additional vehicle trips to/from Hawaii Kai each month.

The principal effect of the *Project* on bicycle travel would be to increase vehicular traffic volumes along many streets designated as bicycle routes, particularly Keahole Street, portions of Hawaii Kai Drive, and Kealahou Street. Conversely, the extension of Hawai Kai Drive between Lunalilo Home Road and Wailua Street would offer a potential new bicycle route with fewer vehicle conflicts than the Lunalilo Home Road and Wailua Street alternative.

2017 CONDITIONS WITH OAHU RTP PLANS AND PROGRAMS

The lower traffic growth projected along Kalanianaole Highway, relative to the Baseline forecast without transit and TDM programs included in the Oahu RTP, would result in a corresponding lower volume-to-capacity ratio at each of the key intersections (Tables 1 and 2). In addition, the additional ewabound lane would greatly reduce the proportion of capacity being used at the Kalaniiki and Laukahi Streets intersections in the morning peak hour.

Based on the analyses with the Oahu RTP improvements, the Kalanianaole Highway intersection with Laukahi Street would have the highest capacity utilization for traffic flow in the afternoon peak

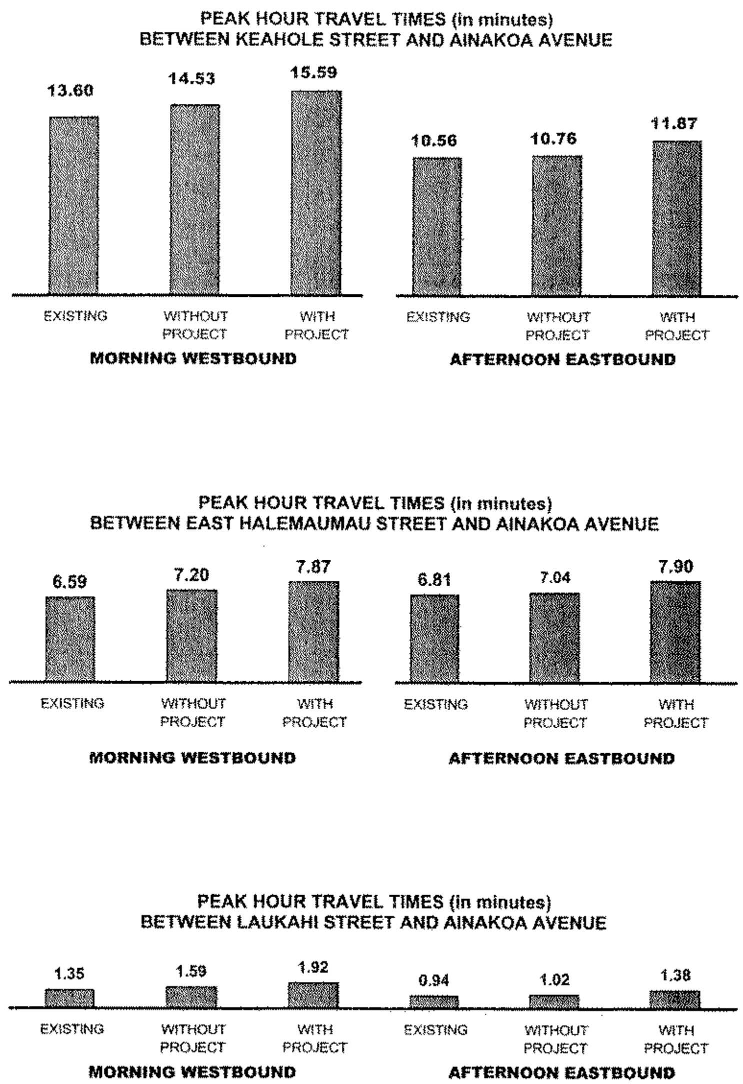


Figure 1
ESTIMATED PEAK HOUR TRAVEL TIMES ALONG KALANIANAOLE HWY (in minutes)

hour, with the forecast traffic volumes at 96 percent of capacity. All other intersections are estimated to operate at 90 percent or less of capacity.

WEEKEND TRAFFIC CONDITIONS

The section of Kalanianaole Highway from Kealahou Street to the Queen's Beach area, and to Windward Oahu, is more heavily travelled on weekends than on weekdays. The *Project* parcels would increase traffic between the Queen's Beach area and Lunalilo Home Road by 5 to 9 percent during the peak traffic hour (12:45 to 1:45 PM) on the weekend (Sunday afternoon). The *Project* traffic would contribute to longer delays for traffic turning left out of the Hanauma Bay and Sandy Beach parking areas.

MITIGATION ACTION

The *Project* would worsen conditions at several locations. The following roadway modifications and other actions should be considered to mitigate effects of the *Project*.

Access to *Project* Parcels

Modification to *Project* driveway connections are proposed to minimize potential disruption of traffic flow.

- **Marina 1/Strip 1**
  - Prohibit the left-turn movement from the driveway to Hawaii Kai Drive;
  - Include a right-turn lane on Kalanianaole Highway for turns into the driveway; and
  - Maintain convenient access and circulation for the relocated park-and-ride facility.
- **Queen's Rise**
  - Provide left-turn storage lane on Kalanianaole Highway at access road connection; and
  - Provide deceleration lane for ewabound traffic turning from Kalanianaole Highway.
- **Queen's Beach Golf Course**
  - Provide left-turn storage lane on Kalanianaole Highway at access road connection; and
  - Provide deceleration lane for traffic turning into driveway from Makapuubound Kalanianaole Highway.

Hawaii Kai Roadways

Intersection modifications should be considered to improve traffic operations at several intersections.

- **Hawaii Kai Drive/Lunalilo Home Road**
  - Restripe westbound approach to allow left-turns from both lanes;
  - Restripe eastbound and southbound approaches to provide two lanes; and
  - Revise traffic signal phasing.

- **Hawaii Kai Drive/Kaluanui Road**
  - Restripe maukabound approach of Hawaii Kai Drive to provide left-turn storage lane.

- **Hawaii Kai Drive/Wailua Street**
  - Restripe Hawaii Kai Drive to provide two maukabound through lanes plus the right-turn lane; and
  - If a Kaluanui 2/3 parcel driveway connection is provided to this intersection, restrict movements to those that do not require special signal phasing and do not interfere with major traffic movements.

- **Hawai Kai Drive at Kawaihae Street and at Kealahou Street**
  - Projected traffic volumes would worsen intersection conditions, but would not be high enough to satisfy minimum volume requirements to allow installation of traffic signals. Therefore, monitor future traffic volumes to identify if actual increases do meet volume requirements for signal controls.

- **Kalanianaole Highway/Keahole Street**
  - Widen mauka side of Kalanianaole Highway to extend the third ewabound through lane through the Keahole Street intersection, with the lane ending on the ewa side of the Kuapa Pond bridge.

Other East Honolulu Intersections

Intersection modifications or other improvements may be needed at other locations, in addition to those included in the Oahu RTP. Modifications that should be considered are:

- **Kalanianaole Highway/Laukahi Street**
  - Widen Waiholo Street to provide two mauka direction lanes; and
  - Extend length of left-turn lane on kokohead direction Kalanianaole Highway.

- **Kalanianaole Highway/Sandy Beach West Driveway**
  - Manual control of traffic may be necessary during peak exiting periods on major summer or holiday weekends, similar to present conditions at Hanauma Bay.

Travel Demand Management

The *Project* should include those actions that promote alternatives to driving during weekday peak hours, particularly telecommuting. These would include:

- Encourage installation of communication lines in new developments that allow high-quality video and graphics transmissions.
- Encourage location of a business service center within Hawaii Kai that provides printing, fax, computer-related services for persons working from their homes.
- Promote programs that facilitate telecommuting.
- Work with State DOT to promote rideshare programs.

1. INTRODUCTION

The Hawaii Kai community has experienced continuing growth for more than three decades, with the location and types of land uses following the overall plan set forth for the area in the 1960s. This growth has resulted from the attractive physical setting, community values, and proximity to the central Honolulu area, which have attracted residents and businesses to the Hawaii Kai area as well as to the adjacent communities of East Honolulu.

Initial development in Hawaii Kai was primarily residential uses, whereas in recent years there has been increased emphasis on development of the retail and office elements of the community plan. At present, the Hawaii Kai community includes approximately 9,600 residential units and over one-half million square feet of commercial uses. These existing uses occupy most of the developable area of Hawaii Kai, with less than two dozen parcels remaining to complete the planned development of the community.

Development is now being proposed for 12 parcels as part of the settlement process for a land use dispute between the City and County of Honolulu and the following parties: 1) Maunalua Associates, Inc., formerly Hawaii Kai Development Company; 2) Kaiser Aluminum and Chemical Corporation; and 3) Kamehameha Schools Bernice Pauahi Bishop Estate. These 12 parcels which have not previously received City approvals for development, are herein referred to as the *Project*.

This report provides an assessment of the transportation-related effects of the 12 Project parcels and other remaining developments within the Hawaii Kai area. The assessment addresses both the effects within Hawaii Kai and for the regional linkages to Hawaii Kai, and identifies any infrastructure improvements needed to accommodate travel to/from these developments.

PROJECT DESCRIPTIONS

The *Project* includes 12 parcels, with a total area of approximately 540 acres. The locations of these 12 parcels are depicted in Figure 1-1. The acreages and proposed uses are as follows:

Parcel	Acres	Proposed Use
Kalama Valley	8.3	176 Low Rise Condo Units
Kamilo Ridge	36.5	5 Single Family Houses
Kamilonui 1	17.4	510 Mid Rise Condo Units
Kamilonui 2	62.8	92 Single Family Houses 272 Townhouses
Marina 4B	5.1	75 Townhouses
Mauuwai	82.7	143 Single Family Houses
Queen's Rise	101.9	194 Single Family Houses

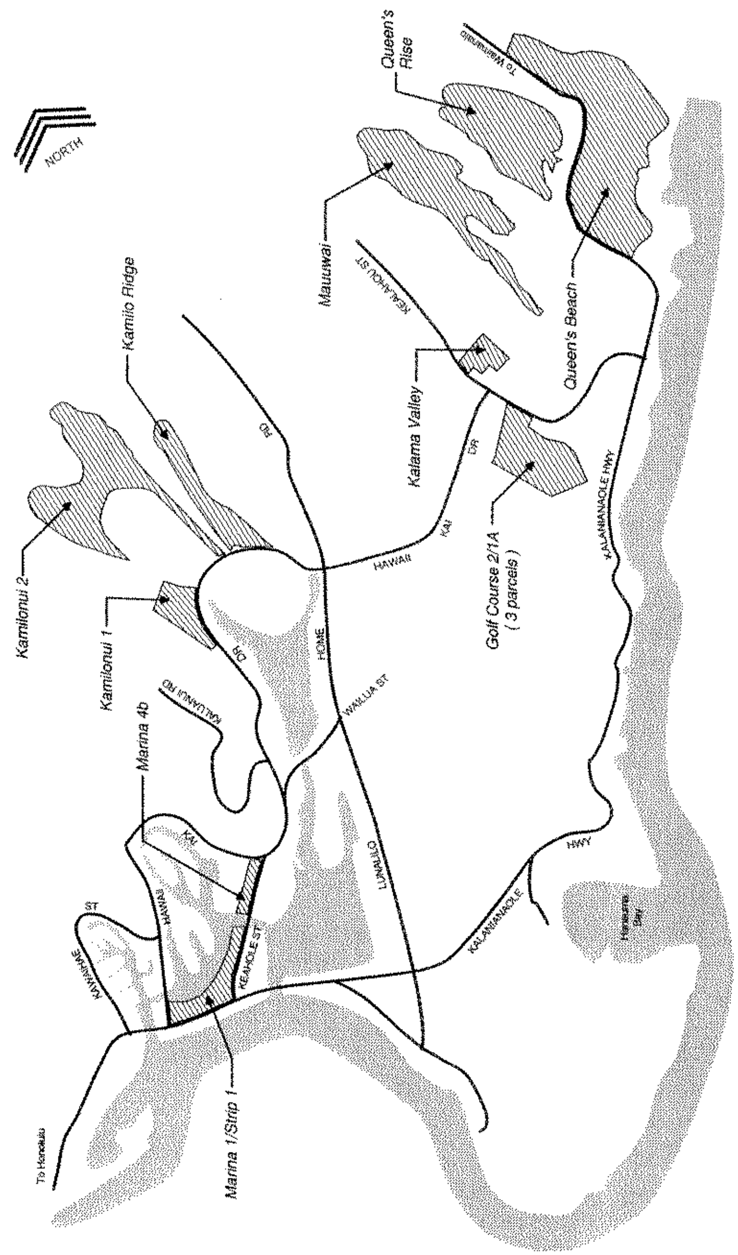


Figure 1-1
LOCATION OF PROJECT PARCELS
PARCELS-7/7/96C

WILBUR SMITH ASSOCIATES

Parcel	Acres	Proposed Use
Golf Course 2/1A	9.8	45 Single Family Houses
Golf Course 2/1A	10.9	Business Park with 100,800 sq. ft. of Floor Area
Golf Course 2/1A	29.1	140-Room Inn
Marina 1/Strip 1	6.6	192,000 sq. ft. of Office and Retail Uses
Queen's Beach	166.0	Golf Course

Those parcels with zoning approvals are not included as part of the *Project*, but are considered in this study as part of the *Without Project* conditions.

Both the approved development and the *Project* parcels could be developed by year 2017, which is used as the future forecast year for this study.

STUDY PURPOSE AND SCOPE

This study assesses the transportation-related effects which would result from the full development of the Hawaii Kai community. The study includes:

- An analysis of existing conditions;
- An analysis of future conditions without the *Project*, which includes future Hawaii Kai developments with City zoning approvals, to be used as a baseline against which to measure project impacts;
- An analysis of future conditions with the *Project*; and
- Identifications of transportation actions appropriate to mitigate the effects of the *Project*.

The analyses reflect conditions in year 2017, by which time full development of the *Project* parcels could be completed. The study analyses reflect cumulative travel increases from both the approved development and the proposed *Project* parcels within Hawaii Kai, as well as development within other East Honolulu communities and increases in background travel growth from existing uses.

The study analyses focus on travel increases and traffic conditions during the weekday commute peak hours, since these periods represent the most heavily travelled periods at most roadway locations. The study includes the key intersections within the Hawaii Kai community which represent either those locations with the present highest traffic volumes and/or worst traffic conditions, or those lower-volume locations that may be most directly affected by the proposed new development. The analyses also encompass the major intersections along Kalanianaole Highway between Hawaii Kai and the H-1 Freeway. These include the Kalanianaole Highway intersections with Kalaniiki Street and Laukahi Street at the west end of the East Honolulu area, where the highest volumes occur on

Kalanianaole Highway. Other intersections include West Hind Drive in the Aina Haina area and East Halemaumau Street in Niu Valley, where large volumes of traffic turn to/from Kalanianaole Highway.

An analysis of weekend conditions was also made for several locations where weekend travel volumes exceed those during the weekday commute hours. The weekend analysis was made for several intersections and roadway sections along the two-lane segment of Kalanianaole Highway between Lunalilo Home Road and Makapuu Point.

2. EXISTING CONDITIONS

Hawaii Kai has developed into the largest community within the East Honolulu corridor. Increased commercial development in recent years has resulted in a diverse mix of residential, retail, office, and community facilities within the Hawaii Kai community. Current residential development includes approximately 7,000 single family and 2,600 multi family dwelling units. Commercial uses include Koko Marina Shopping Center, the Towne Center retail and office complex, Hawaii Kai Shopping Center, and the Hahaione and Kalama area neighborhood shopping centers. Public facilities include Kaiser High School, three elementary schools, post office, public library, parks, fire station, and recreational facilities. In addition, the community is located adjacent to several of the most popular natural attractions on Oahu, which include Hanauma Bay, the Sandy Beach area, and the Blowhole/Bamboo Ridge area. These areas attract large numbers of both Oahu residents and visitors.

Kalanianaole Highway serves as the transportation spine through the East Honolulu corridor. As shown in Figure 2-1, it connects Hawaii Kai, located at the eastern end of East Honolulu, to the H-1 Freeway and the central Honolulu area as well as to the Windward Oahu area. The capacity of the roadway into Honolulu has been increased over the years and with the recently completed widening project, a six-lane divided highway now connects Hawaii Kai to the H-1 Freeway.

The other communities of East Honolulu are located along Kalanianaole Highway, with the developed areas extending from the shoreline up the valley and ridge areas mauka of the highway. The major communities include Kuliouou, Niu Valley, the Aina Haina area, and the Waialae Iki area. Hawaii Kai comprises about 60 percent, or some 29,000 of the 48,000 residents of the East Honolulu area.

METHODOLOGY FOR DATA COLLECTION

The existing travel conditions presented herein generally represent the travel volumes and roadway conditions of January-February 1996. Weekday data represent conditions with schools in session.

Roadway and traffic control information were obtained through field reconnaissance by Wilbur Smith Associates (WSA) engineers during December 1993, and updated in February 1996. The roadway data reflect the completion of the widening of Kalanianaole Highway from Aina Haina to Hawaii Kai. The roadway inventory included those items needed to estimate roadway capacities, such as number and width of lanes, shoulder conditions, types of traffic controls, and traffic signal phasing and timing.

Existing peak hour traffic volumes were developed from manual intersection turning movement counts made by WSA. An initial comprehensive set of intersection counts were made for weekday peak traffic periods in mid-May, 1993, and updated with supplemental counts along Kalanianaole Highway in December 6-7, 1993. Initial weekend counts were made on February 12-13, 1994.

Between January 25 and February 15, 1996, a final set of traffic counts were made within Hawaii Kai and along Kalanianaole Highway. Weekday counts were made at 11 of the 16 intersections

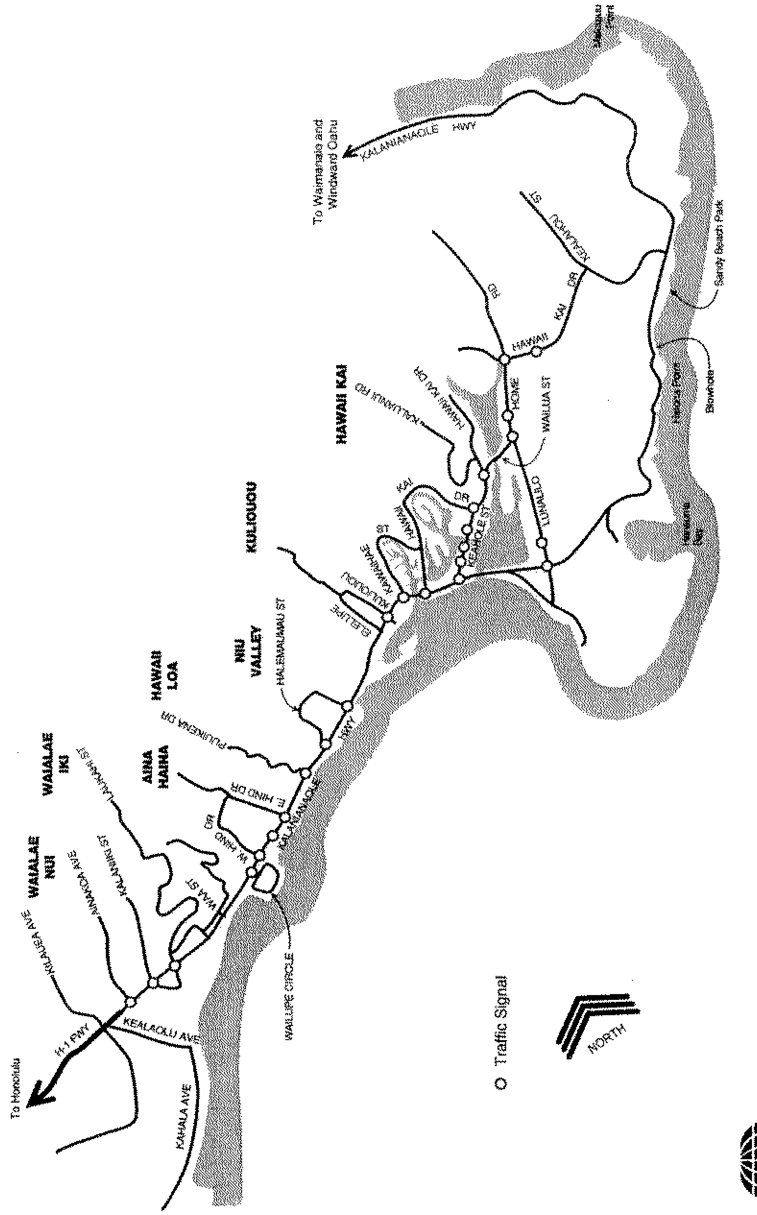


Figure 2-1

STUDY AREA ROADWAYS - HAWAII KAI AND KALANIANAOLE HIGHWAY

BASE-11/18/94C

WSA WILBUR SMITH ASSOCIATES

included in the analyses, with these counts or recent State DOT machine counts used to update the other five intersections. Supplemental Sunday counts were made on February 4, 1996.

On weekdays, traffic volumes for each movement at the subject intersections were counted and recorded every 15 minutes during the morning and afternoon peak traffic periods. On weekends, the counts were made between noon and 4:00 PM. The count data was analyzed to determine volumes for the peak one-hour periods, which were used to evaluate traffic conditions.

Information on travel characteristics was also developed from travel surveys done by WSA in March 1987 and April 1991. These surveys recorded vehicle volumes, automobile occupancies, and person trips by travel mode on Kalanianaole Highway west of Kawaihae Street, and for the contraflow high-occupancy vehicle (HOV) lane at Ainakoa Avenue.

Historic traffic count data were obtained from the State DOT count station on Kalanianaole Highway, west of Kalaniiki Street, as well as earlier State DOT counts of vehicle occupancies.

Information concerning TheBus service was obtained from public bus schedules and from the *Comprehensive Operations Analysis*,[1] which reflects ridership survey data collected in 1993. Passenger volumes for TheBus and private transit operators were also obtained from the 1987 and 1991 WSA surveys.

METHODOLOGY FOR ANALYZING TRAFFIC CONDITIONS

The Transportation Research Board (TRB), a division of the National Science Foundation, has developed standardized methods for use in evaluating the effectiveness and quality of service for roadways and streets. Different methodologies are available for analyzing traffic signal-controlled intersections and unsignalized intersections, and for rural roadway segments, all of which were used in evaluating present and future conditions for this study.

The TRB evaluation methods use a concept known as level-of-service (LOS). This concept describes facility operations on a letter basis from A to F, which signify excellent to unacceptable conditions, respectively. The methods generally compare traffic volumes on a facility to the facility's theoretical capacity. Capacity is estimated based on the facility's physical characteristics (e.g. number of lanes), traffic characteristics (e.g. types of vehicles), and type of traffic controls. The comparisons are frequently referred to as the volume-to-capacity (V/C) ratio. The methodologies are described in the *1994 Highway Capacity Manual* (1994 HCM).[2]

Traffic Signal-Controlled Intersections

Traffic conditions at traffic signal-controlled intersections were evaluated using the *Operations Analysis* methodology described in the 1994 HCM. Using this method, the level-of-service is based

(1) *Comprehensive Operations Analysis, Honolulu TheBus*, prepared for the Honolulu Public Transit Authority by Barton-Aschman Associates, 1993.

(2) Highway Capacity Manual, Special Report 209, Transportation Research Board, Third Edition, Updated 1994.

on the average delay time per vehicle passing through the intersection. The delay time, calculated in seconds, is the result of the phasing and timing of the traffic signal as well as the intersection's physical layout and the composition of the traffic. Average delay time and level-of-service are determined for the entire intersection, for each roadway approach, and for each traffic movement or lane group. A description of the characteristics and criteria associated with LOS A through LOS F is provided in Figure 2-2.

The methodology also calculates a ratio of actual or estimated peak hour traffic volumes to the theoretical capacity of the intersection. This indicates the proportion of available capacity being used by traffic volumes and where there is unused capacity available for future traffic increases. This volume-to-capacity ratio (V/C) reflects the physical characteristics of the intersection and the traffic characteristics, and is somewhat independent of the efficiency of the traffic signal phasing/timing.

Unsignalized Intersections

At intersections with STOP sign controls, the level-of-service was calculated using the 1994 HCM procedures for intersections with two-way STOP sign control (STOP or YIELD signs on minor streets) and for those intersections with STOP signs on all approaches (three- or four-way STOP sign control). In both methodologies, six levels-of-service, A through F, are used to describe traffic conditions.

For three-leg ("T") and four-leg intersections with STOP or YIELD controls on the minor street approaches, the standard procedure provides a comparative measure of delay for those movements which must yield to conflicting movements at the intersection. The movements which must yield include:

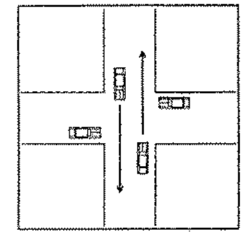
- Left-turn out of the side street;
- Right-turn out of the side street; and
- Left-turn into the side street.

Through vehicles on the major streets are not required to yield to other movements at T- and two-way controlled intersections. The general indicator of intersection delay is determined by calculating the one-hour capacity for each key movement, based on conflicting traffic volumes, and then comparing the number of vehicles making that maneuver to the calculated capacity. The unused or "reserve" capacity for the movement is then used to identify a delay time and a level-of-service for that movement. Unlike signalized analysis, an overall intersection level-of-service is not calculated, but a level-of-service is calculated for each lane group subject to the STOP or YIELD condition.

The level-of-service criteria for unsignalized intersections with minor street STOP controls is defined in Table 2-1.

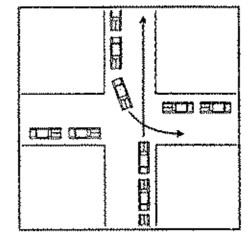
For intersections with STOP or YIELD controls on all approaches, the 1994 HCM uses the *1991 TRB Circular 373* methodology to assess level-of-service. This methodology is also based on analyzing each intersection approach independently, but then provides an average overall level-of-service for the intersection. Flow rates and approach capacities are calculated for each approach and volume-to-capacity ratios and delays are determined. Individual approach levels-of-service are based on volume-to-capacity ratios. A weighted average of approach delays is used in arriving at an overall intersection delay and level-of-service. The level-of-service criteria for all-way STOP

The **OPERATIONS LEVEL METHODOLOGY**, which is described in the Transportation Research Board's Highway Capacity Manual, defines Level of Service (LOS) for signalized intersections in terms of delay. Technically, delay is the amount of time an average vehicle must wait at an intersection before being able to pass through the intersection. For signalized intersections, the relationship between LOS and delay is based on the average stopped delay per vehicle for a fifteen minute period.



LOS 'A'

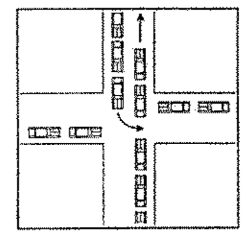
LEVEL OF SERVICE 'A' - Delay 0.0 to 5.0 seconds
Describes operations with very low delay, i.e., less than 5 seconds per vehicle. This occurs when signal progression is extremely favorable. Most vehicles arrive during the green phase and are not required to stop at all.
Corresponding V/C ratios usually range from 0.00 to 0.60.



LOS 'C'

LEVEL OF SERVICE 'B' - Delay 5.1 to 15.0 seconds
Describes operations with delay in the range of 5 to 15 seconds per vehicle generally characterized by good signal progression and/or short cycle lengths. More vehicles are required to stop than for LOS 'A' causing higher levels of average delay.
Corresponding V/C ratios usually range from 0.61 to 0.70.

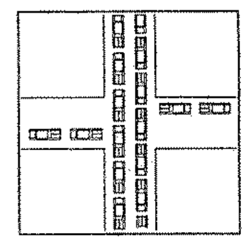
LEVEL OF SERVICE 'C' - Delay 15.1 to 25.0 seconds
Describes operations with delay in the range of 15 to 25 seconds per vehicle. Occasionally, vehicles may be required to wait more than one red signal phase. The number of vehicles stopping at this level is significant although many still pass through the intersection without stopping.
Corresponding V/C ratios usually range from 0.71 to 0.80.



LOS 'D'

LEVEL OF SERVICE 'D' - Delay 25.1 to 40.0 seconds
Describes operations with delay in the range of 25 of 40 seconds per vehicle. At LOS 'D', the influence of congestion becomes more noticeable. Many vehicles stop, and the proportion of vehicles not stopping declines. The number of vehicles failing to clear the signal during the first green phase is noticeable.
Corresponding V/C ratios usually range from 0.81 to 0.90.

LEVEL OF SERVICE 'E' - Delay 40.1 to 60.0 seconds
Describes operations with delay in the range of 40 to 60 seconds per vehicle. These high delay values generally indicate poor signal progression, long cycle lengths and high V/C ratios. Vehicles frequently fail to clear the intersection during the first green phase.
Corresponding V/C ratios usually range from 0.91 to 1.00.



LOS 'F'

LEVEL OF SERVICE 'F' - Delay 60.1 seconds plus
Describes operations with delay in excess of 60 seconds per vehicle. This condition often occurs with oversaturation, i.e., when arrival flow rates exceed the capacity of the intersection.
Corresponding V/C ratios of over 1.00 are usually associated.

SOURCE: Transportation Research Board, "Operational Level Methodology-Signalized Intersections", *Highway Capacity Manual*, Special Report 209, 1985.

LOS-HCB-5/6/94CRL

WSA WILBUR SMITH ASSOCIATES

Figure 2-2
LEVEL OF SERVICE DIAGRAM

controlled intersections is the same as that used for two-way STOP controlled intersections (Table 2-1).

Two-Lane Rural Highways

On a two-lane roadway having one lane in each direction, passing of slower vehicles requires the use of the opposing lane where sight distance and gaps in opposing traffic permit. The level-of-service criteria for two-lane rural highways, in sections without interruption due to traffic controls, are defined primarily in terms of percent time delay behind slower vehicles, with speed and capacity utilization as secondary measures.

Table 2-2 presents the level-of-service criteria for two-lane rural highways, which was used to analyze conditions along Kalanianaole Highway in the Hanauma Bay, Blowhole-Sandy Beach, and Makapuu Point areas.

ROADWAY SYSTEM

The Hawaii Kai community is served by a network of major streets and collector roadways with Hawaii Kai Drive, Keahole Street, Lunalilo Home Road, and Kealahou Street being the most important. Access to/from Hawaii Kai is provided by Kalanianaole Highway, which connects the community to both the Leeward and Windward portions of Oahu. (See Figure 2-1.)

Kalanianaole Highway

In the ewa portion of the East Honolulu corridor, Kalanianaole Highway is a divided six-lane highway within a 110- to 120-foot wide right-of-way. The landscaped median divider has median openings and left-turn storage lanes at key cross streets providing access to the adjacent communities. Double left-turn lanes are provided for the eastbound left-turn movement at West Hind Drive in Aina Haina. A paved outer shoulder area is provided in each direction, with the shoulder area designated for bicycle use. The six-lane segment extends from the H-1 Freeway to Hawaii Kai Drive.

Between Hawaii Kai Drive and Keahole Street, Kalanianaole Highway narrows to a four-lane roadway. Double left-turn lanes are provided on eastbound Kalanianaole Highway to accommodate the large volume of left turns at both Hawaii Kai Drive and Keahole Street. The recently completed widening project also provided three makai-direction lanes on the approaches of these two streets to Kalanianaole Highway, with two lanes designated for the right-turn movement towards Honolulu and the third lane for through and left-turn traffic.

No turn lanes are provided along the four-lane segment, which ends at the Lunalilo Home Road intersection. At this intersection, one of the two eastbound lanes ends as a left-turn lane for traffic turning mauka. The second westbound lane begins as a continuation of the makai-direction right-turn lane from Lunalilo Home Road, with a raised island provided to create a "free" right-turn movement.

East of Lunalilo Home Road, Kalanianaole Highway continues as a two-lane highway through eastern Hawaii Kai to Makapuu Point and into the Windward Oahu area. No left-turn storage lanes

Table 2-1

LEVEL-OF-SERVICE CRITERIA
FOR UNSIGNALIZED INTERSECTIONS
Hawaii Kai Properties EIR

LOS	Average Stopped Delay (seconds/vehicle)
A	<5.0
B	5.1 - 10.0
C	10.1 - 20.0
D	20.1 - 30.0
E	30.1 - 45.0
F	>45

Source: Transportation Research Board, *Circular 373: Interim Materials on Unsignalized Intersection Capacity*, July, 1991, Page 19.

Table 2-2

LEVEL-OF-SERVICE CRITERIA FOR TWO-LANE RURAL HIGHWAYS
Hawaii Kai Properties EIR

LOS	Percent of Time Delay	Maximum V/C Ratio	Maximum Service Flow Rate (pcph)	Description
A	30%	0.15	420	Free flow.
B	45%	0.27	750	Platoons begin to form.
C	60%	0.43	1,200	Traffic flow stable, but long platoons begin to form.
D	75%	0.64	1,800	Traffic flow stable, but long platoons begin to combine into longer chains of vehicles and control speeds.
E	More than 75%	1.00	2,800	Platooning intense and speeds become significantly slower.
F	---	----	---	Heavily congested with volumes exceeding capacity.

Notes: Based on level terrain and zero percent no passing zones as optimum conditions. Maximum service flow rate represents two-way traffic volumes.
LOS = Level-of-Service
pcph = passenger cars per hour
Source: *Highway Capacity Manual*, Chapter 8, Page 8-5.

Wilbur Smith Associates; March 1996

are provided through this segment. Paved shoulders vary in width, with little or no paved shoulder along much of the winding section in the Blowhole area.

Most of the intersections with key cross streets between the H-1 Freeway and Lunalilo Home Road are controlled by traffic signals; there are no signals east of Lunalilo Home Road. The traffic signals from Ainakoa Avenue to Keahole Street are interconnected and timed to facilitate traffic flow through this section. The traffic signals operate on very long cycle lengths to optimize traffic flow along Kalanianaole Highway. Cycle lengths range between 220 and 255 seconds in the AM peak period and 160 seconds in the PM peak period.

A contraflow/reversible lane operation is used weekday mornings to provide an additional westbound travel lane from the vicinity of West Halemaumau Street to the H-1 Freeway. The westbound contraflow lane is open only to vehicles with two or more occupants or those residents who live in the areas along the makai side of the roadway. The reversal of travel direction for one of the eastbound lanes reduces eastbound traffic capacity, and also requires prohibition of all westbound left-turns and eastbound left-turns at almost all streets during the contraflow operation. At Ainakoa Avenue, during the contraflow operations the median opening is blocked, the cross street restricted to right-turns, and the traffic signal locked onto green for Kalanianaole Highway to eliminate disruption to the merge of the contraflow lane traffic into the normal westbound travel lane immediately west of this intersection.

Hawaii Kai Streets

The street system within Hawaii Kai has been developed to connect the valley and ridge residential areas to Kalanianaole Highway and to the commercial areas and public facilities that are concentrated along Lunalilo Home Road and Keahole Street near Kalanianaole Highway. The major Hawaii Kai streets also provide a parallel route that bypasses the Hanauma Bay-Blowhole section of Kalanianaole Highway. The major streets within Hawaii Kai are described in the following paragraphs.

Hawaii Kai Drive - This street was planned as the major roadway serving the community, although the segment around the mauka end of Kuapa Pond has not been completed. The segment west of Kaluanui Road is a broad 64-foot wide road with four travel lanes plus left-turn lanes, while the segment between Lunalilo Home Road and Kealahou Street provides four lanes with no turn lanes. The two "dead-end" segments between Kaluanui and Lunalilo Home Roads provide one lane in each direction in a 40-foot wide roadway.

Lunalilo Home Road - Makai of Hawaii Kai Drive, the 64-foot wide roadway is striped for four through lanes, with an additional turn lane at key intersections. Mauka of Hawaii Kai Drive, the street narrows to two lanes. Parking is permitted along both segments.

Keahole Street - This street has been widened to four lanes plus turn lanes at key intersections. Because of the directness of its connection to Kalanianaole Highway and the concentration of commercial development along it, the intersection with Hawaii Kai Drive has been realigned to establish Keahole Street and the mauka leg of Hawaii Kai Drive as the through street.

Wailua Street - This short connector street provides the only crossing of Kuapa Pond, other than Kalanianaole Highway. The 40-foot wide street is striped for one lane in each direction, with an added (second) left-turn lane at the intersections at each end of the street.

Kealahou Street - This 40-foot wide, two-lane street provides access to the residential areas within the eastern section of Hawaii Kai. The segment makai of Hawaii Kai Drive also serves as part of the local street route through Hawaii Kai for vehicles travelling to/from Windward Oahu.

Kawaihae Street - This collector street provides access to the Kaalakei Valley residential areas of Hawaii Kai. The 40-foot wide street is striped for one lane in each direction, with parking allowed on both sides. During the morning peak traffic period, parking is prohibited along the mauka curb to provide a reserved bus and HOV lane to Kalanianaole Highway.

Traffic Controls - Most of the key intersections in the Marina portion of Hawaii Kai are controlled by traffic signals. One major exception is the Kawaihae Street approach to Hawaii Kai Drive, which is controlled by STOP signs. Most traffic signals are fully actuated and cycle lengths are short. Traffic signals along Keahole Street are interconnected to facilitate traffic flow along this street.

There are no traffic signals in the eastern section of Hawaii Kai. STOP signs are used at the key intersections, with all-way STOP controls at the Hawaii Kai Drive-Kealahou Street intersection.

TRANSIT SERVICE

The Hawaii Kai community is served by an extensive network of TheBus local and express routes, as well as by several privately-sponsored routes that focus on service to schools in the Honolulu area. A park-and-ride facility is located along Keahole Street that includes 139 all-day parking stalls, 12 short-term parking stalls, and 5 bus loading positions.

TheBus routes within Hawaii Kai are depicted in Figure 2-3. Key features of the service for each route are as follows:

Route 1: Kaimuki-Kalihi - Route 1 is a major trunk route that provides local service from the Marina area of Hawaii Kai, through East Honolulu to Downtown Honolulu and the Kalihi area. Service in Hawaii Kai extends from about 5:20 AM until 1:00 AM on weekdays, with similar service hours also on Saturdays and Sundays. Route 1 is split into two branch routes within Hawaii Kai (Hawaii Kai Drive and Lunalilo Home Road) with service frequencies approximating 30 minutes along each branch on weekday peak periods (15 minutes combined) and 60 minutes along each branch during off-peak periods and weekends (30 minutes combined).

Route 58: Honolulu-Hawaii Kai-Sea Life Park - This trunk route provides service through Hawaii Kai to Waikiki and Ala Moana Center. At Sea Life Park, riders can transfer to reach the areas of Windward Oahu. Service in Hawaii Kai extends from about 6:00 AM until 7:30 PM on weekdays, with a slightly shorter service period on Saturdays and Sundays. The service

HAWAII KAI PROPERTIES TRAFFIC IMPACT STUDY

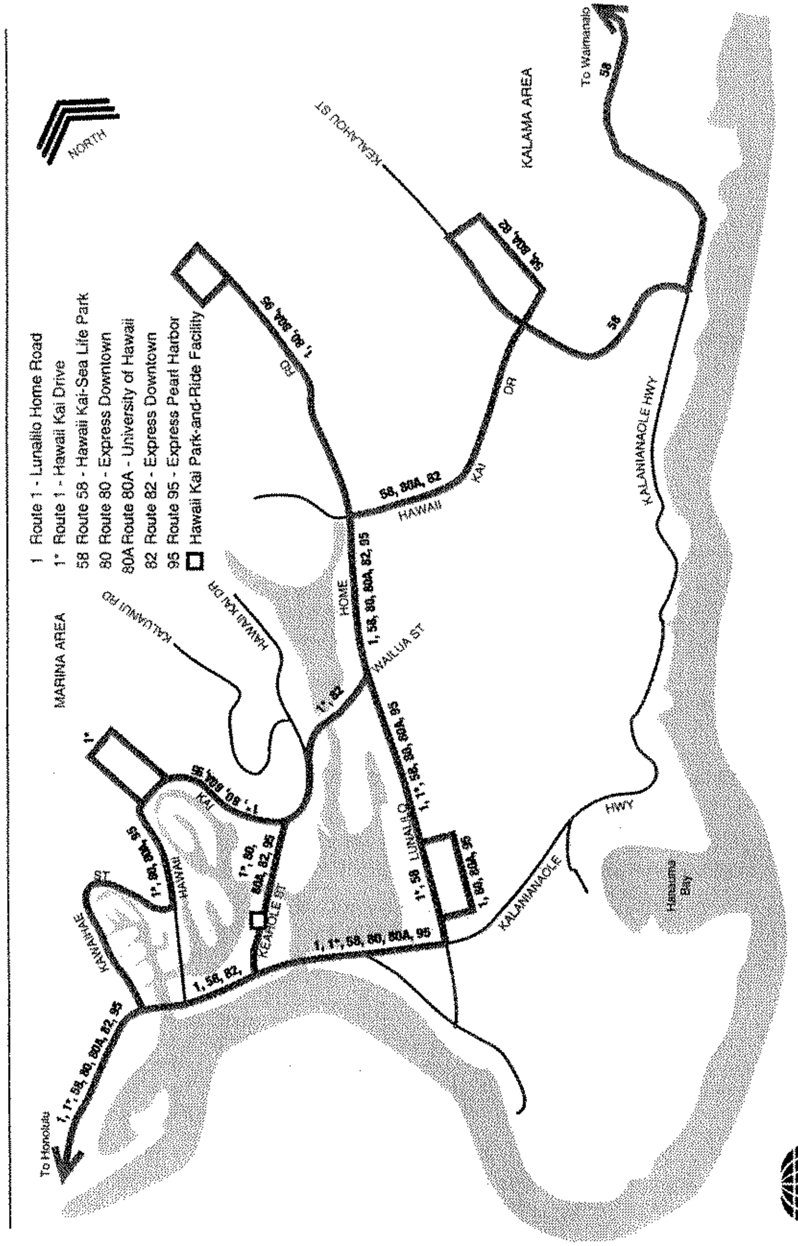


Figure 2-3
EXISTING TheBUS ROUTES
HWIKAI-HWDETAIL-12/2/94C

WILBUR SMITH ASSOCIATES

frequency approximates 30 minutes throughout most of the weekday, and 60 minutes on weekends.

Express Routes - The Hawaii Kai community is served by four TheBus express routes that provide service during weekday commute periods to Downtown Honolulu, the University of Hawaii-Manoa area, and Pearl Harbor. Each of the routes provides service to the park-and-ride facility as well as to different areas of Hawaii Kai. The number of bus trips and service periods are as follows:

Route	Destination	Morning		Afternoon	
		Bus Trips	Departures from Hawaii Kai	Bus Trips	Departures from Employment Area
80	Downtown	7	5:37 - 7:17 AM	6	4:05 - 5:45 PM
80A[1]	U.H.-Manoa	6	5:48 - 7:59 AM	6	2:35 - 5:40 PM
82	Downtown	4	5:28 - 7:03 AM	3	3:50 - 5:15 PM
95	Downtown & Pearl Harbor	1	5:23 AM	1	3:55 PM
	Total	18		16	

(1) For Route 80A, 4 of the AM trips and 2 of the PM trips extend to serve Kalama Valley while the other trips begin/end in the Marina area.

In recent years, SMART (Save Money and Ride together) supported operation of two minibuses and one van which provide service for school children to private schools in Honolulu. The vehicles operated from the Hawaii Kai park-and-ride facility and provided service to Punahou, Maryknoll, Iolani, Hawaii School for Girls, Mid-Pac, and Our Redeemer Schools. This service ended in 1995.

Kamehameha Schools also provides school bus service from the Hawaii Kai park-and-ride facility.

BICYCLE FACILITIES

At present, a bicycle lane is provided in each travel direction along Kalanianaole Highway between the H-1 Freeway and Lunalilo Home Road in Hawaii Kai. This bicycle corridor is extended eastward from -the Lunalilo Home Road intersection to Kalanianaole Highway at the Sandy Beach area via a designated bicycle route along Lunalilo Home Road, Hawaii Kai Drive, and Keauhou Street.

The State's bicycle plan[3] includes additional new bicycle lanes within Hawaii Kai. These are:

- Kawaihae Street;
- Hawaii Kai Drive, Kalanianaole Highway to Wailua Street;
- Wailua Street; and
- Keahole Street.

[3] Bike Plan Hawaii, A State of Hawaii Master Plan, State DOT Highways Division, April 1994.

The State Master Plan also envisions the designation of Kalanianaole Highway as a bicycle route eastward from Lunalilo Home Road through the Kalama area to Windward Oahu.

CHANGES IN TRAVEL CHARACTERISTICS ALONG KALANIANAOLE HIGHWAY

Travel characteristics and travel conditions in the Kalanianaole Highway corridor have changed significantly in recent years. The changes have primarily resulted from actions that have increased the capacity for vehicular traffic through the corridor during the peak commute hours. These actions have included:

- In the mid 1980s, the Honolulu-direction reversible lane on the then four-lane section between Hawaii Kai and Aina Haina, which operated in the morning commute hours, was opened to all vehicles. Before, the lane had been restricted to use by high-occupancy vehicles (HOVs), which included buses and carpools with four or more persons.
- In May 1988, the number of occupants needed in a vehicle to use the contraflow HOV lane between Aina Haina and the H-1 Freeway was reduced from four to three, and the permit requirement(4) was dropped. In April 1989, the number of occupants required to use the lane was further reduced to two.
- Also in 1988, the morning signal cycle was lengthened to increase intersection capacities and a slightly greater proportion of the green time was assigned to through traffic to increase overall corridor capacity.

These actions have both increased capacity and improved conditions for general vehicular traffic. This has greatly reduced or eliminated the travel time savings for buses and carpools in the corridor, and has lessened the incentive for persons to rideshare.

This has resulted in the following changes:

- Approximately 20 percent shorter trip time for general traffic between Hawaii Kai and Downtown Honolulu, based on OMPO travel time surveys conducted for the morning peak periods before and after these changes were made;
- Significant increases in the vehicle volumes travelling into Honolulu during the morning peak hour and peak period;
- Significant reductions in bus ridership in peak periods; and
- A large decline in average automobile occupancy.

(4) When the contraflow HOV lane was first established, the State DOT allowed use only by permit, and vehicles were required to display the permit on the dashboard. Only 700 permits were issued in order to limit the number of vehicles using the HOV lane.

The following sections describe existing travel characteristics and, where possible, provide a comparison to previous conditions.

Travel Mode at Kawaihae Street

Morning traffic surveys were made just Ewa of Kawaihae Street in 1987, 1990, and 1991 to record the number of Honolulu-bound vehicles and the number of occupants in each vehicle. The results for the 1987 and 1991 counts are presented in Table 2-3 for the morning peak hour and in Table 2-4 for the 6:00 to 8:30 AM morning peak period. The information largely reflects Hawaii Kai trips, with trips from the Waimanalo-Kailua area to Honolulu representing about 10 percent of the traffic.

Comparison of the 1991 data to the 1987 data indicates that traffic volumes increased by about 347 and 1,485 vehicles during the peak hour and peak period, respectively. The increase in vehicles actually exceeded the increase in person trips, which increased by 70 and 1,206 persons for the peak hour and peak period, respectively. This reflects the shift from ridesharing to increased automobile driving.

The proportion of trips via transit in 1991 approximated 7.6 percent of peak hour trips, and 7.1 percent of all trips during the morning peak period. However, this is a significant reduction from the levels approximating 10 percent transit use in 1987. There was a net decline in the number of bus riders, even with an increase in bus service.

The surveys indicated a large increase in the number of vehicles with one or two occupants between 1987 and 1991, and a net decline in automobiles with three or more occupants. Automobiles with three or more occupants presently account for 6.5 and 15.3 percent of morning peak hour vehicles and person trips, respectively. Automobile occupancy in 1991 averaged 1.44 persons per vehicle in the morning peak hour.

Travel Mode in Kalanianaole Highway HOV Lane

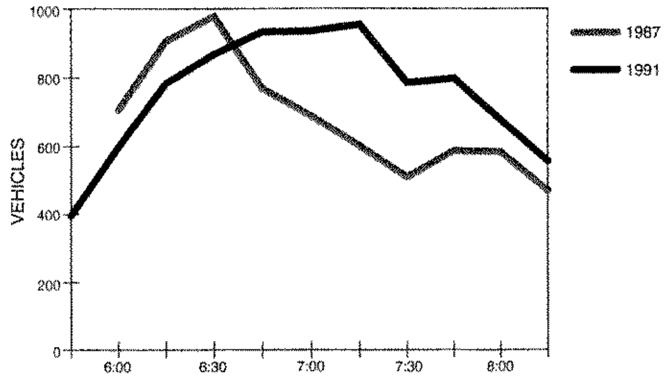
The reduction in use restrictions has allowed an increase in the number of vehicles and person trips using the HOV lane. As indicated in Table 2-5, use in the morning peak hour increased from 320 vehicles in 1987 to 981 vehicles in 1991. The increase primarily resulted from the additional use by two-occupant vehicles.

The total number of persons using the HOV lane in the peak hour increased from about 1,300 in 1987 to 2,500 in 1991. However, average automobile occupancy declined from 4.1 to 2.6 persons per vehicle.

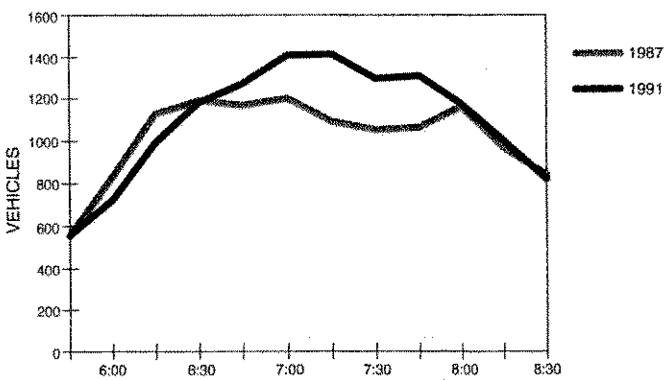
Time of Travel

The numbers of vehicles travelling towards Honolulu in the morning peak period are depicted by 15-minute time increments in Figure 2-4, both at Kawaihae Street and near Kalaniiki Street. The traffic by 15-minute intervals is presented both for the 1987 and 1991 surveys.

At Kawaihae Street, the counts indicate that the peak one-hour period has shifted to a later time, from 6:00-7:00 AM in 1987, to 6:45-7:45 AM in 1991. The additional traffic has also resulted in the higher traffic flow volumes continuing for a longer period of time in 1991.



AT KAWAIHAE STREET



AT KALANIIKI STREET

Figure 2-4

VEHICLE VOLUMES BY 15-MINUTE PERIODS - EWA DIRECTION KALANIANAOLE HWY

WILBUR SMITH ASSOCIATES

VEHVOLS-12/15/94C

Table 2-3

1987 and 1991
MORNING PEAK HOUR TRAVEL VOLUMES
EWA-BOUND KALANIANAOLE HIGHWAY AT KAWAIHAE STREET
Hawaii Kai Properties EIR

Category	1987 Survey[1,2]		1991 Survey[3]		Change	
	Number	% of Total	Number	% of Total	Number	Percent
Vehicles by Occupancy						
Auto with 1 Person	2,204	66.0	2,440	66.2	+236	+10.7
Auto with 2 Persons	777	23.3	992	26.9	+ 215	+27.7
Auto with 3 Persons	190	5.7	153	4.1	- 37	-19.5
Auto with 4 + Persons	155	4.6	88	2.4	- 67	-43.2
Subtotal Autos	**3,326**	**99.6**	**3,673**	**99.6**	**+347**	**+10.4**
Buses	15	0.4	15	0.4	0	--
Total Vehicles	**3,341**	**100.0**	**3,688**	**100.0**	**+ 347**	**+10.4**
Persons by Vehicle Occupancy						
Auto with 1 Person	2,204	38.9	2,440	42.5	+ 236	+10.7
Auto with 2 Persons	1,554	27.4	1,984	34.6	+430	+27.7
Auto with 3 Persons	570	10.1	459	8.0	-111	-19.5
Auto with 4 + Persons	745	13.1	422	7.3	- 323	-43.4
Subtotal Persons	**5,073**	**89.5**	**5,305**	**92.4**	**+ 232**	**+4.6**
Bus Passengers	596	10.5	434	7.6	- 162	-27.2
Total Persons	**5,669**	**100.0**	**5,739**	**100.0**	**+70**	**+1.2**
Average Persons Per Auto (excluding buses)	1.525		1.444		- 0.081	-5.3

Sources:
(1) Highest hourly volume of person trips (6:15 AM - 7:15 AM).
(2) Austin Tsutsumi & Associates survey; March 17-19, 1987.
(3) Wilbur Smith Associates survey; April 9-11, 1991.

Wilbur Smith Associates; March 1996

Table 2-4

1987 and 1991
MORNING PEAK PERIOD TRAVEL VOLUMES
(6:00 - 8:30 AM)
EWA-BOUND KALANIANAOLE HIGHWAY AT KAWAIHAE STREET
Hawaii Kai Properties EIR

Category	1987 Survey[1]		1991 Survey[2]		Change	
	Number	% of Total	Number	% of Total	Number	Percent
Vehicles by Occupancy						
Auto with 1 Person	4,755	70.0	5,986	72.2	+1,231	+25.9
Auto with 2 Persons	1,471	21.6	1,886	22.8	+ 415	+28.2
Auto with 3 Persons	311	4.6	246	3.0	- 65	-20.9
Auto with 4 + Persons	230	3.4	132	1.6	- 98	-42.6
Subtotal Autos	**6,767**	**99.6**	**8,250**	**99.6**	**+ 1,483**	**+21.9**
Buses	29	0.4	31	0.4	+2	+6.9
Total Vehicles	**6,796**	**100.0**	**8,281**	**100.0**	**+ 1,485**	**+21.8**
Persons by Vehicle Occupancy						
Auto with 1 Person	4,755	44.2	5,986	50.0	+ 1,231	+25.9
Auto with 2 Persons	2,942	27.3	3,771	31.5	+ 829	+28.2
Auto with 3 Persons	933	8.7	739	6.2	- 194	-20.8
Auto with 4 + Persons	1,104	10.2	640	5.3	- 464	-42.0
Subtotal Persons	**9,734**	**90.4**	**11,136**	**92.9**	**+ 1,402**	**+14.4**
Bus Passengers	1,036	9.6	840	7.1	- 196	-18.9
Total Persons	**10,770**	**100.0**	**11,976**	**100.0**	**+ 1,206**	**+11.2**
Average Persons Per Auto (excluding buses)	1.439		1.350		-.089	-6.2

Sources:

[1] Austin Tsutsumi & Associates survey; March 17-19, 1987.
[2] Wilbur Smith Associates survey; April 9-11, 1991.

Wilbur Smith Associates; March 1996

Table 2-5

COMPARISON OF VEHICLES USING HOV LANE
KALANIANAOLE HIGHWAY AT AINAKOA AVENUE
1987, 1990 and 1991
Hawaii Kai Properties Transportation Study

Period/ Vehicle Occupancy	Vehicle Count			Change in Number of Vehicles 1991 vs. 1987
	March 1987 Survey	April 1990 Survey	April 1991 Survey	
Morning Peak Period (6:00 AM - 8:30 AM)				
One Person	31	91	194	+ 163
Two Persons	36	1,155	977	+ 941
Three plus Persons	383	320	407	+ 24
Total	**450**	**1,566**	**1,578**	**+1,128**
Morning Peak Hour (6:45 AM - 7:45 AM)				
One Person	22	28	95	+ 73
Two Persons	26	687	597	+571
Three plus Persons	272	223	289	+ 17
Total	**320**	**938**	**981**	**+661**

Source: Wilbur Smith Associates counts.

Wilbur Smith Associates; March 1996

At Kalaniiki Street, the Honolulu-bound traffic flows show similar peaking characteristics in 1987 and 1991. However, the vehicular volumes are approximately 300 vehicles higher per 15-minute interval in 1991 due to the additional capacity afforded by the increased signal green time and the reduced HOV lane use restrictions.

Source of Traffic Increase at Kawaihae Street

An analysis of the Hawaii Kai development activity, area traffic patterns, and the travel mode surveys between 1987 and 1991 indicates that the increase in morning peak period vehicle traffic resulted from a combination of factors. The largest single factor in the increased volume of traffic was the decision by bus riders and riders in three- or four-person carpools to switch to driving or riding in two-person carpools. The contribution of the different factors to the increased peak hour traffic volume is estimated as follows:

	Additional Vehicle Trips	Percent of Increase
Increased Development in Hawaii Kai	150	10
Change from buses and 3/4-Person Carpools to Lower Occupancy Vehicles	616	42
Increased traffic from Windward Oahu	220	15
Increased Peak Hour Trips from Existing Residents	494	33
Total	1,480	100

Source: Wilbur Smith Associates

Summary of Changes

Overall, the increased capacity and reduced congestion have resulted in increased automobile travel during the peak traffic hours, largely as a result of lowering rates of public transit and carpooling usage in the corridor. The reduced congestion has largely eliminated travel time savings to traffic using the high-occupancy vehicle contraflow lane, and thus has removed a major incentive for peak hour travellers to rideshare.

HAWAII KAI VEHICLE TRIP GENERATION AND DISTRIBUTION

Vehicle travel generated by present Hawaii Kai land uses has been estimated based on standard trip generation factors and observed travel volumes.

Hawaii Kai Trip Generation

At present, an estimated 135,000 vehicle trips begin or end at the various individual land uses within the Hawaii Kai area on a typical weekday. Residential uses account for approximately 54 percent of these trip ends, commercial uses for 37 percent, and public land uses for about 9 percent.

During the morning peak hour, an estimated 8,000 vehicle trips begin or end in Hawaii Kai, which include trips made to, from, or between land uses in Hawaii Kai. Approximately 12,100 trips are made during the afternoon peak hour. The substantially higher afternoon peak hour travel reflects the increased activity at the area's shopping centers and recreational areas relative to the morning period, when the major portion of trips are work- or school-related.

Trip Distribution

During the morning peak hour, the majority of trips generated by Hawaii Kai land uses exit Hawaii Kai and travel ewabound on Kalanianaole Highway. These ewabound trips comprise about 64 percent of the morning peak hour trip ends, with about 6 percent destined to East Honolulu and 58 percent continuing into Honolulu. Four percent of the trips generated by Hawaii Kai travel to Windward Oahu, while the remaining 32 percent travel to destinations within Hawaii Kai.

In the afternoon, a much greater proportion of trips are made within Hawaii Kai. Of the trips attracted by Hawaii Kai land uses, an estimated 50 percent are made from other Hawaii Kai areas. For the remainder, inbound trips from Honolulu approximate 40 percent of traffic to Hawaii Kai land uses, with East Honolulu and Windward Oahu each accounting for 5 percent.

Of those persons who work in Hawaii Kai, the large majority also reside in Hawaii Kai. Based on a traffic survey at the commercial uses along Keahole Street during the morning peak period, an estimated 70 percent of the arriving traffic is from within Hawaii Kai.[5]

WEEKDAY TRAFFIC VOLUMES

Within Hawaii Kai, the highest traffic volumes occur on those streets which provide access to Kalanianaole Highway, with the very highest volumes occurring on Keahole Street and on Lunalilo Home Road, since these roadways also serve the major commercial areas within Hawaii Kai. Based on recent State DOT and City DTS counts, weekday traffic volumes approximate 22,500 vehicles on Keahole Street, 16,000 vehicles on Lunalilo Home Road, and 10,000 vehicles on Hawaii Kai Drive. Daily traffic volumes on the other major Hawaii Kai streets generally range between 5,000 and 15,000 vehicles.

Traffic volumes on Kalanianaole Highway are lowest in the eastern section of Hawaii Kai, with the traffic volumes increasing westward through East Honolulu as traffic to/from more communities is added to the roadway. Weekday traffic volumes on Kalanianaole Highway increase from about 11,000 vehicles near Kealahou Street, to 49,000 near Kawaihae Street, to 83,000 near Kalaniiki Street.

Hawaii Kai Peak Hour Traffic Volumes

During the morning peak traffic period, there is a very prominent pattern of traffic flowing from the valley and ridge residential areas towards Kalanianaole Highway and towards the commercial areas

(5) Source: Wilbur Smith Associates traffic survey, October 5, 1994.

along Keahole Street and Lunalilo Home Road. The morning peak hour directional traffic volumes on the major street system are depicted in Figure 2-5.

Most traffic from the eastern area uses Hawaii Kai Drive to travel westbound, rather than using Kalanianaole Highway. Makai-bound traffic volumes increase on Lunalilo Home Road until Wailua Street. At Wailua Street, about 45 percent continue makai on Lunalilo Home Road with the majority turning onto Wailua Street to use Hawaii Kai Drive/Keahole Street. This split is in part a function of the traffic volumes bound to commercial areas and public facilities along Lunalilo Home Road versus Keahole Street areas, and in part reflects an "evening out" of the volume of traffic turning right onto Kalanianaole Highway from Lunalilo Home Road (1,180 vehicles), Keahole Street (760 vehicles), and Hawaii Kai Drive (840 vehicles). Since completion of the Kalanianaole Highway widening project, the volume of right-turn traffic appears to have increased on Lunalilo Home Road and Hawaii Kai Drive, and declined on Keahole Street. Kawaihae and Kealahou Streets accommodate only 290 and 60 right-turns, respectively, onto Kalanianaole Highway.

In the afternoon peak traffic period, these traffic flows are largely the reverse of the morning pattern. As shown in Figure 2-6, the peak directional volumes in the afternoon peak hour occur from the makai areas (Kalanianaole Highway and the commercial areas) towards the valley and ridge residential areas. As compared to the morning, the afternoon directional split is less pronounced with lower peak direction volumes and higher off-peak direction volumes. The afternoon peak hour also varies from the morning peak hour in that the peak direction movement from Kalanianaole Highway to Keahole Street (1,100 vehicles) is almost double the left-turn movements onto Lunalilo Home Road (540 vehicles) and Hawaii Kai Drive (460 vehicles).

Kalanianaole Highway Peak Hour Traffic Volumes

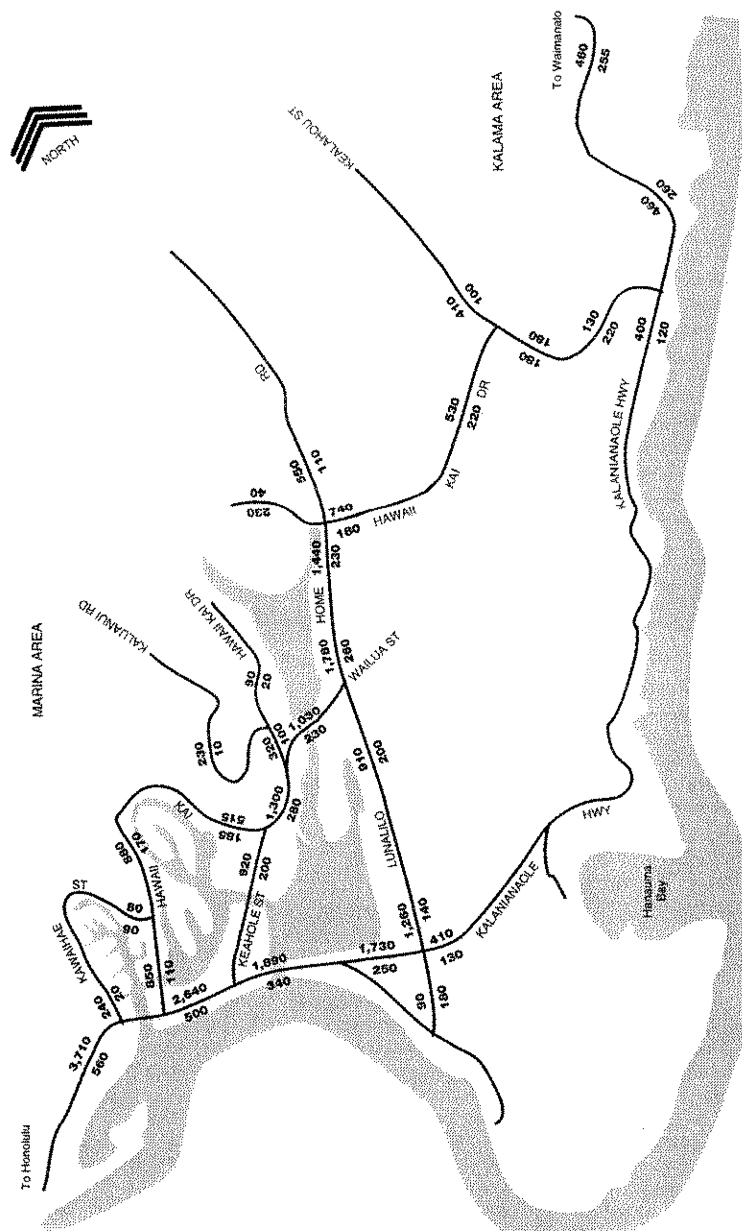
Morning and afternoon peak hour traffic volumes along Kalanianaole Highway and on the major cross streets are depicted in Figure 2-7. The Honolulu-bound morning volumes include the traffic using the contraflow HOV lane from West Halemaumau Street to the H-1 Freeway. Peak hour volume in the contraflow HOV lane occurs near the H-1 Freeway with 1,135 vehicles.

During the morning peak hour, the Honolulu-bound direction traffic increases from 400 vehicles at Lunalilo Home Road, to some 5,600 vehicles near the H-1 Freeway. The largest increases occur at the major Hawaii Kai roadways, since the Hawaii Kai community represents about 60 percent of the East Honolulu population. Outside Hawaii Kai, the largest increases occur at West Hind Drive and at Laukahi Street.

Morning traffic volumes outbound towards Hawaii Kai have increased in recent years due to the new commercial development in Hawaii Kai. However, these eastbound volumes generally amount to only 20 to 30 percent of the peak direction volumes.

Traffic patterns in the afternoon peak hour are the reverse of the morning traffic flows. However, the afternoon peak hour volumes in the peak travel direction are significantly lower than the corresponding morning volumes, while those in the off-peak direction are higher than the morning off-peak direction volumes.

HAWAII KAI PROPERTIES TRAFFIC IMPACT STUDY



WILBUR SMITH ASSOCIATES

Figure 2-5
EXISTING WEEKDAY MORNING PEAK HOUR TRAFFIC - HAWAII KAI ROADWAYS

HWKAI-HWDETAIL-7/7/96C

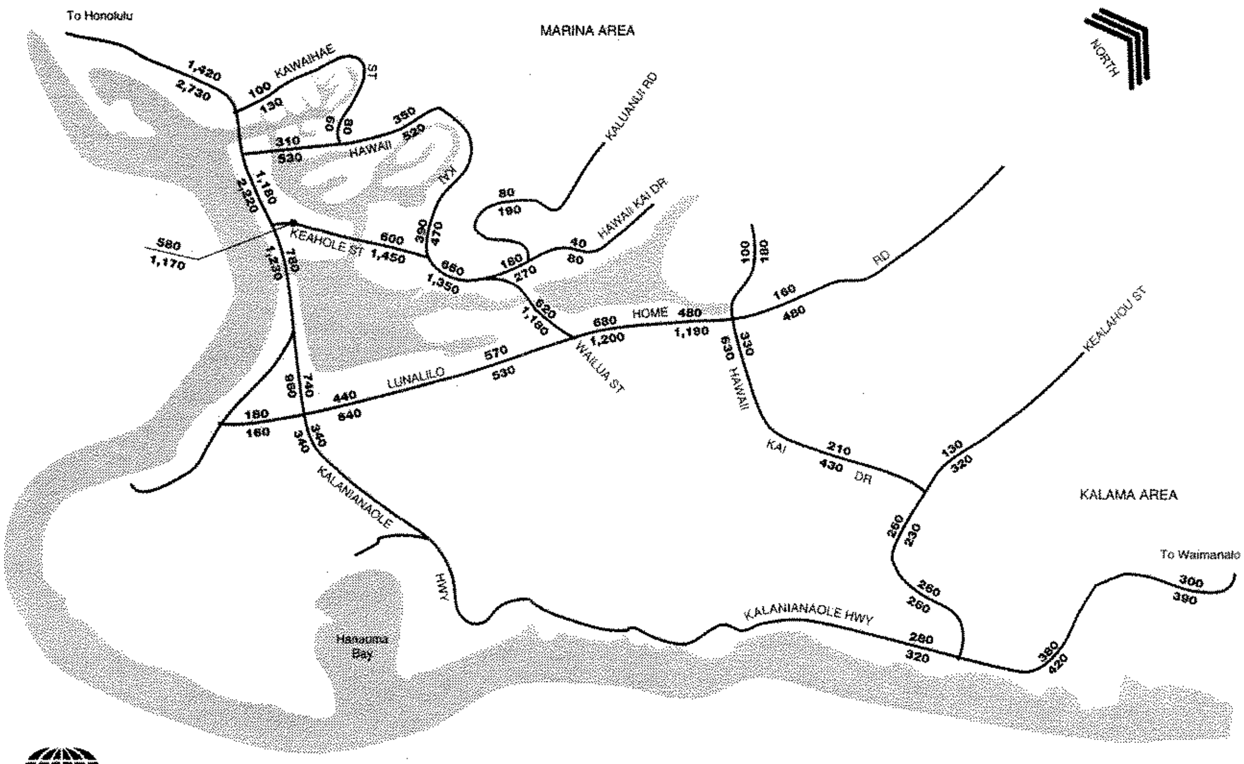


Figure 2-6

EXISTING WEEKDAY AFTERNOON PEAK HOUR TRAFFIC - HAWAII KAI ROADWAYS

WSA WILBUR SMITH ASSOCIATES

DETAIL-7/7/96C

HAWAII KAI PROPERTIES TRAFFIC IMPACT STUDY

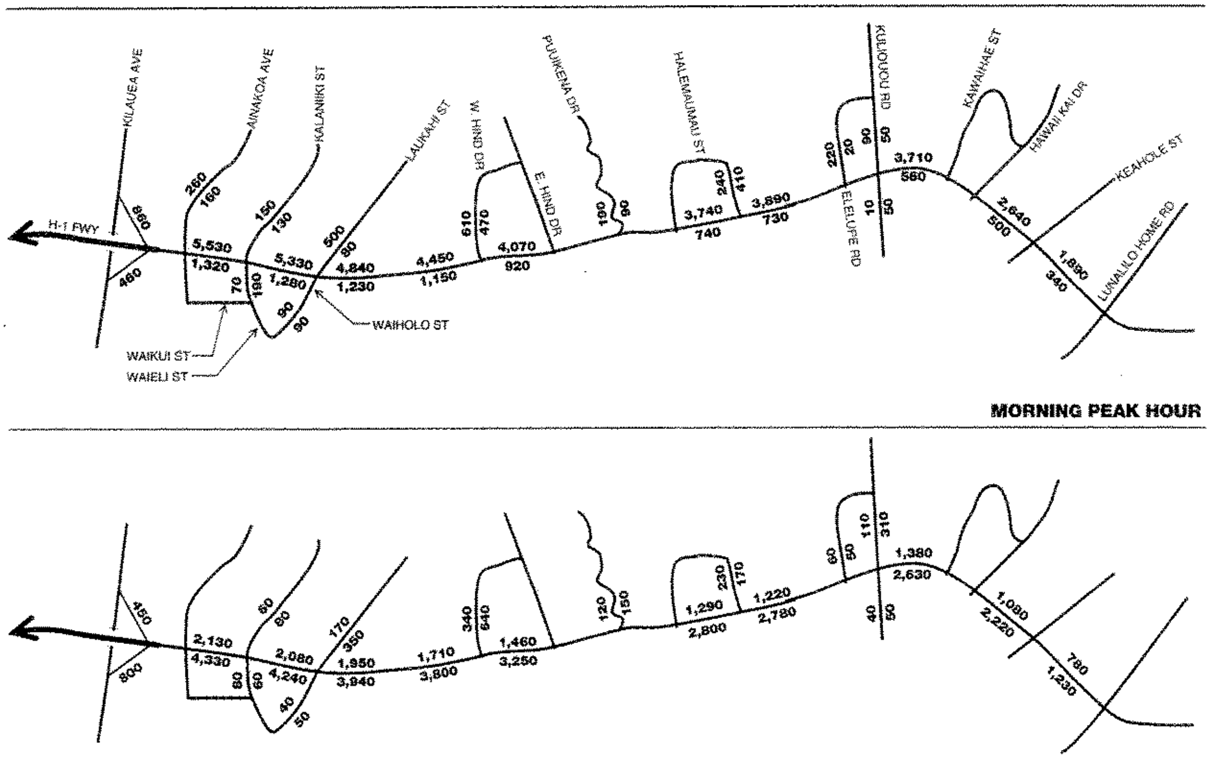


Figure 2-7

EXISTING WEEKDAY PEAK HOUR TRAFFIC - KALANIANAOLE HIGHWAY

WSA WILBUR SMITH ASSOCIATES

HWIKALHWYPEAKHR-4/15/96C

WEEKDAY CONDITIONS AT KEY INTERSECTIONS

Traffic conditions were analyzed at key intersections within Hawaii Kai and along Kalanianaole Highway for the weekday morning and afternoon peak hours. Within Hawaii Kai, the key locations include all intersections between the major roadways, including those with Kalanianaole Highway. Four intersections were analyzed along Kalanianaole Highway outside of Hawaii Kai:

- The West Hind Drive and Laukahi Street intersections, since these have the highest cross street volumes;
- The Kalaniiki Street intersection, since it accommodates the highest through traffic volume in the morning; and
- The East Halemaumau Street, since it represents the highest volume intersection in the Niu Valley-Kuliouou area.

The results of the intersection analyses are summarized in Table 2-6.

Methodology of Evaluating Intersection Conditions

The general methodology for the analyses of signal-controlled intersections is described on page 2-2. The procedure utilizes features specific to each intersection to calculate the theoretical "capacity" of the intersection, and then compares the traffic volumes to the "capacity" to determine a "volume-to-capacity ratio," or what proportion of the capacity is being used by the existing volumes.

These "capacities" and the traffic signal phasing/timing characteristics are then used to estimate average delay times per vehicle for the traffic in each lane group (such as left, through, and right-turn movements), each approach, and the overall intersection. These average delay times, not the volume-to-capacity ratio, are used to identify the intersection "level of service."

The average delay times, and thus the LOS, are highly dependent upon the length of the signal cycle, and the proportion of the traffic on the major through street versus the side street. Thus, it is possible to have intersections with high volume-to-capacity ratios (near 1.00 or 100 percent of capacity being used), but having good to fair service levels (A through D), where the signal time is efficiently allocated, with most allocated to the major movements. Conversely, an intersection can have a comparatively low volume-to-capacity ratio and a fair to poor service level (D through F) due to inefficient allocation of signal timing, use of complex signal phasing, use of long cycle lengths, or other factors. Therefore, for the "Operations" method of analyzing signalized intersections, the level of service does not always directly correspond to the volume-to-capacity ratio.

The specific features used to analyze each intersection include the number and width of lanes, the proportion of trucks and buses, pedestrian crossings, roadway grades, effect of bus stops and parking, and signal timing features. The proportions of through, left-turn, and right-turn traffic on each approach also affect intersection conditions. For existing conditions, all of these factors are identified through field reconnaissance and traffic counts.

In addition to these physical and traffic features that usually vary for each intersection, the intersection analyses also use certain default, or pre-set, factors that represent average conditions

WILBUR SMITH ASSOCIATES

Table 2-6
(Page 1 of 2)

EXISTING INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties Transportation Study

Intersection	AM Peak Hour			PM Peak Hour		
	V/C[1]	AD[2]	LOS	V/C[1]	AD[2]	LOS
1 Kalanianaole Highway/Kalaniiki Street	0.802	9.0	B	0.879	9.3	B
2 Kalanianaole Highway/Laukahi Street	0.772	14.6	B	0.839	11.8	B
3 Kalanianaole Highway/West Hind Street	0.767	13.8	B	0.687	6.3	B
4 Kalanianaole Highway/East Halemaumau Street	0.818	14.1	B	0.638	5.9	B
5 Kalanianaole Highway/Kawaihae Street	0.792	7.1	B	0.578	4.7	A
6 Kalanianaole Highway/Hawaii Kai Drive	0.818	20.1	C	0.495	9.2	B
7 Kalanianaole Highway/Keahole Street	0.806	27.9	D	0.630	15.8	C
8 Kalanianaole Highway/Lunalilo Home Road	0.453	13.3	B	0.618	20.3	C
9 Kalanianaole Highway/Kealahou Street[3]						
Southbound Left-Turn	--	10.2	C	--	10.6	C
Southbound Right-Turn	--	4.2	A	--	4.2	A
Eastbound Left-Turn	--	3.5	A	--	3.5	A
10 Kawaihae Street/Hawaii Kai Drive[3]						
Westbound Left/Through/Right-Turn	--	9.4	B	--	8.1	B
Eastbound Left/Through/Right-Turn	--	15.8	C	--	13.0	C
Northbound Left-Turn	--	6.3	B	--	3.3	A
Southbound Left-Turn	--	2.4	A	--	3.8	A
11 Hawaii Kai Drive/Keahole Street	0.378	10.4	B	0.562	13.0	B

WILBUR SMITH ASSOCIATES

Table 2-6
(Page 2 of 2)

EXISTING INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties Transportation Study

Intersection	AM Peak Hour			PM Peak Hour		
	V/C(1)	AD(2)	LOS	V/C(1)	AD(2)	LOS
12 Wailua Street/Hawaii Kai Drive	0.472	6.7	B	0.852	18.1	C
13 Hawaii Kai Drive/Kaluanui Road						
Westbound Left-Turn	--	4.7	A	--	5.4	B
Eastbound Left-Turn	--	3.7	A	--	3.0	A
Northbound Left-Turn	--	2.3	A	--	2.5	A
14 Wailua Street/Lunalilo Home Road	0.634	3.9	A	0.650	8.0	B
15 Hawaii Kai Drive/Lunalilo Home Road	0.741	18.7	C	0.619	7.3	B
16 Hawaii Kai Drive/Kealahou Street(4)	--	5.6	B	--	8.8	B

Notes:

(1) Values in this column represent volume-to-capacity (V/C) ratios for signalized intersections.
(2) AD = Average delay per vehicle, in seconds.
(3) Two-way STOP sign controls.
(4) All approaches controlled by STOP signs.
LOS = Level-of-Service.

Wilbur Smith Associates; March 1996

for all intersections. These average "default" values are used unless special field surveys are made to determine the actual values for a specific location. For this study, field measurements and adjustments were made for two of these "default" values:

1. **Saturation Flow** - The saturation flow rate is the maximum number of vehicles per lane that can pass through an intersection in a given lane group (e.g. through lanes or turn lanes) if given one hour continuous (non stop) green time. The default value is 1,900 vehicles per lane, which is then adjusted to reflect lane widths, traffic composition, and signal timing.

2. **Lane Utilization Factor** - This factor applies where a traffic movement is provided more than one lane to reflect that traffic typically does not distribute evenly among the lanes available for a movement. For a two-lane movement, the default value is the heavier-used lane will have 5 percent higher volumes than the average for the two lanes (factor of 1.05). For three or more lanes, the default value is that the heaviest-used lane will accommodate 10 percent higher volumes than the average of the lanes (factor of 1.10).

   The distribution of traffic among lanes will vary based on turns and features upstream and downstream from the intersection. Typically, the traffic will tend to spread evenly across the lanes as the volume approaches capacity, and a lane utilization factor of 1.00 may be used with volumes nearing, at, or over capacity.

Because of the high volumes of traffic and expressway-like conditions along Kalanianaole Highway near its ewa terminus at the H-1 Freeway, field measurements were made for both saturation flow and lane utilization factors. The surveys were made for the through lanes of Kalanianaole Highway at the Kalaniiki Street intersection in both the morning and evening peak traffic hours. The survey results were as follows:

- Saturation flow rate averaged almost 2,100 vehicles per hour of green time in the morning peak hour, and over 2,030 in the afternoon peak hour. The statistical level of accuracy is plus or minus 50 vehicles. These higher saturation flow rates imply that the East Honolulu commute driver is a more aggressive and alert driver (shorter gaps between cars) than the average driver reflected in the default value of 1,900.

- The lane utilization factor was 1.03 and 1.06 for the peak direction through lanes on Kalanianaole Highway in the morning and afternoon peak hours, respectively.

These survey results were used to adjust the default values for the Kalaniiki Street and nearby Laukahi Street intersections. The values used in the analyses of traffic conditions at the two intersections were as follows:

- Saturation flow rates of 2,050 and 2,000 vehicles were used for the through lanes on Kalanianaole Highway in the morning and afternoon peak hours, respectively. These values reflect the observed flow rates rounded downward to reflect the accuracy of the survey (± 50 vehicles).

- The lane utilization factors of 1.03 and 1.06 were used for the peak direction through lanes in the morning and afternoon periods, respectively.

Morning Conditions at Hawaii Kai Intersections

The roadways within Hawaii Kai operate at acceptable service levels with the morning peak hour traffic flows. Most intersections operate at very good service levels— LOS A to LOS C—with present traffic volumes utilizing 80 percent or less of the theoretical capacity of the intersection.

In the morning peak hour, traffic volumes at the intersection of Hawaii Kai Drive and Lunalilo Home Road utilize the highest proportion of the available capacity (74 percent) of those intersections within Hawaii Kai. The level-of-service (LOS C) indicates that average delay times are within the acceptable range. The key factor increasing the volume-to-capacity level is the very large volume of vehicles (about 700 in the peak hour) turning left from Hawaii Kai Drive onto makai-bound Lunalilo Home Road from a single lane for left-turning vehicles.

At the Lunalilo Home Road intersection with Wailua Street, the analyses indicate that the overall intersection is operating at a very satisfactory level. The makai-bound right-turn onto Wailua Street operates at about two-thirds of its potential capacity, due to the 960 vehicles turning right in the morning peak hour.

A similar situation occurs at the Lunalilo Home Road intersection with Kalanianaole Highway. There, the makai-bound right-turn towards Honolulu (1,180 vehicles) utilizes about two-thirds of the capacity of the present single free-flow right-turn lane.

The intersections of the Hawaii Kai streets with Kalanianaole Highway all operate at acceptable levels. The Keahole Street intersection experiences the longest average delay times (LOS D). Traffic volumes at the Keahole Street intersection, as well as the Hawaii Kai Drive and Kawaihae Street intersections, utilize approximately 80 percent of the existing capacity of these intersections. The average delay time remains at very acceptable levels (LOS B) for Kawaihae Street, since there are proportionately much lower traffic volumes that must wait through the long signal cycle on Kawaihae Street, relative to the volume of vehicles on Kalanianaole Highway which receive most of the green time and experience little or no delays.

Morning Conditions at East Honolulu Intersections

The key Kalanianaole Highway intersections west of Hawaii Kai operate at very acceptable service levels (LOS B or C) during the morning peak hour, although traffic volumes at several locations utilize a high proportion of the theoretical capacity of the intersections. This results from the heavy volume of through traffic along Kalanianaole Highway being allocated a large majority of the signal green time and thus experiencing little or no delays at the traffic signals (LOS A or B). The comparatively smaller traffic volumes on the cross streets are allocated a much smaller portion of the signal green time and at several locations, experience long delay times and poor service levels (LOS E or F). However, the average overall delay time (LOS B) remains short, since the large majority of the traffic through the intersection experiences little delay.

At the East Halemaumau Street intersections, with the reversed third Honolulu-bound lane, the peak direction traffic along Kalanianaole Highway operates at LOS A. However, each of the turning

movements into or out of East Halemaumau Street experiences delays equivalent to LOS E or F. The very good service level afforded traffic along Kalanianaole Highway, combined with the poor service levels for East Halemaumau Street traffic, result in an overall intersection service level of B. The present traffic utilizes about 82 percent of the overall intersection capacity, since the contraflow HOV lane does not begin until the Ewa side of the intersection.

West Hind Drive serves as the access point for most Aina Haina area traffic to/from the central Honolulu area and thus accommodates a large volume of traffic turning right onto or left from Kalanianaole Highway. West Hind Drive is restricted to right-turns at this T-intersection, which simplifies the traffic signal operation since this movement can be permitted at the same time as the left-turn from Kalanianaole Highway. With this simple signal operation and the double turn lanes to/from West Hind Drive, the morning traffic utilizes only 77 percent of the available capacity.

At the Laukahi/Waiholo Street intersection, the large volume of Waialae Iki vehicles turning right onto Kalanianaole Highway, combined with the left-turns from Waiholo Street, require a significant amount of green signal time. Although the overall intersection operates at acceptable levels (LOS B), the traffic exiting Laukahi Street experiences long delays (LOS F). The present traffic approximates 77 percent of the intersection capacity.

The Kalaniiki-Waieli Streets intersection, located adjacent to Kalani High School, is the critical location controlling traffic flow along Kalanianaole Highway during the morning peak traffic period. As the Ewa-most signal in the morning, this intersection accommodates the highest through volumes on Kalanianaole Highway as well as serving traffic accessing the school. A majority of the school's students arrive from the west and must cross the town-bound traffic flow to reach the school. Since left-turns are prohibited from the Kokohead-direction lanes during the contraflow lane operation in the morning, the parent or student vehicles use Waieli Street, either by turning into Waikui or Waieli Streets to cross Kalanianaole Highway, or by dropping off the students on Waieli Street and then exiting onto Kalanianaole Highway. The traffic exiting Kalaniiki and Waieli Streets experience long delays (LOS F). However, the overall intersection averages LOS B since the through traffic along Kalanianaole Highway operates at LOS A (eastbound) and LOS B (westbound). Existing traffic volumes use 80 percent of the intersection capacity.

The critical movements at each of the key intersections controlled by STOP signs operate at LOS C or better in the morning peak hour.

Afternoon Conditions at Hawaii Kai Intersections - In the afternoon peak traffic hour, the major roadways and intersections in Hawaii Kai generally function at service levels equal to or better than morning conditions at those locations. This is largely due to lower peak directional volumes in the afternoon, although the combined two-way traffic approximates or exceeds the morning two-way traffic. The peak direction traffic (east or mauka-bound) is spread over a longer time period with a lower peak volume, as compared to the morning peak direction volumes (west or makai-bound).

The signalized intersections on the interior roadways within Hawaii Kai operate at LOS B or C in the afternoon peak hour, with peak hour traffic using less than 65 percent of the theoretical capacity at most locations. The highest capacity utilization occurs at the Hawaii Kai Drive-Wailua Street intersection, where the large volume of right-turn traffic onto Wailua Street (1,107) results in a volume-to-capacity ratio of 0.85 in the afternoon peak hour.

The traffic signal-controlled intersections along Kalanianaole Highway in the Marina section of Hawaii Kai also accommodate the afternoon traffic volumes at acceptable service levels. The Kawaihae Street, Hawaii Kai Drive, and Keahole Street intersections each operate at lower levels of capacity utilization and with shorter average delay times than in the morning. At the Lunalilo Home Road intersections, the delay times and volume-to-capacity ratio both increase from the morning levels, but remain at acceptable conditions. The afternoon increase results from the increase in the Kokohead direction left-turn volume.

Conditions at the key STOP sign controlled intersections are at LOS C or better in the afternoon peak hour.

Afternoon Conditions at East Honolulu Intersections - Afternoon traffic conditions at the key Kalanianaole Highway intersections are generally better than morning conditions, with similar to shorter average delay times at the four analyzed intersections and lower levels of capacity utilization at several locations. The shorter delay times, equivalent to LOS B at all four of the study intersections, result from the shorter signal cycle length in the afternoon and fewer vehicles entering/exiting the cross streets at most of the intersections.

Existing traffic volumes at both the Kalaniiki and Laukahi Street intersections use a higher proportion of the capacity than during the morning peak hour. The afternoon volume-to-capacity ratios are 0.879 for the Kalaniiki Street intersection, and 0.839 for Laukahi Street. The higher volume-to-capacity ratios in the afternoon reflect the absence of the additional contraflow lane and the slightly less capacity-efficient shorter cycle lengths in afternoon, as well as the lower saturation flow rate and higher lane utilization rates in the afternoon.

SUNDAY PEAK HOUR TRAFFIC AT KEY INTERSECTIONS

For the two-lane section of Kalanianaole Highway in the Hawaii Kai area, the highest traffic volumes occur during Sunday afternoons. This results from the active recreational attractions at Hanauma Bay and Sandy Beach, as well as sightseer traffic through the area. Conversely, this section of roadway is little used by work trips during weekday commute periods.

Existing Traffic Volumes

On Sunday, February 4, 1996, Wilbur Smith Associates conducted traffic counts at the key intersections and driveways along this section. The peak one-hour periods occurred in early afternoon (12:45 - 1:45 PM) as visitors arrived, and in later afternoon as many visitors began to exit the area. The traffic movements at these intersections are depicted in Figure 2-8. No counts are shown for the Hanauma Bay driveway in the early afternoon period since the parking area was full and entrance closed at the beginning of the survey period.

The early afternoon period recorded the highest volumes, with traffic near Lunalilo Home Road approximately 90 percent greater than the weekday peak hour, and 3 percent greater than the Sunday late afternoon peak hour.

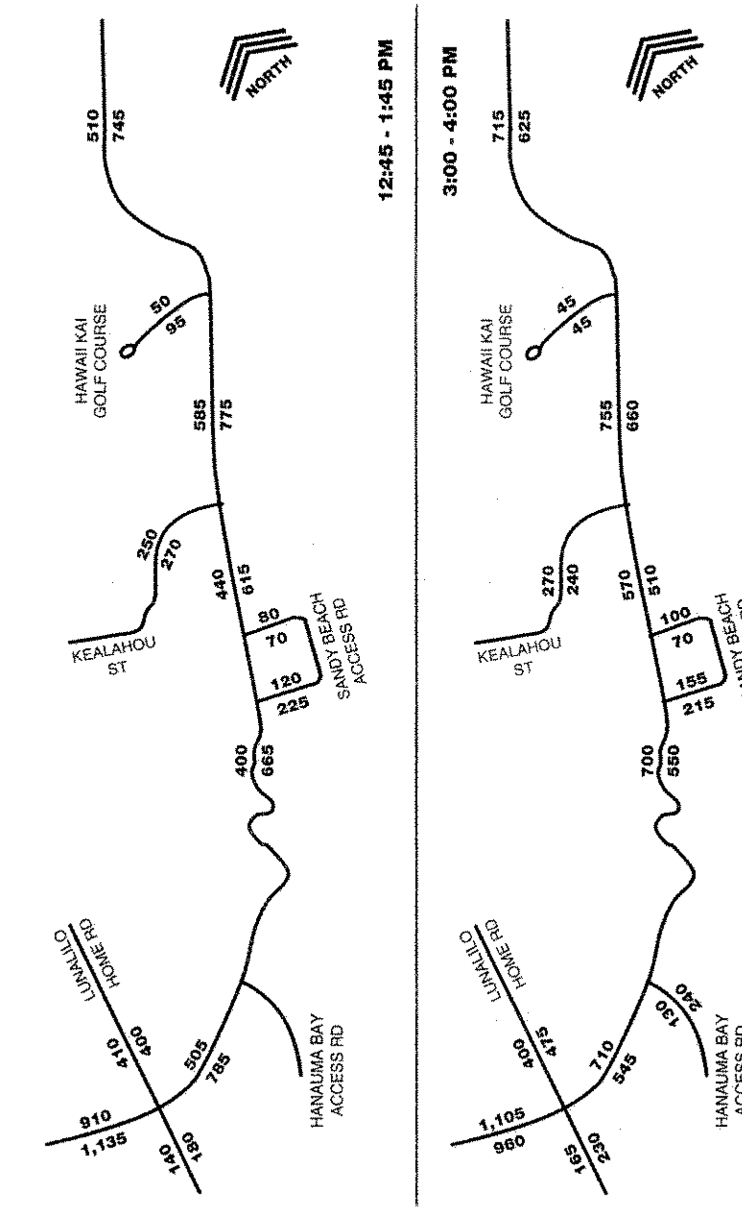


Figure 2-8
EXISTING SUNDAY PEAK HOUR TRAFFIC
SUNDAY-4/8/96C

WILBUR SMITH ASSOCIATES

Intersection Traffic Conditions

Traffic conditions at the signal-controlled intersection of Kalanianaole Highway and Lunalilo Home Road were at acceptable levels during both Sunday periods. During the early afternoon, the intersection operated at LOS B and a volume-to-capacity ratio of V/C 0.63; during the later Sunday period, it operated at LOS C, with traffic using about 85 percent of the intersection capacity.

The STOP sign-controlled intersection at Kealahou Street operated at unacceptable levels, with the left-turn movement from Kealahou Street experiencing LOS F conditions during both the early and late afternoon peak hours. The left-turn movement from the Hanauma Bay driveway also experiences LOS F conditions during the late afternoon period. The Sandy Beach West Driveway traffic experience LOS C and LOS D conditions during the early and late afternoon periods, respectively.

KALANIANAOLE HIGHWAY TWO-LANE SEGMENT SERVICE LEVELS

The two-lane section of Kalanianaole Highway includes several segments with steep grades and restrictive horizontal and vertical curves. Conditions were analyzed for traffic through the most restrictive segments, which were the long hill section between Lunalilo Home Road and Hanauma Bay, the winding segment between the Hanauma Bay and Sandy Beach areas (Blowhole segment), and the uphill segment at Makapuu Point.

The analysis indicates the following average service levels for traffic through these segments:

Segment	Level-of-Service	
	Weekday PM Peak Hour	Sunday 12:45 - 1:45 PM
Hanauma Bay Hill	C	E
Blowhole Segment	D	E
Makapuu Point	D	E

The levels of service are primarily indicators of travel speeds through these segments. The LOS E conditions in the Sunday afternoon period indicates that vehicles are more likely to be delayed by slower moving vehicles with little opportunity to pass. Existing traffic volumes in the weekday peak hour use 33 to 37 percent of the roadway capacity, while traffic volumes in the Sunday peak hour use between 59 and 63 percent of the capacity of these roadway segments.

3. YEAR 2017 TRAVEL CONDITIONS WITHOUT THE PROJECT

Both the approved developments within Hawaii Kai and the proposed developments included in the Master Plan (the *Project*) could be completed by Year 2017. Therefore, the analysis of future conditions reflects forecast travel for 2017.

The travel forecasts and conditions without the proposed *Project* developments are presented for 2017 as a baseline from which to identify the incremental effects of the *Project*. The forecasts without the *Project* include travel increases from both Hawaii Kai and the surrounding areas.

The travel forecasts and conditions presented in this chapter reflect only those planned transportation system modifications that could readily be implemented during the next five years or so, such as the planned improvements at the intersection of Kalanianaole Highway and Kealahou Street, and the potential extension of the morning contraflow lane operation from Niu Valley to Hawaii Kai. Conditions with those other planned transportation programs that may require an extended period for implementation, or may not be implemented until well in the future, are discussed in Chapter 5.

ASSUMPTIONS AND METHODOLOGY

Future travel without the *Project* was forecast by increasing existing travel volumes to reflect those previously approved projects in Hawaii Kai, development of other projects in the East Honolulu area, and the continued travel increases to/from existing uses. The forecasts represent the peak commute hour conditions on a typical weekday, except where Sunday conditions are noted.

Hawaii Kai Developments

A number of developments have received City approvals for development, but had not yet been constructed and/or occupied at the time of the 1996 traffic counts. These included several projects that have been completed but have not yet been fully occupied, such as Kalele Kai, or have not been fully constructed, such as the Towne Center office and retail project. The developments included in the *Without Project* baseline scenario are as follows:

Project	Size of Remaining Development
Residential	
Kalele Kai	▸ 8 unoccupied townhouses ▸ 80 unoccupied mid-rise condominium units
Peninsula	▸ 276 low-rise residential units ▸ 354 mid-rise residential units
Kaalakei 1-A	▸ 252 units of retirement apartments ▸ 120-bed nursing care facility

Project	Size of Remaining Development
Kaluanui 1	▸ 194 townhouses ▸ 96 low-rise condominium units
Kaluanui 2 & 3	▸ 325 mid-rise condominium units
Kamilo Estates	▸ 7 single family houses
Kamehame Ridge	▸ 155 single family houses
Commercial	
Executive Plaza	▸ 42,200 sq. ft. of offices
Towne Center	▸ 8,240 sq. ft. of retail area
Kalama Village	▸ 17,140 sq. ft. of retail area

Traffic estimates were prepared for each of these approved developments for incorporation into the *Without Project* travel forecasts. The methodology and assumptions used in the forecasts include:

- Vehicle trip generation rates for most of the developments are based on standard industry rates,[1] as compiled by the Institute of Transportation Engineers (ITE). The trip generation rates are listed in Table 3-1.
- The distribution of trips within and outside of Hawaii Kai are based on the existing trip patterns, as summarized in Chapter 2. Some 70 percent of the new employment at the office and retail developments is assumed to be filled by Hawaii Kai residents based upon the traffic counts at the existing Hawaii Kai Shopping Center, Towne Center, and Executive Plaza driveways.
- The time of travel and travel mode characteristics are assumed to remain similar to existing conditions for Hawaii Kai.

Other New East Honolulu Developments

The City and County of Honolulu Planning Department estimates that approximately 605 additional residential units could be developed within the East Honolulu area, exclusive of the Hawaii Kai area.[2] The anticipated locations of these new residential units are:

- 232 in the Waialae Iki area;
- 28 in the Aina Haina area;
- 229 in the Hawaii Loa Ridge area;
- 51 in Niu Valley; and
- 65 in the Kuliouou area.

(1) *Trip Generation, Fifth Edition*, Institute of Transportation Engineers, 1991.

(2) Telephone discussion with Mr. Fred Saiki of the Planning Department, February 9, 1996.

WILBUR SMITH ASSOCIATES

Table 3-1

VEHICLE TRIP GENERATION RATES FOR WITHOUT PROJECT USES
Hawaii Kai Properties EIR

Land Use	Rate Basis	Morning Peak Hour		Afternoon Peak Hour		Daily to/from Use
		To*	From*	To*	From*	
Residential						
Single Family	Dwellings	0.19	0.55	0.65	0.36	9.55
Townhouses	Dwellings	0.07	0.37	0.36	0.19	5.86
Low Rise Condos	Dwellings	0.07	0.37	0.36	0.19	5.86
Mid Rise Condos	Dwellings	0.06	0.28	0.23	0.14	4.18
Retirement Village	Apartments	0.08	0.09	0.14	0.11	2.42
Nursing Facility	Beds	0.15	0.09	0.05	0.07	2.62
Commercial						
Office	KSF	1.83	0.25	0.31	1.76	15.50
Community Retail Center	KSF	0.76	0.44	2.52	2.51	53.60
Convenience Retail	KSF	1.76	1.04	5.28	5.28	115.85

Source: *Trip Generation, Fifth Edition*, Institute of Transportation Engineers, 1991.
* To/from each individual development
KSF Per one-thousand square feet of floor area.

Wilbur Smith Associates; March 1996

294022

There is no time constraint on this development, but the increases are likely to occur within a 20-year time horizon.

For this study, it is assumed that all of these additional East Honolulu housing units would be developed by 2017. The following methodology was used for the travel forecasts:

- All of the units in each area are completed by 2017;
- Vehicle trip generation is based on ITE trip rates as listed in Table 3-1; and
- The distribution of trips towards Honolulu or Hawaii Kai was initially based on present vehicle turning movement patterns in each area. This initial distribution was modified where appropriate to reflect increased trips to/from the new office and retail uses in Hawaii Kai, i.e. to match the distribution of new trips to/from the new Hawaii Kai land uses.

Area Traffic Growth Factor

An areawide growth factor was applied to existing traffic volumes to reflect increased travel to/from existing land uses in the East Honolulu/Hawaii Kai area, as well as an increase in through traffic.

Based on forecast information from the Oahu Regional Transportation Plan Study,[3] daily traffic volumes at the ewa end of Kalanianaole Highway (Kapakahi screenline) are estimated to increase by approximately 24 percent between 1990 and 2020. This is equivalent to an average annual rate of increase of 0.70 percent.

During this time interval, the population in East Honolulu is projected to increase by 11 percent. Thus, the population increase alone could account for almost one-half of the total increase, with the remainder due to increased employment (28 percent) and increased trip making.

For the purpose of this study, it was assumed that the increased trip making (background growth) would account for about one-half of the annual rate of increase, or about 0.35 percent per year. This rate of growth would amount to a total 7.6 percent increase between 1996 and 2017. To account for background growth through 2017, the existing (1996) traffic volumes are increased by this 7.6 percent amount.

TRANSPORTATION SYSTEM IMPROVEMENTS

The recently completed widening of Kalanianaole Highway between Niu Valley and Hawaii Kai was the major transportation improvement planned for the East Honolulu corridor. This roadway project extended the six-lane, divided highway cross section eastward to Hawaii Kai Drive. Within Hawaii Kai, the project also provided a left-turn lane for eastbound traffic turning onto Kawaihae Street (left-turns were previously prohibited), double (two) left-turn lanes for eastbound traffic

[3] *Oahu Regional Transportation Plan*, prepared for Oahu Metropolitan Planning Organization (OMPO), by Kaku Associates, November 1995.

turning onto Hawaii Kai Drive, and restriped Keahole Street and Hawaii Kai Drive approaches to add a third makai-bound lane on each street at Kalanianaole Highway. The traffic volumes and analyses described in Chapter 2, "Existing Conditions," reflect these capacity improvements, as do the analyses of future conditions.

State and City transportation improvement plans include a number of projects and programs that would likely affect travel in this corridor. Some of these can be implemented over the near term, while many may require a longer period for implementation. This "baseline" analysis of 2017 travel conditions includes only those actions that could be readily implemented over the next five years or so. These include:

1. Intersection improvements on Kalanianaole Highway at Kealahou Street; and
2. Extension of the morning contraflow lane to Hawaii Kai.

Other planned improvements, which may require a longer implementation period, are identified in the following paragraphs. However, the analyses of travel conditions with these longer-range improvements are discussed in Chapter 5, both without and with the Hawaii Kai development project.

Roadway Modifications

Improvements are planned for the intersection of Kalanianaole Highway and Kealahou Street in the eastern section of the Hawaii Kai area. The State DOT plans to install traffic signal controls at this intersection, and construct a storage lane for vehicles turning left from Kalanianaole Highway into Kealahou Street. Construction on this project should start in 1996. These improvements are reflected in the analysis of year 2017 conditions.

The *Oahu Regional Transportation Plan*[4] also identifies a widening project along ewabound Kalanianaole Highway between Laukahi Street and the Kilauea Avenue off-ramp. The OMPO plans include this State DOT project for the time period between 2006 and 2020. It is likely that implementation of this widening project would not occur until traffic conditions substantially worsen along Kalanianaole Highway. Therefore, this planned roadway widening is not included in the baseline analysis. However, the effects of this project are evaluated in Chapter 5.

No major roadway modifications are included within Hawaii Kai. Several development projects, such as the Kaluanui 2/3 and Peninsula developments, are likely to restripe the adjacent street sections to provide left-turn storage lanes for traffic entering the project driveways.

Public Transit and Travel Demand Management (TDM)

The *Oahu Regional Transportation Plan* includes Public Transit and Travel Demand Management (TDM) plan elements that identify actions to reduce the vehicular demands placed on the

[4] Op. cit., Table 3-1.

transportation system, particularly during the peak commute traffic periods. The Transit Element[5] includes development of a rapid transit system, and the restructuring and expansion of TheBus routes. The TDM Element[6] includes measures and strategies such as expanded system of high occupancy vehicle (HOV) lanes, rideshare programs, parking management actions, and work hour changes (flex time).

A major expansion of transit services will mostly occur over the intermediate to longer term. Near term constraints on the City budget and other funding sources will likely result in a near-term emphasis on optimizing use of present level of transit resources in the most effective and cost efficient way. The baseline forecasts (Chapter 3 and 4) of East Honolulu travel conditions thus reflect a continuation of transit use at levels similar to current usage. The effects of major increases are discussed in Chapter 5.

The East Honolulu corridor presently has a contraflow HOV lane operation in the morning peak period between the vicinity of West Halemaumau Street and the H-1 Freeway. The TDM Element of the OMPO Plan includes the extension of the HOV lane operations kokohead to Hawaii Kai (implementation in the 2001 to 2005 period), and the continuation of the contraflow lane onto the H-1 Freeway to Kapiolani Boulevard, where it would connect to an HOV lane on that roadway (implementation in 2006 to 2020 period).

The recently completed widening of Kalanianaole Highway was designed to permit the extension of the contraflow HOV lane from its present terminus near West Halemaumau Street to Hawaii Kai. The widening project included the placement of pavement markings and permanent signing for the future HOV lane extension. HOV lane operations can be initiated along this segment when State DOT considers the extension warranted to improve travel conditions. The study analyses reflect this kokohead extension occurring prior to 2017. The contraflow HOV lane operation is assumed to begin on the kokohead side of Keahole Street.

The ewa extension of the contraflow HOV lane to Kapiolani Boulevard will require construction of ramp connections at Kapiolani Boulevard. This extension is not reflected in the baseline analysis.

The implementation of other TDM measures will likely occur throughout the period through year 2020. The cumulative effect of these actions are not included in the baseline forecasts, but are evaluated in Chapter 5.

TRIP GENERATION FOR NEW DEVELOPMENTS

The approved developments in Hawaii Kai would add 220 vehicle trips into the new land uses and 564 vehicle trips out from the new uses during the morning peak hour. In the afternoon peak hour, vehicle trips into and out from the new uses total 591 and 412, respectively. These increases in vehicle trip ends include both trips between different origins and destinations within Hawaii Kai, and trips to/from points outside of the community. The estimated vehicle trips beginning or ending at each individual development are summarized in Table 3-2.

[5] Op. Cit., Section IV, "Transit Element."

[6] Op. Cit., Section V, "Transportation Demand Management Element."

Table 3-2

ESTIMATED WEEKDAY VEHICLE TRIPS FOR WITHOUT PROJECT USES
Hawaii Kai Properties EIR

Location	Use & Quantity	AM Peak Hour		PM Peak Hour		Daily To/From Use
		To	From	To	From	
Hawaii Kai						
Kalele Kai	8 Townhouses	1	3	3	2	47
	80 Mid Rise Condos	5	22	18	11	335
Peninsula	276 Low Rise Condos	19	102	99	53	1,618
	354 Mid Rise Condos	22	99	81	50	1,480
Kaalakei 1-A	252 Units	20	23	35	28	610
	120 Beds	18	11	6	8	315
Kaluanui 1	194 Townhouses	14	72	69	37	1,137
	96 Low Rise Condos	7	35	34	18	563
Kaluanui 2&3	325 Mid Rise Condos	20	91	75	46	1,359
Kamilo Estates	7 Single Family Homes	1	4	5	3	67
Kamehame Ridge	155 Single Family Homes	29	86	100	56	1,480
Executive Plaza	42,200 SF Office	46	6	8	42	655
Towne Center	8,240 SF Retail	5	3	18	18	442
Kalama Village	17,140 SF Retail	13	8	40	40	1,986
Total		**220**	**564**	**591**	**412**	**12,094**
Other East Honolulu						
Waialae Iki	232 Single Family Homes	43	129	150	84	2,216
Aina Haina	28 Single Family Homes	5	16	18	10	268
Hawaii Loa Ridge	229 Single Family Homes	42	127	148	83	2,187
Nui Valley	51 Single Family Homes	9	28	33	19	487
Kuliouou	65 Single Family Homes	12	36	42	24	621
Total		**112**	**336**	**391**	**220**	**5,778**

Wilbur Smith Associates; March 1996

On a typical weekday, the new Hawaii Kai developments would add an estimated 12,094 vehicle trip ends, or an increase of about 9.0 percent over 1996 levels of travel. About 75 percent of the trip ends would be to or from residential uses, and 25 percent to or from the commercial developments.

Table 3-2 also summarizes the trip generation for the additional housing developments elsewhere along Kalanianaole Highway. These developments would generate 448 and 611 vehicle trip ends in the morning and afternoon peak hour, respectively.

WEEKDAY TRAFFIC VOLUMES

The forecast traffic volumes without the *Project* reflect the cumulative increases due to developments within Hawaii Kai that have received City approvals, plus other anticipated increases in East Honolulu development, plus traffic growth from existing land uses.

Trip Distribution and Assignment

The distribution of the additional trips for the approved developments reflects the existing trip patterns for Hawaii Kai. The overall proportion of internal trips within Hawaii Kai, versus the trips to locations outside Hawaii Kai, remains similar to the existing levels, as discussed in Chapter 2.

During the morning peak hour, the net outflow of trips from Hawaii Kai would amount to 68 percent of the new trips exiting the approved projects (385 of 564 exiting vehicles). When the new outflow is added to existing, the overall proportion of trips exiting Hawaii Kai would remain similar to the existing (1996) distribution of Hawaii Kai trips.

During the afternoon peak hour, the proportion of external trips would also remain similar to existing conditions. About 51 percent of trips to the new uses would be from outside Hawaii Kai, versus 50 percent at present.

The increased employment, shopping, and business opportunities in Hawaii Kai would also affect travel to/from other communities in East Honolulu. A small portion of those East Honolulu peak hour trips now being made to/from Honolulu would be diverted to Hawaii Kai.

Traffic was assigned to the street system in conformance with present travel patterns.

Hawaii Kai Peak Hour Traffic Volumes

Year 2017 traffic volumes with completion of the approved developments are depicted in Figures 3-1 and 3-2 for the morning and afternoon peak hour periods, respectively. The key segments of the roadway system with large proportional increases in peak hour, peak direction traffic over existing volumes include the following:

HAWAII KAI PROPERTIES TRAFFIC IMPACT STUDY

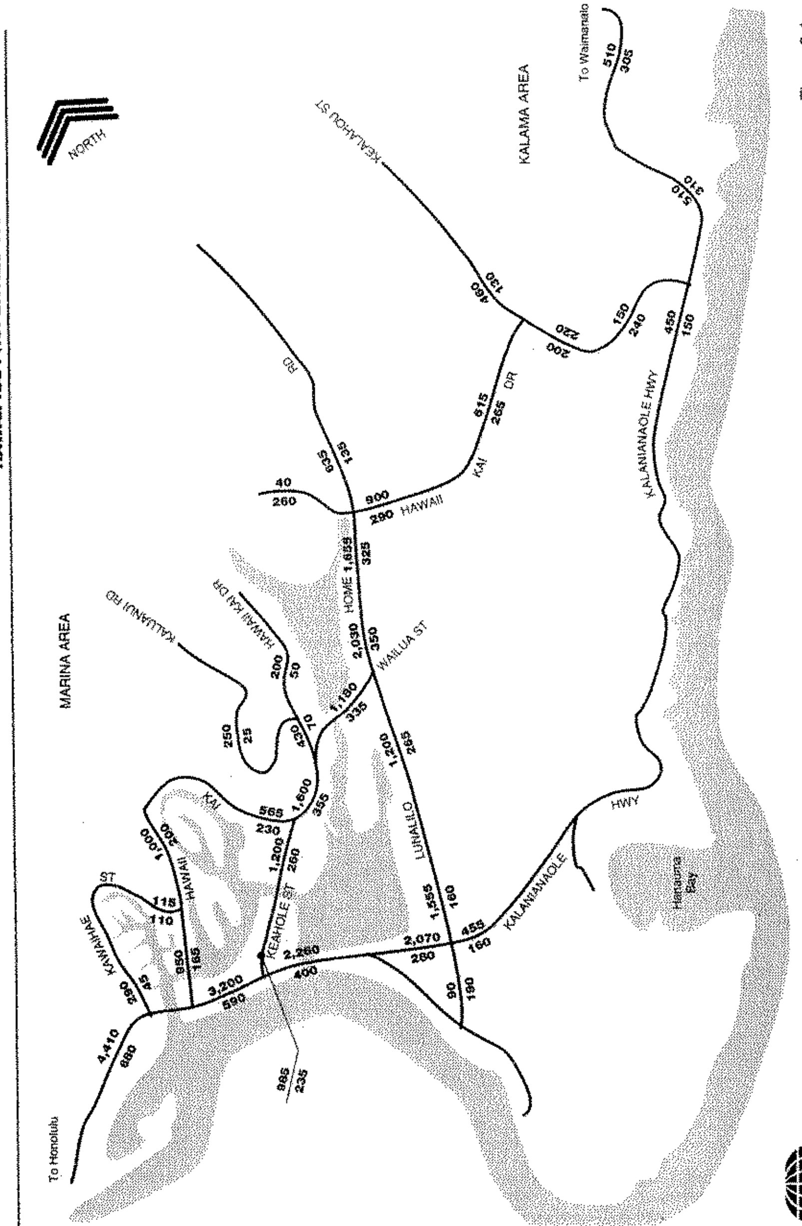


Figure 3-1
FUTURE WEEKDAY MORNING PEAK HOUR TRAFFIC WITHOUT PROJECT - HAWAII KAI ROADWAYS
DETAIL-4/15/96C
WILBUR SMITH ASSOCIATES

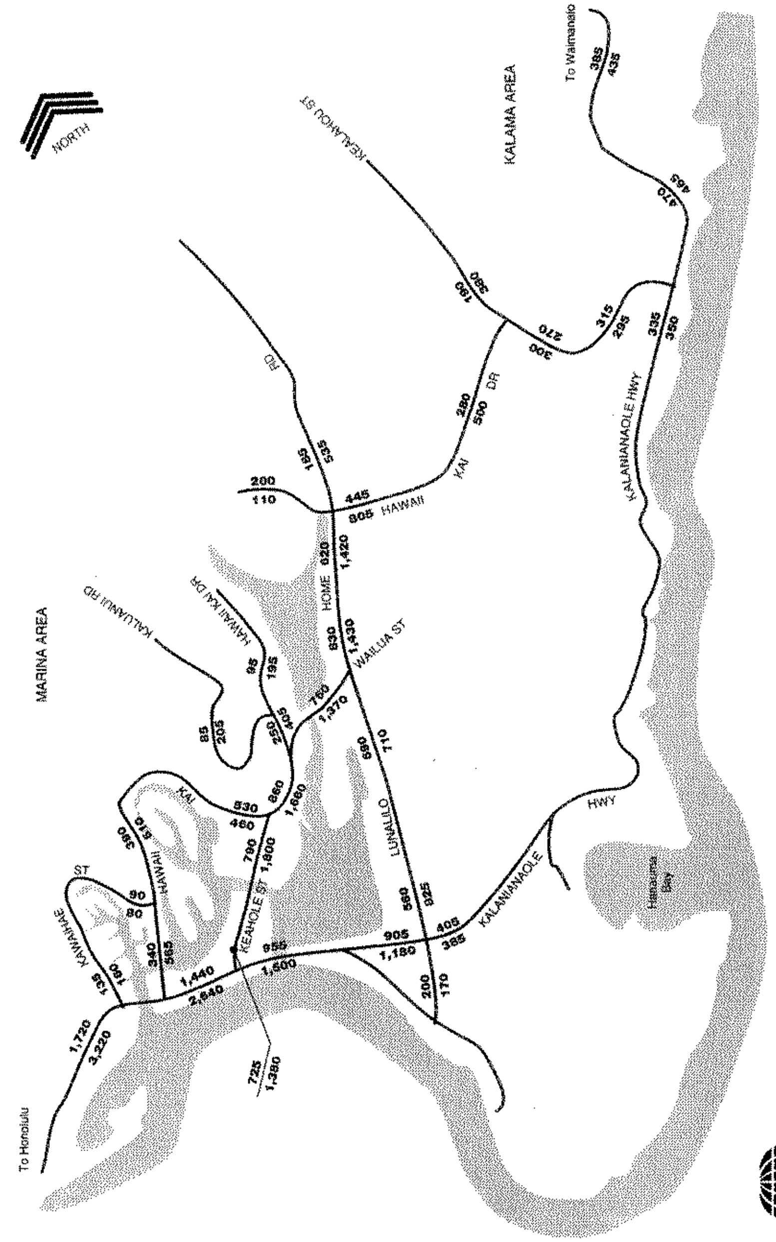


Figure 3-2
FUTURE WEEKDAY AFTERNOON PEAK HOUR TRAFFIC WITHOUT PROJECT - HAWAII KAI ROADWAYS

WSA WILBUR SMITH ASSOCIATES

DETAIL-4/15/96C

Roadway/Location	Morning Peak Hour		Afternoon Peak Hour	
	Direction	Increase	Direction	Increase
Hawaii Kai Dr. East of Lunalilo Home Rd.	WB	21.8%	EB	27.5%
Lunalilo Home Rd. North of Wailua St.	SB	13.9%	NB	19.1%
Lunalilo Home Rd. South of Wailua St.	SB	23.9%	NB	28.4%
Wailua St.	WB	11.5%	EB	15.7%
Keahole St. South of Hawaii Kai Drive	SB	30.3%	NB	23.8%

The large increase on Hawaii Kai Drive, east of Lunalilo Home Road, results from development of Kamehame Ridge area as well as increased travel to/from Windward Oahu. The increased volumes on Lunalilo Home Road reflect access to/from the Peninsula development. The Keahole Street increase reflects both traffic to/from the Kaluanui developments, as well as traffic to the expanded facilities in the Towne Center and Executive Plaza.

Kalanianaole Highway Peak Hour Traffic Volumes

The combination of the approved Hawaii Kai developments, additional residential units outside Hawaii Kai, and background traffic growth would result in sizeable increases to peak hour traffic flow along Kalanianaole Highway. The estimated peak hour volumes in 2017 are depicted in Figure 3-3. The increases at the two ends of the corridor are as follows:

Location	Morning Peak Hour			Afternoon Peak Hour		
	Existing Vehicles	Additional Vehicles	Percent Increase	Existing Vehicles	Additional Vehicles	Percent Increase
West of Kawaihae Street						
▸ Eastbound	560	120	21.4%	2,630	590	22.4%
▸ Westbound	3,710	700	18.9%	1,380	340	24.6%
East of Kalaniiki Street						
▸ Eastbound	1,280	170	13.3%	4,240	730	17.2%
▸ Westbound	5,330	960	18.0%	2,080	250	12.0%

At Kalaniiki Street, the sources of the increase in westbound traffic during the morning peak hour are estimated as follows:

- Hawaii Kai Approved Development: . 330 vehicles
- Other East Honolulu Development: . . 220
- Background Increase: . . . . <u>410</u>

Total: . . . . 960 vehicles

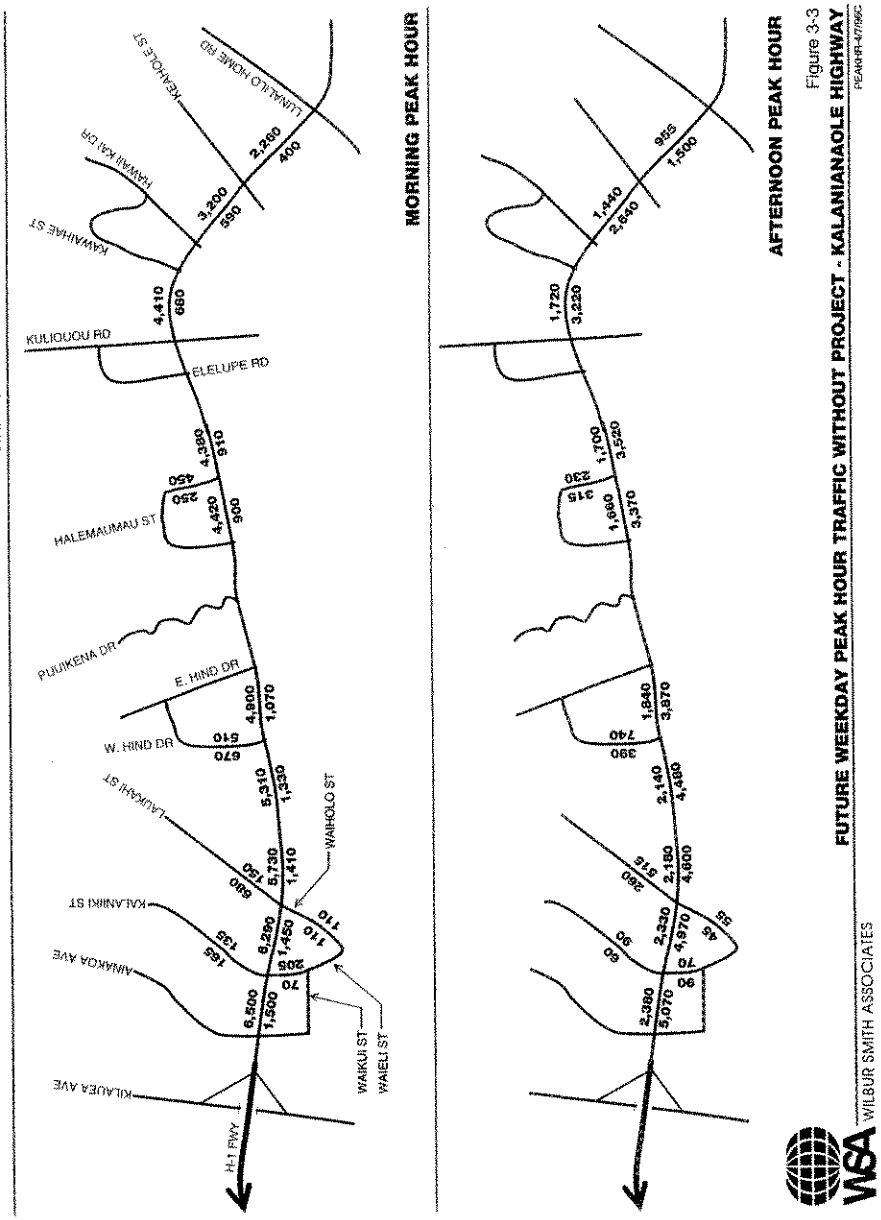


Figure 3-3
FUTURE WEEKDAY PEAK HOUR TRAFFIC WITHOUT PROJECT - KALANIANAOLE HIGHWAY

The aforementioned increases include traffic in both the normal flow lanes and the HOV lane. At Kalaniiki Street, the estimated volume in the HOV lane is 1,335 vehicles, with 4,955 vehicles in the westbound normal flow lanes. With extension of the contraflow HOV lane to Hawaii Kai, the estimated volume in the HOV lane is 870 vehicles at Kawaihae Street.

WEEKDAY CONDITIONS AT KEY INTERSECTIONS

Traffic conditions were analyzed for the key intersections within Hawaii Kai and at other East Honolulu intersections for 2001 traffic volumes. Traffic conditions for the morning and afternoon peak hour are summarized in Table 3-3.

Hawaii Kai Intersections

Most of the key intersections within the Hawaii Kai area, including those along Kalanianaole Highway, would operate at acceptable service levels during both the morning and afternoon peak hours. Forecast volumes with the approved developments would utilize around 90 percent of capacity or more at two intersections along Hawaii Kai Drive, those being Lunalilo Home Road and Wailua Street, and at the Keahole Street intersection with Kalanianaole Highway.

- **Hawaii Kai Drive - Lunalilo Home Road Intersection** - During the morning peak hour, increases to the large volume of vehicles (860) turning left from Hawaii Kai Drive onto makaibound Lunalilo Home Road result in traffic volumes approximately 90 percent of intersection capacity. The conditions could be improved by restriping the westbound approach to allow left-turns from both of the existing lanes and modifying the traffic signal to provide separate phases for the eastbound and westbound approaches.

- **Hawaii Kai Drive - Wailua Street Intersection** - During the afternoon peak hour, the forecast traffic volumes would approximate 96 percent of the intersection capacity. This results from the large volume of vehicles (1,307) turning right from mauka-direction Hawaii Kai Drive onto Wailua Street, combined with the conflicting vehicles turning left from makaibound Hawaii Kai Drive onto Wailua Street. The volumes of the other traffic movements are well below the capacities available to each movement.

- **Keahole Street - Kalanianaole Highway Intersection** - The increases to the large volumes of makaibound traffic turning right from Keahole Street and the ewabound through traffic on Kalanianaole Highway would result in intersection volumes at about 88 percent of capacity in the morning peak hour. Conditions at this intersection would be worse than the nearby Hawaii Kai Drive and Kawaihae Street intersections, which accommodate higher traffic volumes,since the widening to three ewabound lanes occurs ewa of this intersection.

Peak hour traffic conditions at other intersections along the widened section of Kalanianaole Highway would be slightly better than existing conditions, given operation of a contraflow HOV lane through this section during the morning peak period. This improvement in traffic conditions would occur due to the projected shift of more vehicles into the new contraflow lane than the increase in peak direction traffic volumes at these intersections.

Table 3-3
(Page 2 of 2)

YEAR 2017 WITHOUT PROJECT INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties EIR

Intersection	AM Peak Hour			PM Peak Hour		
	V/C[1]	AD[2]	LOS	V/C[1]	AD[2]	LOS
12 Hawaii Kai Drive/Wailua Street	0.534	7.1	B	0.963	17.5	C
13 Hawaii Kai Drive/Kaluanui Road						
Westbound Left-Turn		5.9	B		7.4	B
Eastbound Left-Turn		4.5	A		3.3	A
Northbound Left-Turn		2.7	A		2.8	A
14 Wailua Street/Lunalilo Home Road	0.721	5.7	B	0.742	16.8	C
15 Hawaii Kai Drive/Lunalilo Home Road	0.891	18.1	C	0.785	11.2	B
16 Hawai Kai Drive/Kealahou Street[4]	--	7.8	B		11.2	C

Notes:

(1) Values in this column represent volume-to-capacity (V/C) ratios for signalized intersections.
(2) AD = Average delay per vehicle, in seconds.
(3) Two-way STOP sign controls.
(4) All approaches controlled by STOP signs.
LOS = Level-of-Service.

Wilbur Smith Associates; March 1996

WSA WILBUR SMITH ASSOCIATES
HAWAII KAI PROPERTIES EIR

Table 3-3
(Page 1 of 2)

YEAR 2017 WITHOUT PROJECT INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties EIR

Intersection	AM Peak Hour			PM Peak Hour		
	V/C[1]	AD[2]	LOS	V/C[1]	AD[2]	LOS
1 Kalanianaole Highway/Kalaniiki Street	0.916	9.8	B	0.896	5.2	B
2 Kalanianaole Highway/Laukahi Street	0.946	23.7	C	0.928	15.2	C
3 Kalanianaole Highway/West Hind Street	0.885	16.7	C	0.828	7.2	B
4 Kalanianaole Highway/East Halemaumau Street	0.776	11.4	B	0.777	7.3	B
5 Kalanianaole Highway/Kawaihae Street	0.742	8.5	B	0.698	5.8	B
6 Kalanianaole Highway/Hawaii Kai Drive	0.791	23.2	C	0.601	9.4	B
7 Kalanianaole Highway/Keahole Street	0.878	29.0	D	0.779	18.9	C
8 Kalanianaole Highway/Lunalilo Home Road	0.519	13.3	B	0.796	24.2	C
9 Kalanianaole Highway/Kealahou Street[3]	0.365	8.7	B	0.39	17.4	C
10 Kawaihae Street/Hawaii Kai Drive[3]						
Westbound Left/Through/Right-Turn		12.5	C		9.4	B
Eastbound Left/Through/Right-Turn		29.5	D		18.5	C
Northbound Left-Turn		7.8	B		3.5	A
Southbound Left-Turn		2.5	A		4.1	A
11 Hawaii Kai Drive/Keahole Street	0.501	10.7	B	0.728	15.0	C

Other East Honolulu Intersections

During the morning peak hour, year 2017 traffic conditions at the East Halemaumau Street intersection are projected to improve slightly as compared to existing conditions. Morning traffic would use about 78 percent of capacity, versus 82 percent in 1996. The improved condition would result from the diversion of peak direction traffic into the contraflow HOV lane, once the HOV lane is extended through this intersection. In the afternoon, 2017 traffic would use 78 percent of capacity. Level of service, as measured by average delay per vehicle, should remain at acceptable levels (LOS B).

At the West Hind Drive intersection with Kalanianaole Highway, the estimated traffic increases would result in volumes approximately 88 and 83 percent of intersection capacity in the morning and afternoon peak hours, respectively. The estimated increase in vehicle delay would result in LOS C conditions in the morning peak hour, versus LOS B with existing volumes.

The estimated traffic increases at the Laukahi and Kalaniiki Street intersections would result in volumes equivalent to between 90 and 95 percent of capacity during each peak hour. These volume-to-capacity ratios reflect the change in the lane utilization factor to 1.00, from an existing 1.03 and 1.06 for the morning and afternoon peak hours, respectively. As the future traffic volumes increase to levels approaching capacity, the traffic volumes will tend to be more evenly distributed among each lane along Kalanianaole Highway, which would be reflected by a lane utilization factor of 1.00. (See page 2-14 for discussion of lane utilization factors.) Although a portion of the more even distribution of lane volumes would occur with the traffic increases between existing and "Future Without Project" scenarios and a portion with the traffic increases between the "Future Without Project" and "Future With Project" scenarios, the entire shift to balanced lane volumes has been reflected in the "Without Project" scenario. Without this change, the volume-to-capacity ratios at these two intersections would be about 0.02 higher in the morning peak hour, and 0.03 to 0.04 higher in the afternoon peak hour.

The service levels, based upon average vehicle delay times, would be at LOS B for Kalaniiki Street intersection in both peak hours and for Laukahi Street in the morning peak hour. In the afternoon peak hour, the Laukahi Street intersection would operate at LOS C. These service levels reflect an "average" condition for all traffic passing through the intersection. The large volumes of traffic along Kalanianaole Highway would experience little delay (LOS A and B), while traffic on the cross streets would experience very long average delays of 60 to 120 seconds (LOS F).

Future traffic conditions worsen more for the Laukahi Street intersection than for Kalaniiki Street. This results from the assumed development of several hundred additional houses along Laukahi Street, which add to the traffic turning to or from this street.

SUNDAY PEAK HOUR TRAFFIC CONDITIONS

The traffic volumes along Kalanianaole Highway between Lunalilo Home Road and Kealahou Street would be primarily affected by increased use of the recreational attractions along this section and by sightseers. The approved developments in Hawaii Kai would have little effect on the intersection conditions in this area.

At the Lunalilo Home Road intersection, early Sunday peak hour traffic would use 69 percent of intersection capacity; conditions would remain at LOS B, with small increases in the average delay time. In the late afternoon period, the forecast traffic volumes would use 92 percent of intersection capacity. The average delay would remain at LOS C during this period.

With the installation of a traffic signal at Kealahou Street, the intersection would operate at LOS B on Sunday afternoons. The forecast traffic volumes would use about 50 percent of intersection capacity.

Conditions for vehicles turning left out of the Sandy Beach West driveway would worsen from LOS C to D during the early afternoon and from LOS D to E in the late afternoon period. Conditions would be at LOS F for vehicles turning left from the Hanauma Bay driveway.

KALANIANAOLE HIGHWAY TWO-LANE SEGMENTS

With the increases from background traffic growth and the approved Hawaii Kai developments, the service levels would remain the same in 2017 as for the existing conditions on the three roadway segments included in the analyses (at Hanauma Bay, in the Blowhole section, and at Makapuu Point). The forecast volumes would use between 37 and 41 percent of the capacity of each roadway segment in the weekday afternoon peak hours. For the Sunday peak hour, the forecast volumes would use 62 to 68 percent of the capacity of the two-lane roadway sections.

4. YEAR 2017 TRAVEL CONDITIONS WITH THE PROJECT

The proposed development within the Hawaii Kai community would include 12 parcels in addition to those parcels that have already received City and County of Honolulu approvals for development. These 12 additional parcels are herein referred to collectively as the proposed *Project*. This chapter summarizes the assessment of the anticipated travel increases and transportation system impacts with development of these *Project* parcels. The assessment addresses the cumulative effects of both the approved development and the proposed *Project* parcels. Assessment of individual parcels is primarily focussed on the proportional contribution of each to the additional increment of travel, and to ingress-egress for each parcel.

As in the "Without Project" scenario (Chapter 3), the travel forecasts and conditions presented in this chapter reflect only those regional transportation system modifications that could readily be implemented during the next five years or so. These include the planned improvements at the intersection of Kalanianaole Highway and Kealahou Street, and the extension of the morning contraflow lane operation along Kalanianaole Highway from Niu Valley to Hawaii Kai. Conditions with other longer-range planned improvements, that may not be implemented until well into the future, are evaluated in a separate analysis and discussed in Chapter 5.

PROJECT DESCRIPTION

The 12 *Project* parcels include the proposed development of 1,512 residential units, approximately 49 acres of commercial development, plus a golf course. The locations of the *Project* parcels are depicted in Figure 1-1. A brief description of the proposed development for each parcel is presented in order from west to east.

Marina 1/Strip 1 - This mixed use commercial development would extend from Hawaii Kai Drive to Keahole Street, and mauka along Keahole Street to include a portion of the existing park-and-ride lot. The park-and-ride facility would be relocated mauka of the new commercial development. For purposes of this traffic analysis, the parcel was assumed to include:

- About 172, 800 sq. ft. of retail space;
- About 19,200 sq. ft. of office space; and
- A marina facility with 62 boat slips.

The Hawaii Kai Marina Community Association would be responsible for obtaining permits/approvals and constructing the boat slips. The boat slips are included in the *Project* traffic generation to provide a comprehensive assessment.

Access is planned to/from each of the adjacent roadways:

- An intersection with Hawaii Kai Drive approximately midway between Kalanianaole Highway and the bridge;
- A driveway allowing right-turns into and out of the site along Kalanianaole Highway; and

- Use of the existing intersection near Gas Express for access to Keahole Street, to be shared with the park-and-ride facility.

Marina 4B - This parcel is planned for development of 75 townhouses. Access is via Ainakoa Street.

Kamilonui 1 - This multi-family residential development would contain approximately 510 mid-rise condominium units on the 17-acre parcel. Access would be provided via driveways to a new segment of Hawaii Kai Drive, to be constructed through the Kamilonui area to connect the existing eastern and western segments of the street.

Kamilonui 2 - This parcel, located mauka of the Kamilonui Agricultural Subdivision, would contain 364 residential units. Access would be via a new roadway outside the eastern boundary of the agricultural area, with the new roadway connecting to the planned extension of Hawaii Kai Drive.

Kamilo Ridge - Five single-family residential units would be developed immediately mauka of the planned extension of Hawaii Kai Drive.

Kalama Valley - This residential project with 176 low-rise condominium units would be developed on the vacant land north and east of the present Kalama Village commercial center. Access would be provided to Mokuhano Street.

Golf Course 2/1A - Development of this 10.9 acre area would include three separate uses:

i. A residential development with 45 single-family houses;
ii. An inn with 140 rooms; and
iii. A business park with 100,800 square feet of floor space oriented to service and storage uses.

Access to all three elements would be provided via a new street connecting to Kealahou Street opposite Kalohelani Place.

Mauuwai - This 82.7-acre development is expected to include 143 single family houses. Access is planned via a new roadway connection from the site along the western edge of the golf driving range to the drainage channel, and then westward along the mauka side of the drainage channel to connect with and serve as the east leg of the intersection of Hawaii Kai Drive and Kealahou Street. The new two-lane road would have a 40-foot wide pavement within a 56-foot wide right-of-way.

As an alternative, access to this parcel may be provided from Kalanianaole Highway via a driveway shared with the Hawaii Kai Golf Course. If access is provided to Kalanianaole Highway, then no connection would be provided to Kealahou Street.

Queen's Rise - Approximately 194 single-family houses are planned for this area. Access would be provided via a new street connection to Kalanianaole Highway.

Queen's Beach - This 166-acre parcel would be used for recreational uses. These include an 18-hole golf course, a golf clubhouse and a golf driving range. At the south end of the parcel, an area will be made available to the City and County of Honolulu for use in providing public use of the shoreline areas. Separate driveway connections would be provided along the makai side of Kalanianaole Highway for the golf course and beach access areas.

ROADWAY SYSTEM MODIFICATIONS

The missing segment of Hawaii Kai Drive at the mauka end of Kuapa Pond would be constructed as part of the *Project*. The connection of the existing eastern and western segments of Hawaii Kai Drive would both maximize accessibility to the new Kamilonui Valley developments and serve as an alternative to Wailua Street for travel between the upper Lunalilo Home Road area and the Keahole Street area.

The existing segments of Hawaii Kai Drive at either end of this missing segment provide a 40-foot pavement width within a 56-foot wide right-of-way. This cross section extends mauka from Kaluanui Road and ewa from Lunalilo Home Road to the present terminus on either end of the missing segment. The 40-foot pavement allows one through lane in each direction, with width to provide on-street parking or separate left-turn lanes at key locations. At present, on-street parking occurs only adjacent to the Anchorage subdivision where houses front directly onto Hawaii Kai Drive.

The *Project* envisions the continuation of the 40-foot pavement width along the new segment to connect the eastern and western portions of Hawaii Kai Drive. The two-lane roadway connection would allow use by through traffic, but should not provide the speed characteristics or capacity of a major thoroughfare that would attract use by large volumes of through traffic.

The other new roadways that provide access to individual parcels, as described in the preceding section, would be local streets.

Other transportation system modifications included in the analyses are the intersection improvements on Kalanianaole Highway at Kealahou Street, and the extension of the contraflow HOV lane along Kalanianaole Highway to Hawaii Kai, during the morning peak commute period. These are described in Chapter 3.

ASSUMPTIONS AND METHODOLOGY

The future traffic volumes were estimated using the standard procedure of trip generation, distribution of trips between origins and destinations, and assignment of trips to the roadway system. Where appropriate, current travel characteristics were used in the forecast of future travel.

Trip Generation

Vehicle trip generation rates for the proposed new Hawaii Kai developments are based on standard national rates as compiled by the Institute of Transportation Engineers.(1) Field counts made as a part of prior traffic studies in Hawaii Kai confirmed that the national average rates are reasonably

(1) *Trip Generation, Fifth Edition*, Institute of Transportation Engineers, 1991.

reflective of trip rates in Hawaii Kai. The vehicle trip generation rates used for the *Project* land uses are presented in Table 4-1. The trip rates presented for Sundays are for those *Project* parcels that would most directly affect the two-lane section of Kalanianaole Highway, where weekend traffic volumes equal or exceed weekday volumes.

The increase in transit trips along Kalanianaole Highway, for the initial forecast, is based on the recent ratio of local and express bus passengers relative to automobile trips. Based on the travel data summarized in Table 2-4 for 1991 conditions, there is approximately one express or local bus rider travelling ewa on Kalanianaole Highway per 8.5 vehicles during the morning peak hour, which represents 7.6 percent of the total persons travelling ewa.

Distribution of Trips

The distribution of project trips within and outside of Hawaii Kai is based on the existing trip patterns and characteristics, as summarized in Chapter 2. The general framework for the distribution of project trips are as follows:

1. A preliminary initial distribution of project trips to/from East Honolulu, Honolulu, Windward Oahu, and other areas within Hawaii Kai was developed based on present trip origin-destination patterns for each peak hour period.

2. The preliminary distribution was then adjusted to reflect the proportion of project trips associated with commercial uses as compared to existing conditions. In particular, the afternoon peak hour distribution was adjusted to result in close to 70 percent of the trips to the new commercial uses being drawn from within Hawaii Kai, as in the present patterns. Most of this shift in trip destinations was diverted from trips that otherwise would travel to/from Honolulu to patronize retail and service establishments there.

3. The increased commercial development included within the *Project* would also attract increased trips from East Honolulu. Trips between the East Honolulu and Honolulu areas were reduced to reflect the number of existing trips diverted to the new Hawaii Kai commercial uses.

Little change was made to the distribution of Hawaii Kai trips during the morning peak hour since few of the Project's retail and business uses would be open in the morning peak hour. These commercial uses should attract some employees from within Hawaii Kai who would otherwise work outside Hawaii Kai and would commute during the morning peak hour. However, this potential reduction to morning peak hour trips along Kalanianaole Highway is not reflected in the traffic forecasts.

Assignment to the Roadway System

In general, the new vehicle trips were assigned to area roadways in conformance with present travel patterns and routings. The principal exception was forecast volumes on the planned connection of the eastern and western segments of Hawaii Kai Drive through the Kamilonui Valley area, which would provide an alternative route to present use of Lunalilo Home Road and Wailua Street for travel between the Keahole Street area and the upper Lunalilo Home Road area.

Table 4-1

VEHICLE TRIP GENERATION RATES FOR *PROJECT* USES
Hawaii Kai Properties EIR

Land Use	Rate Basis	Morning Peak Hour		Afternoon Peak Hour		Daily to/from Use
		To	From	To	From	
Weekdays						
Single Family Residential	Dwellings	0.19	0.55	0.65	0.36	9.55
Townhouses	Dwellings	0.07	0.37	0.36	0.19	5.86
Low Rise Condos	Dwellings	0.07	0.37	0.36	0.19	5.86
Mid Rise Condos	Dwellings	0.06	0.28	0.23	0.14	4.18
Apartments	Units	0.09	0.42	0.43	0.19	6.47
Light Industrial	KSF	0.44	0.09	0.03	0.22	6.73
Inn/Hotel	Rooms	0.20	0.13	0.38	0.32	8.27
Golf Course	Per Hole	2.27	0.47	1.74	1.61	35.84
Office	KSF	2.73	0.34	0.46	2.22	21.30
Retail	KSF	0.80	0.49	2.69	2.69	57.56
Yacht Club	Berths	0.03	0.05	0.11	0.08	2.96
Sunday						
Single Family Residential	Dwellings	--	--	0.45	0.45	8.78
Townhouses	Dwellings	--	--	0.22	0.23	4.84
Low Rise Condots	Dwellings	--	--	0.22	0.23	4.84
Light Industrial	KSF	--	--	0.05	0.05	0.68
Golf Course	Per Hole	--	--	3.19	1.24	41.70
Inn/Hotel	Rooms	--	--	0.35	0.40	8.48

Source: *Trip Generation, Fifth Edition*, Institute of Transportation Engineers, 1991.
KSF 1,000 square feet of floor area.

Wilbur Smith Associates; March 1996

The new route would be a longer distance, and would likely require a longer travel time, than the existing route. Between the Hawaii Kai Drive intersections with Lunalilo Home Road and with Wailua Street, the new "connection" route would be 8,400 feet in length versus 6,000 feet via Wailua Street, and would result in an estimated travel time of 3.1 minutes versus 2.2 minutes via the present route.

With a nearly one minute longer travel time, only a small portion of the existing traffic through this corridor would likely be diverted to use of Hawaii Kai Drive around the mauka end of Kuapa Pond. For this traffic analysis, the use of this new roadway was assumed to include:

- Trips to/from the new developments proposed for the Kamilonui Valley area;
- Most of the trips between the existing Mariner's Cove and Waioli Street area (about 450 houses) and the Keahole Street area; and
- Diversion of a small portion of other trips from the existing Lunalilo Home Road/Wailua Street route, approximately equal to the number of vehicle trips added to Lunalilo Home Road/Wailua Street by the new projects.

The combined effect of these routings would result in future traffic volumes along the Lunalilo Home Road/Wailua Street route at or slightly below traffic volumes without the *Project*. This assignment allows the testing of the capacity of the new Hawaii Kai Drive Extension to accommodate all new traffic growth and thus avoid worsening future conditions in the Wailua Street area, and the assessment of impacts of such traffic volumes on the adjacent land uses.

In the Kalanianaole Highway corridor, 21 percent of the additional ewa-direction traffic in the morning peak hour was assumed to use the HOV lane. This proportion is similar to the current levels at the present HOV lane terminus in Niu Valley.

VEHICLE TRIP GENERATION BY THE PROJECT

For the morning peak hour of an average weekday, the proposed land uses are estimated to result in a combined total of 462 vehicles entering the 12 *Project* parcels, and 729 vehicles exiting the *Project* parcels. In the afternoon, totals of 1,186 and 953 vehicles are estimated to enter and exit the 12 parcels, respectively. For the average weekday, vehicle traffic is estimated at 22,962 vehicles, with half entering and half exiting the 12 *Project* sites. The estimated vehicle trips entering and exiting each site are listed in Table 4-2.

The proportional increases in the total numbers of vehicles entering or exiting all land uses within Hawaii Kai are as follows:

Table 4-2

ESTIMATED WEEKDAY VEHICLE TRIPS FOR PROJECT USES
Hawaii Kai Properties EIR

Location	Use & Quantity	AM Peak Hour		PM Peak Hour		Daily To/From Use
		To	From	To	From	
Kamilonui 1	510 Mid Rise Condos	31	142	117	72	2,132
Kamilonui 2	92 Single Family Homes	17	51	60	33	879
	272 Townhouses	19	101	97	52	1,594
Marina 4B	75 Townhouses	5	28	27	14	440
Kamilo Ridge	5 Single Family Homes	1	3	3	2	48
Kalama Valley	176 Low Rise Condos	12	65	63	34	1,032
Mauuwai	143 Single Family Homes	26	79	94	52	1,366
Queen's Rise	194 Single Family Homes	37	106	127	71	1,853
Golf Course 2/1A	45 Single Family Homes	8	25	30	16	430
	100,800 SF Business Park	44	9	3	22	679
	Hotel, 140 Rooms	29	19	53	45	1,324
Queen's Beach	18-Hole Golf Course	41	8	31	29	645
Marina 1/Strip 1	19,200 SF Office	52	6	9	46	409
	172,800 SF Retail	138	85	465	465	9,947
	62 Berth Marina	2	2	7	5	184
	Total	**462**	**729**	**1,186**	**958**	**22,962**
Subtotals by Type of Use						
	Residential Uses	156	600	618	346	9,774
	Commercial Uses	306	129	568	612	13,188

Wilbur Smith Associates; March 1996

Hawaii Kai Land Uses	Morning Peak Hour		Afternoon Peak Hour		Total Weekday Enter/Exit Vehicles
	Entering Vehicles	Exiting Vehicles	Entering Vehicles	Exiting Vehicles	
Year 2017 Without Project	2,800	5,923	7,743	5,369	146,838
Project Parcels	462	729	1,186	958	22,962
Total	**3,262**	**6,652**	**8,929**	**6,327**	**169,800**
Percent Increase	16.5%	12.3%	15.3%	17.8%	15.6%

The entering/exiting vehicle volumes include both new vehicle trips and additional stops by vehicles that would be travelling through the area whether or not the project parcels are developed. These additional stops, referred to as pass-by trips, occur primarily for commercial uses, and principally the retail and service uses. The ITE "*Trip Generation*" manual[2] provides a methodology and equation for estimating the proportion of the generated vehicle trip ends that are "pass-by" trips. For the proposed Marina 1 retail center approximately 30 percent of the entering exiting/traffic would represent pass-by trips in the afternoon peak hour when the retail/services uses would by fully operational. New trip ends would amount to 325 entering and 325 exiting vehicles, respectively. Vehicle trip ends for the other land uses are assumed to reflect new trips.

DISTRIBUTION OF PROJECT TRIPS

A key feature of the trip generation estimates is the closer balance between the number of vehicles entering and exiting the 12 Project parcels during each peak hour, on a combined basis, as compared to the existing trip patterns in Hawaii Kai. In the morning peak hour, vehicles entering the *Project* parcels equal 63 percent of exiting vehicles, versus 47 percent for existing Hawaii Kai land uses. In the afternoon peak hour, vehicles exiting the *Project* parcels equals 81 percent of the number entering the parcels, versus 69 percent for existing Hawaii Kai. This is primarily a result of a larger portion of the *Project* trips being generated by commercial uses than is the case for present Hawaii Kai.

This closer balance between entering and exiting vehicles volumes -- between residential and commercial uses -- should result in a higher proportion of internal trips made within Hawaii Kai, and a lower proportion of trips made to/from locations outside Hawaii Kai. However, to provide a conservative (high) estimate of morning peak hour, peak direction traffic flows, the distribution of project traffic was assumed to reflect the existing pattern. This use of the present distribution reflects the much smaller contributions of the commercial uses to traffic generation during the morning commute peak hours, and the possibility that more employees may have to be drawn from areas outside Hawaii Kai.

The much larger influence of the Marina 1 and other commercial uses in the afternoon peak hour was reflected in a change to the trip distribution pattern. Internal trips from within Hawaii Kai were estimated to increase to 57 percent of the vehicle trips into these Project parcels, versus 50 percent

(2) Op. Cit., Section VII.

at present. The distribution for peak hour, peak direction trips are summarized in the following table for existing and Project land uses.

Area	Morning Peak Hour Destinations For Trips Beginning in Hawaii Kai		Afternoon Peak Hour Origin Area for Trips To Hawaii Kai	
	Existing Uses	Project Uses	Existing Uses	Project Uses
Internal within Hawaii Kai	32	32	50	57
East Honolulu	6	6	5	6
Honolulu	58	58	40	32
Windward Oahu	4	4	5	5
Total	100	100	100	100

WEEKDAY TRAFFIC VOLUMES

The developments proposed for the *Project* parcels would result in traffic increases on many of the major streets within Hawaii Kai, as well as on Kalanianaole Highway. The resultant Year 2017 volumes and the magnitude of the increases are summarized in the following sections.

Peak Hour Traffic on Hawaii Kai Roadways

The estimated traffic volumes on the major roadways within Hawaii Kai are depicted in Figures 4-1 and 4-2 for the morning and afternoon peak hours, respectively. The estimated volumes reflect completion and occupancy of the *Project* parcels, as well as the cumulative traffic increases from completion of all of the approved developments within Hawaii Kai and from background traffic growth through Year 2017. The assigned traffic volumes also reflect the completion of the missing segment of Hawaii Kai Drive through the Kamilonui Valley area.

The change in peak hour traffic volumes as a result of the *Project* is summarized in Table 4-3 for a number of key roadway sections. These locations represent many of the roadway sections most directly affected by the development of the project parcels.

One of the largest proportional increases within the Hawaii Kai area would occur on the section of the Kalanianaole Highway between Kealahou Street and the access roadways to the Queen's Rise and Queen's Beach developments. The combined effects of trips to/from these parcels, as well as *Project* traffic to/from Windward Oahu, result in increases of about 25 to 35 percent.

The increases north of these parcels, through the Makapuu area, are much lower with an increase of 85 and 100 vehicles, combined for both directions, in the morning and afternoon peak hours, respectively. This amounts to an 8 to 15 percent increase in traffic. The number of vehicles and percentage increase would decline through the Waimanalo area. Most of these vehicle trips would represent Windward residents travelling to/from Hawaii Kai to work at or patronize the commercial uses included within the *Project*.

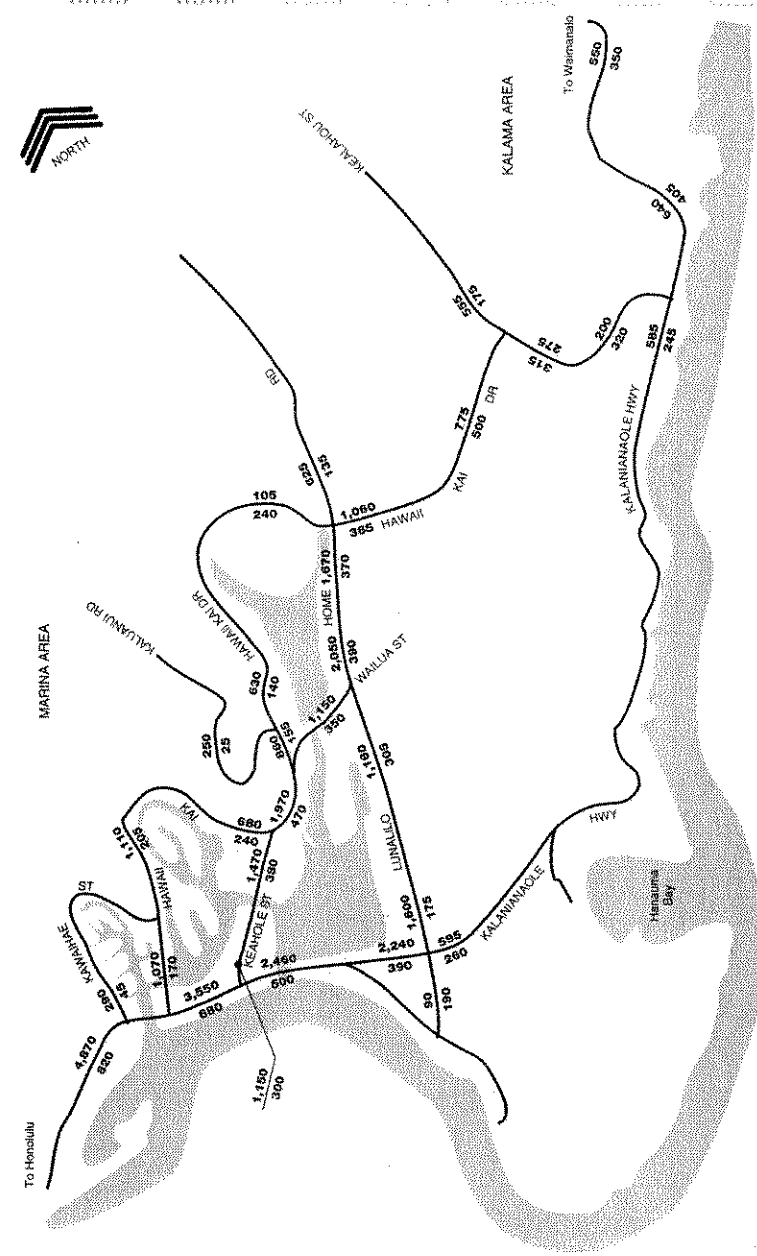


Figure 4-1
2017 WEEKDAY MORNING PEAK HOUR TRAFFIC WITH PROJECT - HAWAII KAI ROADWAYS

WILBUR SMITH ASSOCIATES

DETAIL-7/7/96C

Table 4-3

ESTIMATED PEAK HOUR TRAFFIC INCREASES (DECREASES) WITH THE PROPOSED PROJECT
Hawaii Kai Properties EIR

Roadway/Location	Direction	Morning			Afternoon		
		Traffic w/o Project	Project Increase	Percent Increase	Traffic w/o Project	Project Increase	Percent Increase
Kalanianaole Hwy at Makapuu Pt.	NB SB	305 510	45 40	14.8 7.8	435 385	45 55	10.3 14.3
Kalanianaole Hwy East of Kealahou St.	EB WB	310 510	95 130	30.6 25.5	465 470	155 50	33.3 10.6
Hawaii Kai Dr. East of Lunalilo Home Rd.	EB WB	290 900	115 160	39.7 17.8	805 445	185 145	23.0 32.5
Hawaii Kai Dr. West of Lunalilo Home Rd.	EB WB	260 40	-20 65	-7.7 162.5	110 200	100 60	90.9 30.0
Hawaii Kai Dr. North of Kaluanui Rd.	NB SB	50 200	90 430	180.0 215.0	195 95	465 250	238.5 263.0
Lunalilo Home Rd. North of Wailua St.	NB SB	350 2,050	40 20	11.4 1.0	1,430 830	-20 0	-1.4 0.0
Wailua St. East of Hawaii Kai[1]	EB WB	335 1,180	15 -30	4.5 -2.5	1,370 760	-35 25	-2.6 3.3
Hawaii Kai Dr. South of Kawaihae St.	NB SB	950 165	120 5	12.6 3.0	565 340	15 5	2.7 1.5
Keahole St. South of Hawaii Kai Dr.	NB SB	260 1,200	120 270	46.2 22.5	1,800 790	415 250	23.1 31.6
Kalanianaole Hwy. West of Kawaihae St.	EB WB	680 4,410	140 460	20.6 10.4	3,220 1,720	395 130	12.3 7.6
Kalanianaole Hwy. West of Kalaniiki St.	EB WB	1,500 6,500	120 410	8.0 6.3	5,070 2,380	330 150	6.5 6.3

Wilbur Smith Associates; March 1996

HAWAII KAI PROPERTIES TRAFFIC IMPACT STUDY

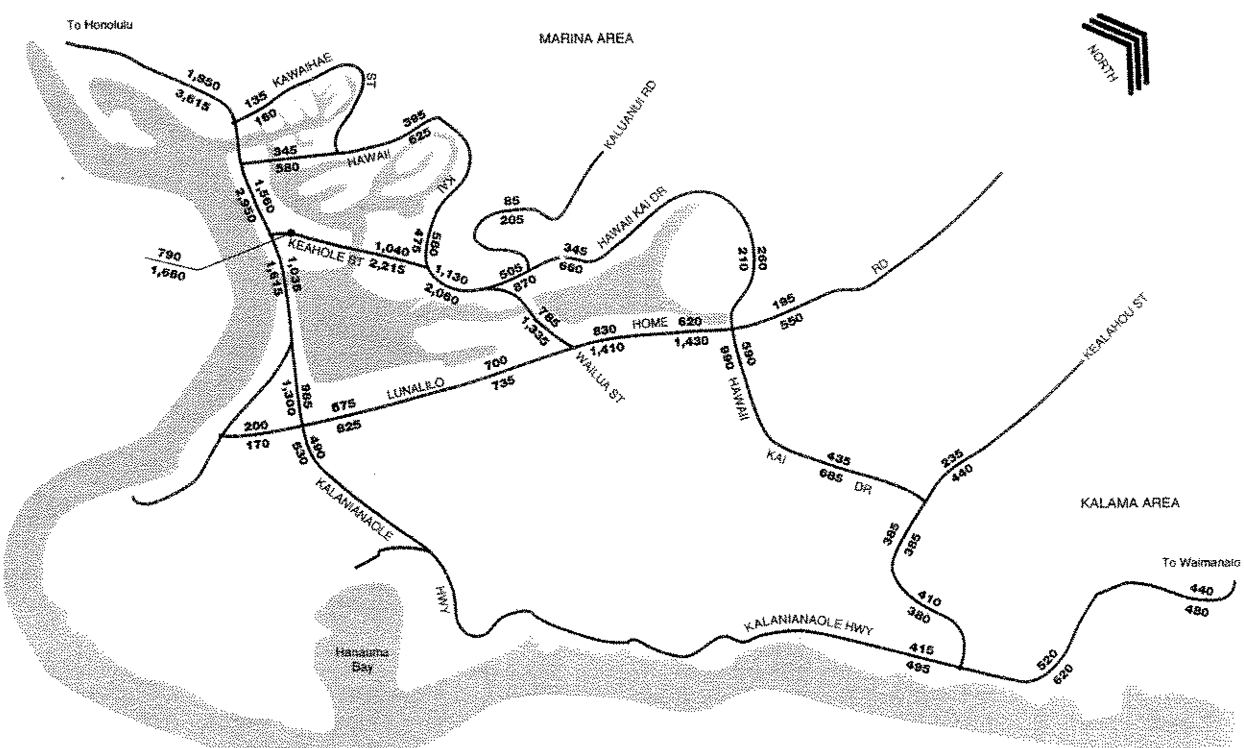


Figure 4-2
2017 WEEKDAY AFTERNOON PEAK HOUR TRAFFIC WITH PROJECT - HAWAII KAI ROADWAYS

The *Project* parcels in the eastern section of Hawaii Kai would substantially increase traffic along Hawaii Kai Drive to/from the Lunalilo Home Road area. Peak direction traffic volumes through this roadway segment are estimated to increase by about 15 and 26 percent during the morning and afternoon peak hours, respectively. The increase in the two-way volume would amount to 275 and 330 vehicles in the morning and afternoon peak hours, respectively.

With the proposed connection of Hawaii Kai Drive through the Kamilonui area, the combined two-way volumes on the segment would approximate 360 and 770 vehicles near Lunalilo Home Road and Kaluanui Road, respectively, during the morning peak hour, and 470 and 1,005 vehicles, respectively, during the afternoon peak hour. The volumes are higher at the Kaluanui Road end since most of the traffic to/from the present and planned developments along this section of roadway would use this segment for travel to the Keahole Street commercial uses and to Honolulu. Through traffic represents an estimated 120 and 200 vehicles during the morning and afternoon peak hours, respectively.

The connection of Hawaii Kai Drive through the Kamilonui area would result in either small increases or decreases in traffic volumes along Lunalilo Home Road and Wailua Street.

One of the largest traffic increases on Hawaii Kai streets would occur along Keahole Street, with a two-way increase of about 390 and 660 vehicles in the morning or afternoon peak hours, respectively. This approximately 30 percent increase reflects the additional commercial developments along this street, as well as usage by the Kamilonui area traffic for travel to/from Kalanianaole Highway.

Peak Hour Traffic on Kalanianaole Highway

Weekday morning and afternoon peak hour traffic volumes along Kalanianaole Highway, with the addition of *Project* traffic, are depicted in Figure 4-3. The morning peak hour volumes include vehicles in both the normal flow lanes and the HOV lane. The *Project* increases to traffic volumes at Kawaihae Street and at Kalaniiki Street are included in Table 4-3.

The largest increases occur at the Kawaihae Street end of the corridor since this segment includes the *Project* trips to/from both the East Honolulu and Honolulu areas, whereas the Kalaniiki Street numbers reflect only the trips to Honolulu. The net increase at the Kalaniiki Street end is also reduced by the diversion of some East Honolulu trips to the *Project*, that otherwise would travel into Honolulu. The *Project* would increase peak direction traffic in the morning peak hour by 460 vehicles at Kawaihae Street and 410 vehicles at Kalaniiki Street. In the afternoon peak hour, the peak direction increase would amount to 330 vehicles at Kalaniiki Street and 395 vehicles at Kawaihae Street.

Volumes in the HOV Lane

Usage of the contraflow HOV lane was assumed to increase in direct relationship to the overall increase in traffic. The resultant volumes are summarized in Table 4-4. The HOV lane volumes in the morning peak hour at Kawaihae Street are estimated as 965 vehicles, or 21 percent of the ewabound traffic, and at Kalaniiki Street, 1,420 vehicles, or 21.1 percent of the ewabound traffic.

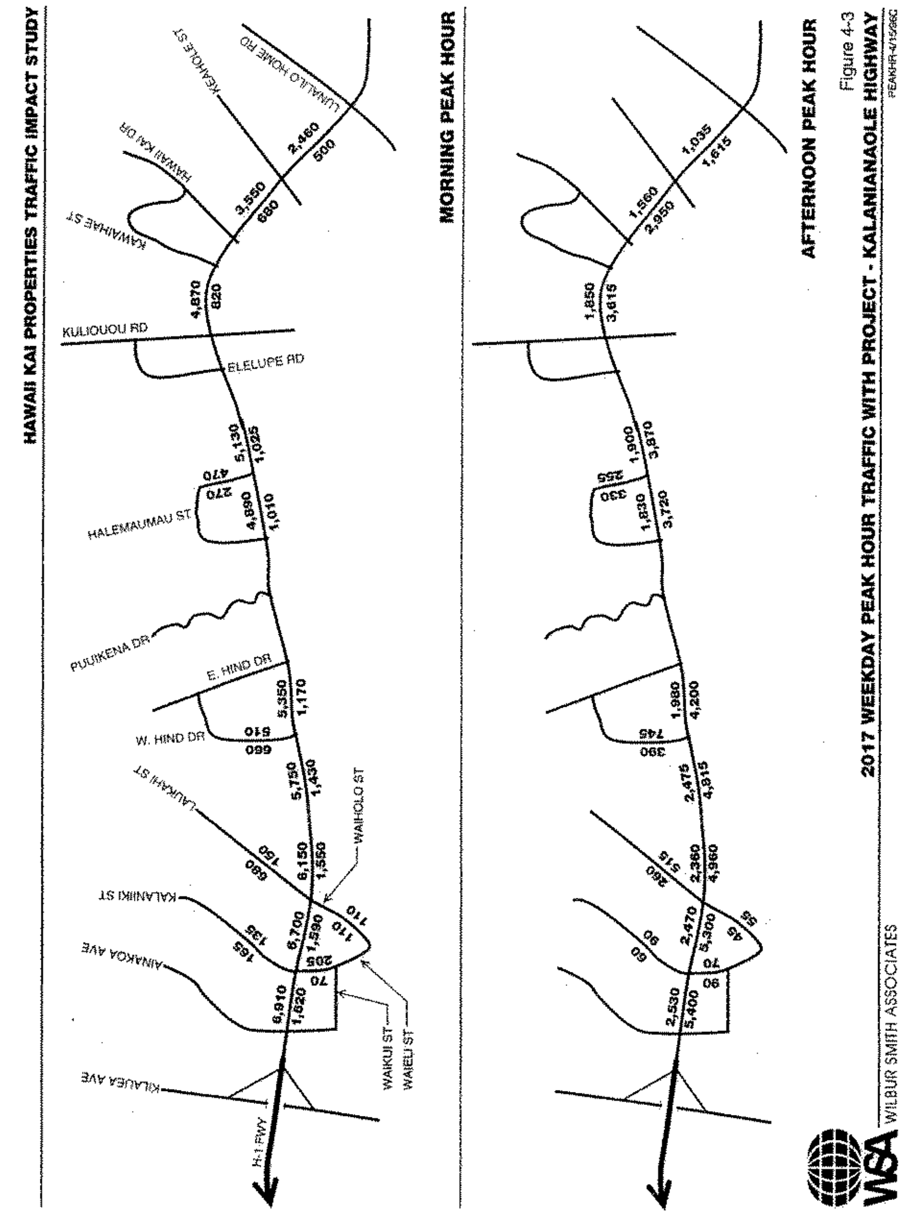


Figure 4-3
2017 WEEKDAY PEAK HOUR TRAFFIC WITH PROJECT - KALANIANAOLE HIGHWAY

Table 4-4

HIGH OCCUPANCY VEHICLE (HOV) LANE USAGE
MORNING PEAK HOUR
Hawaii Kai Properties EIR

Location/Scenario	Item		Ewabound Vehicles		
			Normal Flow Lanes	Contraflow HOV Lane	Total
Kalanianaole Highway at Kawaihae Street					
Existing			3,470	-0-	3,470
Year 2017 Without Project	Shift of Existing Vehicles to HOV Lane[1]		(730)	+730	—
	New Traffic		+540	+140	+680
		Total	3,280	870	4,150
Year 2017 With Project	New Traffic		+355	+95	+450
		Total	3,635	965	4,600
Kalanianaole Highway at Kalanilki Street					
Existing			4,195	1,135	5,330
Year 2017 Without Project	New Traffic		+760	+200	+960
		Total	4,955	1,335	6,290
Year 2017 With Project	New Traffic		+325	+85	+410
		Total	5,280	1,420	6,700

(1) Estimated use of Contraflow HOV lane by existing traffic, if the HOV lane is extended to Hawaii Kai.

Wilbur Smith Associates; March 1996

WEEKDAY CONDITIONS AT KEY INTERSECTIONS

Traffic conditions at the key intersections within Hawaii Kai and along Kalanianaole Highway are summarized in Table 4-5 for Year 2017 weekday morning and afternoon peak hours. The following sections discuss the intersection conditions starting from the east.

Hawaii Kai Intersections

Within the eastern section of Hawaii Kai, the new intersections of the Queen's Rise and Queen's Beach access roadways with Kalanianaole Highway would operate at acceptable levels of delay with STOP sign controls.

The intersection analyses indicate that the Hawaii Kai Drive-Kealahou Street intersection would operate as LOS E in the afternoon peak hour, based on continuation of the present all-way STOP sign controls. Conditions would worsen from LOS C Without the *Project* due to the combined effects of; 1) an increase in intersection complexity and traffic conflicts with the addition of the Mauuwai access road as the fourth leg of this present three-leg intersection; and 2) the cumulative increase of Project traffic through the intersection. Conversion to two-way STOP controls (Kealahou Street as the through street) would result in LOS E conditions. Installation of traffic signal controls could improve overall operating conditions to LOS B. However, the projected peak hour volumes are below the minimum needed to satisfy Warrent 11 (Peak Hour Volumes) to allow installation of a traffic signal.[3] Thus, installation of a traffic signal may not be appropriate at this intersection.

At the intersection of Hawaii Kai Drive with Lunalilo Home Road, the forecast traffic with the *Project* would approximate 95 percent of the intersection capacity, based on the present lanes and traffic signal operation. Intersection conditions could be improved by restriping the west and north legs to indicate two lanes, by restriping the east leg to allow left-turns from both lanes, and by modifying the signal phasing to provide separate phases for the eastbound and westbound approaches of Hawaii Kai Drive.

The Wailua Street intersections with Lunalilo Home Road and Hawaii Kai Drive would operate at acceptable levels. The forecast traffic levels at the Hawaii Kai Drive intersection would utilize about 92 percent of the theoretical capacity in the afternoon peak hour, primarily due to the northbound right-turn movement onto Wailua Street.

The Kalanianaole Highway intersections with Lunalilo Home Road, Hawaii Kai Drive, and Kawaihae Street are each projected to operate at acceptable levels of capacity usage and delay times during both morning and afternoon peak traffic hours. The morning conditions reflect the extension of the contraflow HOV lane eastward through the Keahole Street intersection. Without the contraflow lane, the Hawaii Kai Drive intersection would approach unacceptable conditions in the morning.

At the Keahole Street intersection with Kalanianaole Highway, the projected traffic volumes would approximate 96 and 91 percent of intersection capacity during the morning and afternoon peak hours, respectively. Average delay times would remain at acceptable levels (LOS D or better).

(3) *Manual of Uniform Traffic Control Devices for Streets and Highways*, Federal Highway Administration, 1988.

Table 4-5
(Page 1 of 3)

YEAR 2017 WITH PROJECT INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties EIR

Intersection	AM Peak Hour			PM Peak Hour		
	V/C(1)	AD(2)	LOS	V/C(1)	AD(2)	LOS
1 Kalanianaole Highway/Kalaniiki Street	0.970	12.7	B	0.951	8.3	B
2 Kalanianaole Highway/Laukahi Street	1.008	*	*	1.016	27.7	D
3 Kalanianaole Highway/West Hind Drive	0.922	18.0	C	0.900	7.8	B
4 Kalanianaole Highway/East Halemaumau Street	0.894	17.3	C	0.858	8.2	B
5 Kalanianaole Highway/Kawaihae Street	0.858	9.9	B	0.781	6.5	B
6 Kalanianaole Highway/Hawaii Kai Drive	0.881	27.0	D	0.668	10.4	B
7 Kalanianaole Highway/Keahole Street	0.959	37.6	D	0.910	23.1	C
8 Kalanianaole Highway/Lunalilo Home Road	0.619	13.3	B	0.845	23.2	C
9 Kalanianaole Highway/Kealahou Street	0.482	9.8	B	0.491	13.6	B
10 Kawaihae Street/Hawaii Kai Drive(3)						
Westbound Left/Through/Right-Turn		14.5	C		9.6	B
Eastbound Left/Through/Right-Turn		41.1	E		19.1	C
Northbound Left-Turn		9.0	B		3.5	C
Southbound Left-Turn		2.5	A		4.2	A

Table 4-5
(Page 2 of 3)

YEAR 2017 WITH PROJECT INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties EIR

Intersection	AM Peak Hour			PM Peak Hour		
	V/C(1)	AD(2)	LOS	V/C(1)	AD(2)	LOS
11 Hawaii Kai Drive/Keahole Street	0.586	11.5	B	0.865	16.7	B
12 Hawaii Kai Drive/Wailua Street	0.658	13.2	B	0.917	21.2	C
13 Hawaii Kai Drive/Kaluanui Road						
Westbound Left-Turn		9.1	B		22.2	D
Eastbound Right-Turn		9.7	B		4.9	A
Northbound Left-Turn		4.3	A		3.9	A
14 Wailua Street/Lunalilo Home Road	0.687	6.5	B	0.818	18.3	C
15 Hawaii Kai Drive/Lunalilo Home Road	0.943	21.6	C	0.949	18.2	C
16 Hawai Kai Drive/Kealahou Street(4)		15.6	C		31.8	E
17 Kalanianaole Highway/Queen's Beach						
Westbound Left-Turn		11.0 3.2	A		3.7	A
~~Southbound~~ Northbound Left-Turn		~~[illegible]~~	C		12.4	C

WILBUR SMITH ASSOCIATES

Table 4-5
(Page 3 of 3)

YEAR 2017 WITH PROJECT INTERSECTION LEVELS-OF-SERVICE
Hawaii Kai Properties EIR

Intersection	AM Peak Hour			PM Peak Hour		
	V/C[1]	AD[2]	LOS	V/C[1]	AD[2]	LOS
18 Kalanianaole Highway/Queen's Rise						
Eastbound Left-Turn		4.0	A		4.0	A
Southbound Left-Turn		6.2	B		5.7	B

Notes:

(1) Values in this column represent volume-to-capacity (V/C) ratios for signalized intersections.
(2) AD = Average delay per vehicle, in seconds.
(3) Two-way STOP sign controls.
(4) All approaches controlled by STOP signs.
LOS = Level-of-Service.
* Average delay and Level of Service are not calculated.

Wilbur Smith Associates; March 1996

Without the contraflow lane operation, forecast volumes would exceed capacity in the morning peak hour.

Other East Honolulu Intersections

With the addition of *Project* traffic, traffic conditions would remain at acceptable levels for both the East Halemaumau Street and West Hind Drive intersections with Kalanianaole Highway (Table 4-5).

The projected traffic volumes would use approximately 90 to 92 percent of capacity at the West Hind Drive intersection in the peak traffic hours. At the East Halemaumau Street intersection, the projected volumes would approximate 89 and 86 percent of capacity during the morning and afternoon peak hours, respectively. The average delay per vehicle passing through these two intersections is estimated to remain at acceptable levels (LOS B and C). The *Project* traffic would result in small increases to the overall delay at each intersection. The potential shift of more green time to Kalanianaole Highway traffic could increase delays to traffic exiting these cross streets. This would most likely impact the left-turn movement from East Halemaumau Street and the right-turn from West Hind Drive during the morning peak hour. The additional delay may average 5 to 15 seconds per vehicle.

The Kalanianaole Highway intersections with Kalaniiki and Laukahi Street would continue to function as the capacity constraints to traffic flow through this corridor. In 2017, conditions at the Laukahi Street intersection are projected to be worse than those at Kalaniiki Street. The traffic volumes are projected to exceed the estimated capacity of the existing Laukahi Street intersection by about 1 to 2 percent during each peak hour. At Kalaniiki Street, the projected volumes approximate 97 and 95 percent of intersection capacity in the morning and afternoon peak hours, respectively.

Traffic delays are expected to increase at both intersections. Overall intersection level of service, as measured by the average delay per vehicle, is estimated to remain at acceptable levels (LOS D or better) for the Kalaniiki Street intersection, and for the Laukahi Street intersection in the afternoon peak hour. Delays will likely increase to unacceptable levels for Laukahi Street in the morning peak hour. The more limited impact on average delay time/level of service, as compared to the level of capacity use, results from several factors:

- The traffic signals at these intersections operate using long cycle lengths with most time allocated to Kalanianaole Highway traffic. The signals are interconnected and provide good timing progression, thus minimizing the stops and delays to Kalanianaole Highway traffic.
- Most of the delays occur to traffic exiting the cross streets, which must wait though much of the long cycle length. Average delays to this traffic range from a minimum of 60 seconds to over 130 seconds per vehicle, both limits reflecting LOS F conditions.
- Because 90 to 95 percent of the traffic passes through these intersections along Kalanianaole Highway, with little or no delay, the overall intersection average delay per vehicle remains relatively low. With signal timing similar to present conditions, the average delay per vehicle for peak direction traffic would near double, from 4 to 5 seconds Without the *Project*, to 9 to 10 seconds with the *Project*.

The OMPO Regional Transportation Plan includes plans and programs that would affect traffic condition at these two intersections. These are discussed in Chapter 5. Other mitigation actions are discussed in Chapter 6.

PROJECT IMPACT ON TRAVEL TIME ALONG KALANIANAOLE HIGHWAY

The most recent travel time study along Kalanianaole Highway was made in February 1992 for the OMPO.[4] The study reflects travel conditions with the four-lane section in the Niu Valley-Kuliouou area, but with the reversible lane operations. Since the 1992 field studies were made during construction of the Kalanianaole Highway widening project, the 1992 travel times may be worse than present travel times. However, the 1992 study results should provide a reasonable approximation of present peak hour travel times for the purpose of this assessment.

That study recorded elapsed travel times during both the morning and afternoon peak traffic periods, between Keahole Street in Hawaii Kai and Vineyard Boulevard in Downtown Honolulu. Intermediate control points were identified at a number of locations along Kalanianaole Highway, including Ainakoa Avenue near the beginning of the H-1 Freeway. Vehicle runs were made at 15-minute intervals throughout the peak period for three days (February 11, 12 and 13).

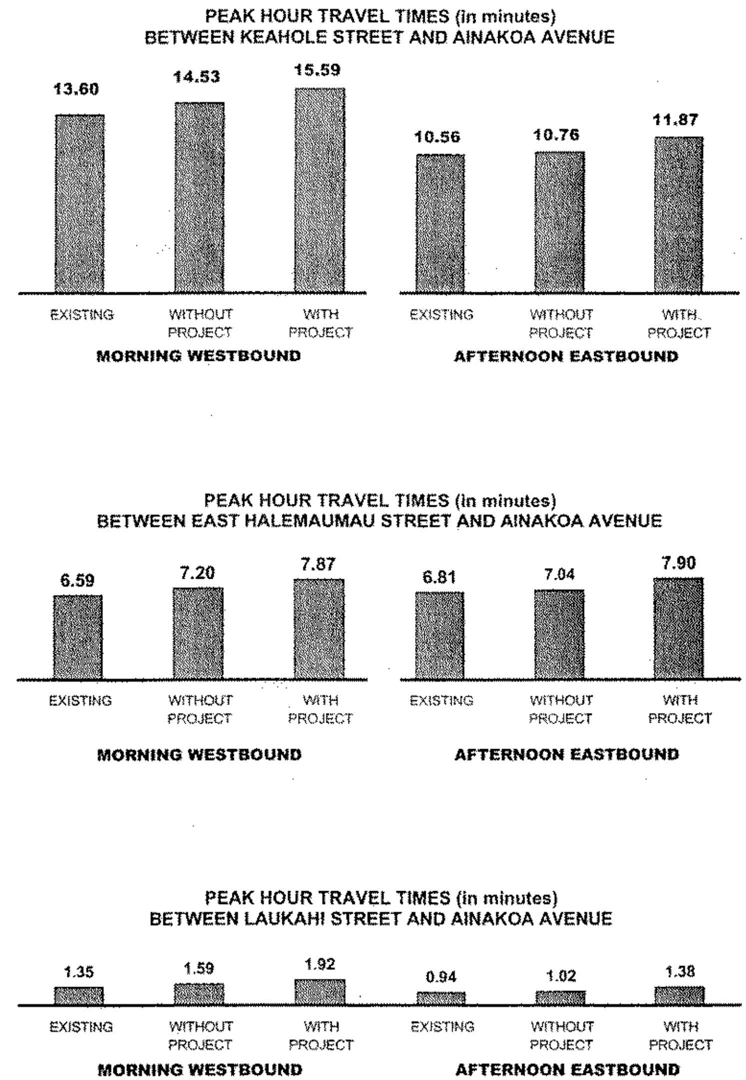
Based on data in the 1992 OMPO study, the peak direction travel time between Keahole Street and Ainakoa Avenue averaged 13.60 minutes in the morning peak hour, and 10.56 minutes in the afternoon peak hour. This approximates an average speed of 19.2 mph in the morning period and 24.7 mph in the afternoon period. The total travel time between Hawaii Kai and Vineyard Boulevard averaged 31.33 and 20.06 minutes in the morning and afternoon, respectively.

Along Kalanianaole Highway the affect of increased traffic volumes would occur primarily at the traffic signal-controlled intersections since these are the primarily constraints to traffic flow. Future changes to travel times were estimated based on the estimates of increased delay times at the traffic signals, as obtained from the analyses of the key intersections for the existing (1996), Without Project, and With Project scenarios. Since this study analyzed only 7 of the intersections, the average delay for these 7 intersections were assumed to also occur at each of the other traffic signals. For each end point, the delay for traffic turning onto or off of Kalanianaole Highway was included in the traffic time.

The comparative changes in travel times are depicted in Figure 4-4 between Keahole Street and Ainakoa Avenue. Travel times are also presented from East Halemaumau Street and from Laukahi Street.

Between Keahole Street and Ainakoa Avenue, year 2017 average travel times in the morning peak hour are estimated to increase by 0.93 minutes, from 13.60 to 14.53 minutes, without the *Project*. The additional *Project* traffic is estimated to increase the average travel time by an additional 1.06

[4] *1992 Peak Period Travel Times for Three Selected Routes on Oahu*, prepared for Oahu Metropolitan Planning Organization (OMPO) by the Hawaii Bicycling League and Julian Ng, Inc., June 1992.



WSA WILBUR SMITH ASSOCIATES

Figure 4-4

ESTIMATED PEAK HOUR TRAVEL TIMES ALONG KALANIANAOLE HWY (in minutes)

TRAVEL-7/7/96C

minutes, thus resulting in an estimated total travel time of 15.59 minutes, or about 2 minutes longer than the present travel time.

In the afternoon peak hour, the average travel time from Ainakoa Avenue to Keahole Street is estimated to increase by 0.2 minutes in year 2017 Without the *Project*. The additional *Project* traffic would increase the travel time by 1.11 minutes.

The proportional increase in average travel times are similar for travel between either the East Halemaumau Street or Laukahi Street intersections and Ainakoa Avenue. The travel time for each include any additional delays in turning out of (morning) or into (afternoon) these two streets.

SUNDAY PEAK HOUR INTERSECTION CONDITIONS

The development of the *Project* parcels would add traffic along the two-lane section of Kalanianaole Highway, where the highest traffic volumes occur on Sundays due to the major recreational and sightseer attractions in this area. To assess the *Project* impacts to this area, traffic forecasts were prepared and conditions analyzed for the four key intersections during the Sunday early afternoon (beachgoer arrivals) and late afternoon (departures) peak hours.

The forecast traffic volumes, and the *Project* contribution to these volumes, are depicted in Figure 4-5. The *Project* adds about 190 to 200 vehicles (17 percent increase) through the Sandy Beach-Hanauma Bay segment and about 290 vehicles (20 percent increase) through the Kealahou Street-Queen's Beach segment during each peak hour. Most of the increase would result from the Queen's Rise and Queen's Beach developments. On the Windward side of these parcels at Makapuu Point, the increase would approximate 120 vehicles, or an 8 percent increase.

With the addition of the *Project* traffic, traffic conditions would remain at acceptable service levels (LOS B or C) at the two traffic signal-controlled intersections along this segment (Kalanianaole Highway at Lunalilo Home Road and at Kealahou Street). Traffic volumes would approach 95 percent of the capacity of the Lunalilo Home Road intersection during the late Sunday afternoon period. This is due to the single ewabound through lane to accommodate the traffic travelling towards Honolulu. Conditions at these intersections are summarized in Table 4-6. Future Kealahou Street conditions reflect the planned addition of traffic signal controls as well as a left-turn lane on Kalanianaole Highway.

The estimated increase in *Project* traffic along Kalanianaole Highway would result in increased delays for vehicles turning left from the Sandy Beach and Hanauma Bay park driveways. As summarized in Table 4-6, the delays to vehicles turning left from the Sandy Beach west driveway towards Honolulu would worsen from LOS D to LOS E in the early afternoon period, and from LOS E to LOS F in the late afternoon period. These conditions likely overstate the problem at the Sandy Beach driveway since installation of a traffic signal at the nearby Kealahou Street intersection would provide gaps in the ewabound traffic flow to facilitate the left turns. Also, more of the left-turn traffic could exit via the less-used east driveway.

Delays would increase at the Hanauma Bay driveway, although the average delay would not be likely to increase by the extent shown in Table 4-6 (to 435 seconds). The stop sign analyses methodology is unstable when volumes exceed the theoretical capacity. The assessment does indicate that actions

HAWAII KAI PROPERTIES TRAFFIC IMPACT STUDY

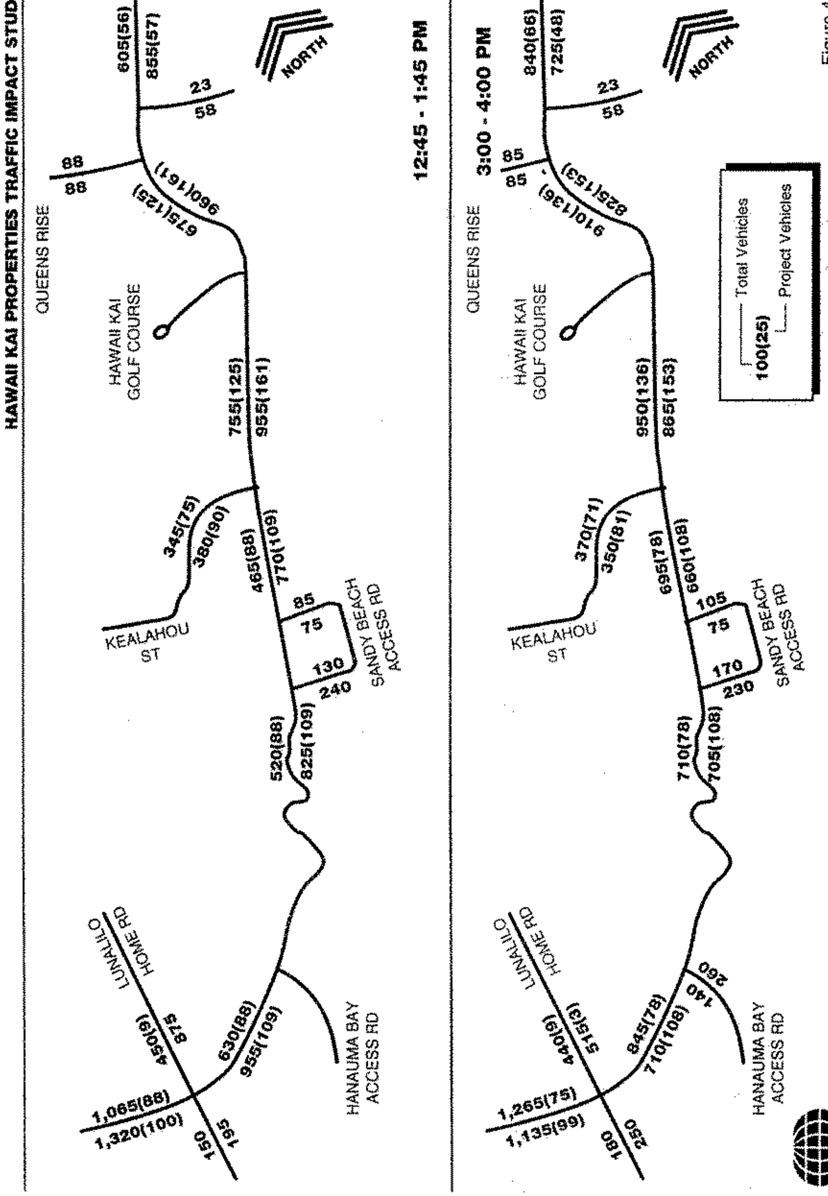


Figure 4-5
2017 SUNDAY PEAK HOUR TRAFFIC WITH PROJECT
SUNDAY-7/7/96C

Table 4-6
(Page 2 of 2)

SUNDAY INTERSECTION LEVELS OF SERVICE
Hawaii Kai Properties EIR

Intersection/Scenario	Early Afternoon			Late Afternoon		
	V/C(1)	ADPV	LOS	V/C(1)	ADPV	LOS
Kalanianaole Highway at Kealahou Street						
Existing(2)	--	166	F	--	383	F
2017 Without Project	0.517	9.4	B	0.547	10.0	B
2017 With Project	0.618	11.0	B	0.641	11.6	B
Kalanianaole Highway at Queen's Rise Access Road						
2017 With Project	--	14	C	--	17	C
Kalanianaole Highway at Queen's Beach Golf Course Driveway						
2017 Wth Project	--	28	B	--	33	E

(1) = Reserve capacity is shown for STOP sign controls.
(2) = STOP sign-controlled intersection.
* = Driveway closed on day of survey due to parking constraints.
V/C = Volume-to-Capacity Ratio
ADPV = Average delay per vehicle per second
LOS = Level-of-Service

Wilbur Smith Associates; March 1996

Table 4-6
(Page 1 of 2)

SUNDAY INTERSECTION LEVELS OF SERVICE
Hawaii Kai Properties EIR

Intersection/Scenario	Early Afternoon			Late Afternoon		
	V/C(1)	ADPV	LOS	V/C(1)	ADPV	LOS
Kalanianaole Highway at Lunalilo Home Road						
Existing	0.632	11.6	B	0.853	17.6	C
2017 Without Project	0.689	12.8	B	0.924	22.4	C
2017 With Project	0.745	13.5	B	0.946	24.0	C
Kalanianaole Highway at Hanauma Bay Driveway(2)						
Existing	*	*	*	--	53	F
2017 Without Project	*	*	*	--	109	F
2017 With Project	*	*	*	--	435	F
Kalanianaole Highway at Sandy Beach West Driveway(2)						
Existing	--	16	C	--	26	D
2017 Without Project	--	20	D	--	38	E
2017 With Project	--	34	E	--	100	F

may be needed to reduce delays on peak visitation days to the Hanauma Bay park facilities. A mitigative action would be use of manual control of traffic at the driveway intersection during the period when most traffic exits the parking lot.

SERVICE LEVELS ON KALANIANAOLE HIGHWAY TWO-LANE SEGMENT

Traffic conditions were analyzed along the two-lane segment of Kalanianaole Highway where operations are affected by the horizontal and vertical alignment features of the roadway. The analysis results are summarized in Table 4-7 for the uphill segment near Hanauma Bay, the winding segment near the Blowhole, and the uphill segment at Makapuu Point.

The *Project* traffic would reduce the service level on each of the three roadway segments during the weekday afternoon peak hour; from LOS C to D at Hanauma Bay, and from LOS D to E for the Blowhole and Makapuu Point segments. These service levels indicate that vehicle speeds would be controlled by the slowest-moving vehicles, and that long platoons would form. The projected traffic volumes would use 50 percent or less of the roadway capacity.

The higher traffic volumes on Sunday afternoon would result in all three segments operating at LOS E conditions, both for existing and future conditions. The future traffic would amount to approximately 70 to 76 percent of capacity with the *Project*, with the *Project* adding 5 to 9 percent to the usage level. With the slower speeds, more of the "through" traffic, particularly to/from the *Project* parcels, would likely choose to travel through Hawaii Kai via Kealahou Street-Hawaii Kai Drive-Lunalilo Home Road than through the Blowhole segment. Traffic volumes on these Hawaii Kai roadways are much lighter on weekends and holidays, when additional traffic may travel on these roads to bypass the Blowhole section, and therefore should be able to accommodate the increases without a substantial impact on traffic conditions.

MAUUWAI ACCESS VIA KALANIANAOLE HIGHWAY

The access road to the Mauuwai residential area is planned to connect to the Hawaii Kai Drive-Kealahou Street intersection. However, dependent on further studies, the Mauuwai access road may be connected to Kalanianaole Highway instead of the Hawaii Kai Drive connection. The alternative plan would be to connect the access road to Kalanianaole Highway near the present access to the Hawaii Kai Golf Course, with the Golf Course access modified to share one common access roadway with the Mauuwai development. Such a modification would directly affect future conditions at the shared Mauuwai-Hawaii Kai Golf Course access roadway intersection with Kalanianaole Highway, and at the Hawaii Kai Drive-Kealahou Street intersections.

Without the connection, the Hawaii Kai Golf Course driveway would accommodate an estimated 25 entering and 6 exiting vehicles in the morning peak hour, and 36 entering and 83 exiting vehicles in the afternoon peak hour in year 2017. Approximately 90 percent of these vehicles turn to/from the ewa direction. With the shared roadway, the access road would accommodate 56 entering and 98 exiting vehicles in the morning peak hour, and 135 entering and 148 exiting vehicles in the afternoon peak hour.

Table 4-7

KALANIANAOLE HIGHWAY TWO-LANE SEGMENTS PEAK HOUR LEVELS OF SERVICE
Hawaii Kai Properties EIR

Location/ Scenario	Weekday Afternoon			Sunday Afternoon		
	Two-Way Volume	V/C(4)	LOS	Two-Way Volume	V/C(4)	LOS
Hanauma Bay(1)						
Existing	672	0.33	C	1,288	0.63	E
2017 Without Project	791	0.39	C	1,387	0.68	E
2017 With Project	1,019	0.50	D	1,584	0.76	E
Blowhole(2)						
Existing	592	0.33	D	1,152	0.59	E
2017 Without Project	681	0.37	D	1,230	0.62	E
2017 With Project	909	0.50	E	1,416	0.71	E
Makapuu Point(3)						
Existing	689	0.37	D	1,253	0.60	E
2017 Without Project	821	0.41	D	1,349	0.65	E
2017 With Project	967	0.45	E	1,462	0.70	E

(1) Long uphill segment between Lunalilo Home Road and Hanauma Bay Access Road.
(2) Winding segment between Hanauma Bay Access Road and Sandy Beach.
(3) Segment west of Makapuu Point
(4) The volume-to-capacity (V/C) indicates the ratio of the existing or estimated peak hour traffic volume to the calculated maximum vehicle flow rate at LOS E.
LOS Level-of-Service

Wilbur Smith Associates; March 1996

Intersection conditions are summarized in Table 4-8 with the two Mauuwai access alternatives. The shared access connection to Kalanianaole Highway would have little effect on delay times for most vehicles turning left to/from the driveway, except for the left-turn out of the shared roadway, which would worsen from LOS C to D in the morning peak hour. However, this is within acceptable limits and only affects about 7 vehicles in the morning peak hour.

The deletion of the connection to the Hawaii Kai Drive-Kealahou Street intersection would improve conditions at that intersection. The deletion of the fourth leg would primarily affect afternoon peak hour conditions, when the intersection would operate at LOS D without the Mauuwai roadway connection, versus LOS E with the Mauuwai connection.

The Mauuwai connection to Kalanianaole Highway, rather than to Hawaii Kai Drive, would also shift some of the project traffic to use of Kalanianaole Highway to travel into East Honolulu and Honolulu, rather than using Hawaii Kai Drive and travel through the Marina section. The estimated change in year 2017 peak hour traffic volumes between the two routes is as follows:

	Kalanianaole Highway Through Blowhole-Hanauma Bay			Hawaii Kai Drive Across Kamehame Area		
	Volume With Current Plan	Change With Driveway Change	Percent Change	Volume With Current Plan	Change With Driveway Change	Percent Change
Morning Peak Hour						
Westbound	585	+39	+6.7	775	-39	-5.0
Eastbound	245	+12	+4.9	500	-12	-2.4
Afternoon Peak Hour						
Westbound	415	+18	+4.4	435	-18	-4.3
Eastbound	495	+52	+10.5	685	-52	-7.6

PUBLIC TRANSIT

The development of the *Project* parcels would affect both the bus services and usage levels in Hawaii Kai. Key considerations regarding TheBus are summarized in the following paragraphs.

***Project* Access to TheBus Routes** - Most of the parcels are located adjacent to existing TheBus routes (Marina 1, Marina 4B, Kalama Valley, Golf Course 2/1A, Queen's Rise, and Queen's Beach parcels). The Kamilonui 1 and Kamilo Ridge are located adjacent to the planned connection of Hawaii Kai Drive and could be readily serviced by a new or rerouted TheBus route. The Kamilonui 2 and Mauuwai parcels are each located about one-half mile from a bus route, well beyond convenient walking distance. Most bus riders from these two parcels would likely have to access a bus stop via automobile or bicycle.

Hawaii Kai Drive Connection - The roadway connection through the Kamilonui area would allow routing of either Route 1, Route 58, Route 80A, Route 82, or a new route(s) to serve this area. This would improve bus access to the Mariner's Cove, Anchorage, and Kealaula Kai residential areas, as well as to the *Project* parcels. If existing TheBus trips are routed through this roadway, a comparable reduction in service may occur along lower Lunalilo Home Road.

Table 4-8

INTERSECTION CONDITIONS WITH MAUUWAI CONNECTION TO KALANIANAOLE HIGHWAY
Hawaii Kai Properties EIR

Intersection	Scenario	Morning Peak Hour Average Delay/Vehicle (Seconds)	Morning Peak Hour Level of Service	Afternoon Peak Hour Average Delay/Vehicle (Seconds)	Afternoon Peak Hour Level of Service
Kalanianaole Highway & Hawaii Kai Golf Course - Mauuwai Driveway[1]					
• Left Turn from Driveway	Mauuwai Connects to Hawaii Kai Drive	14.1	C	18.2	C
	Mauuwai Connects to Kalanianaole Highway	15.6	C	25.9	D
• Eastbound Left Turn into Driveway	Mauuwai Connects to Hawaii Kai Drive	4.3	A	3.9	A
	Mauuwai Connects to Kalanianaole Highway	4.4	A	4.4	A
Hawaii Kai Drive - Kealahou Street[2]					
	Mauuwai Connects to Hawaii Kai Drive	15.6	C	31.8	E
	Mauuwai Connects to Kalanianaole Highway	11.8	C	20.9	D

(1) Mauuwai and Hawaii Kai Golf Course share common driveway at new location east of existing driveway.
(2) With present all-way STOP controls.

Wilbur Smith Associates; March 1996

Park-and-Ride Facility Layout - Development of the Marina 1/Strip 1 parcel would result in a shift of the park-and-ride facility further mauka. Adequate circulation provisions should be included in the new layout to maintain convenient accessibility for both buses and automobiles, and safety for both vehicles and pedestrians.

Park-and-Ride Facility Capacity - The present lot includes 139 stalls for all-day parking. At present, about 60 to 70 stalls are used on weekdays. Based on the present ratio of users to housing units, the approved and *Project* parcels would result in total usage of about 90 to 100 stalls, or about 70 percent of the present number of stalls.

Increases in TheBus Passengers - Ewabound TheBus service from Hawaii Kai is heavily used during the morning peak period. The future passenger use, based on the current mode split, would be as follows:

	Morning Peak Hour	Morning Peak Period
Present Riders	435	840
Approved Development	80	155
Project Parcels	55	105
Total	**570**	**1,100**

Two-thirds of the riders use express buses and one-third use local bus services.

Increase in Bus Service - The estimated increase in TheBus riders would require 3 to 4 additional bus trips from Hawaii Kai during the morning peak period. This may require an additional 2 to 4 buses. A similar increase in bus trips would be needed in the afternoon peak period. Two of the additional bus trips in each peak period would result from the *Project*, with the other trips a result of the approved developments.

Increase in TheHandi-Van Use - Fiscal Year 1996 ridership for Oahu amounts to 53,472 riders per month, or about 0.18 riders per household.(5) An average 2.6 riders are served on each TheHandi-Van vehicle trip. The 1,512 new housing units planned for the *Project* parcels could thus generate an estimated 273 riders per month, which may require about 105 additional TheHandi-Van vehicle trips to/from Hawaii Kai each month.

The estimated TheBus and TheHandi-Van riders and vehicle requirements may not represent increases to each system. Given that the riders would likely reside on Oahu with or without the *Project*, the ridership and vehicle trip estimates would primarily reflect a change in the location of the travel origin, rather than an increase in systemwide totals.

(5) TheHandi-Van Operations Summaries for March and April, 1996, Laidlaw Transit Services.

BICYCLE FACILITIES

The principal effect of the *Project* on bicycle travel would be an increase in vehicular traffic volumes along many of the streets designated as bicycle routes. The bicycle routes most affected by these traffic increases would be:

- Keahole Street;
- Hawaii Kai Drive between Lunalilo Home Road and Kealahou Street;
- Kealahou Street; and
- Kalanianaole Highway between Lunalilo Home Road and Queen's Beach.

The *Project* may reduce traffic along Lunalilo Home Road and Wailua Street. The magnitude of these traffic increases and decreases during peak traffic periods is discussed in previous sections of this chapter.

The connection of Hawaii Kai Drive through the Kamilonui area would offer another potential bicycle route. This route would likely provide fewer traffic conflicts than the parallel Wailua Street-Lunalilo Home Road route.

5. YEAR 2017 TRAVEL CONDITIONS WITH OAHU REGIONAL TRANSPORTATION PLAN IMPROVEMENTS

The Oahu Regional Transportation Plan (Oahu RTP)[1] includes roadway, public transit, and travel demand management (TDM) plans and programs that would affect travel conditions in the Kalanianaole Highway corridor. These plans are summarized in "Transportation System Improvements" in Chapter 3. The Oahu RTP includes several roadway projects for the corridor, but most of the corridor changes are related to transit improvements and TDM actions.

The "baseline" analyses of future traffic conditions presented in Chapters 3 and 4 reflect only two planned modifications, both implementable within the next several years. These are:

- Intersection modifications on Kalanianaole Highway at Kealahou Street; and
- Extension of the morning contraflow HOV lane to Hawaii Kai.

This chapter assesses the potential effects of other plans and programs on travel conditions along Kalanianaole Highway. These programs are primarily focused on encouraging alternatives to driving, and are likely to result in gradual changes over a longer period of time.

OAHU RTP ELEMENTS

The description of the Oahu RTP elements, as considered in this study, are outlined in the following paragraphs.

Highway Element

The Oahu RTP includes the widening of Kalanianaole Highway to add a westbound lane between Laukahi Street and the Kilauea Avenue off-ramp. This would increase capacity for the Laukahi Street, Kalaniiki Street, and Ainakoa Avenue intersections.

The additional lane could begin on the ewa side of Laukahi Street, with a channelized island provided to permit a "free" right turn movement from Laukahi Street. The right-turn from Laukahi Street would then only have to stop for pedestrian crossings of Laukahi Street, and could continue at the same time as the through movements along Kalanianaole Highway.

The Laukahi Street vehicles would have to merge into the ewabound through lanes before reaching the Kilauea Avenue off-ramp. At the Kilauea Avenue off-ramp, the additional westbound lane would end as a deceleration lane exiting onto the off-ramp. The additional lane would function as a "weaving lane," accommodating Laukahi Street traffic merging into ewabound through lanes and traffic weaving into the lane to exit the off-ramp. In the morning peak hours, with the large volumes of traffic entering at Laukahi Street and exiting onto the Kilauea Avenue off-ramp, the

[1] *Oahu Regional Transportation Plan*, prepared for the Oahu Metropolitan Planning Organization (OMPO) by Kaku Associates, November 1995.

additional lane would accommodate traffic volumes comparable to those in each of the three through lanes.

The widening project is planned for implementation in the 2006 to 2020 period, at an estimated cost of $20 million. The widening would likely require some right-of-way acquisition along the mauka side of the roadway.

Transit Element

The Transit Element includes a number of improvements to expand capacity of the transit services, and to improve transit operations. The principal elements that would affect the Kalanianaole Highway corridor are:

- Expansion of TheBus fleet to 715 buses, from the present 525 buses, which would likely provide for increased express and local bus services to East Honolulu.
- Construction of a rapid transit system from UH Manoa area to Pearl City. Although the rapid transit line would not extend into East Honolulu, it could benefit corridor travel by:
  1. Freeing up some buses now used in the rapid transit corridor for redeployment to increase bus services in the East Honolulu corridor.
  2. Improving transit access from East Honolulu to the Kakaako, Iwilei, Airport, Pearl Harbor and Pearl City areas.
  3. Providing improved midday or peak hour service between areas in the U.H. Manoa-Pearl City corridor for East Honolulu residents working in or visiting these areas.

The transit improvements, when combined with TDM actions, are intended to increase transit use and to reduce vehicle trips.

TDM Element

The TDM Element encompasses a broad range of actions intended to reduce vehicle trips in the peak traffic periods. Included are improvements to the system of HOV lanes, park-and-ride facilities, bicycle facilities, and pedestrian facilities. It also encompasses programs to encourage changes in work hours, parking management programs, and programs to facilitate and coordinate ridesharing actions.

The TDM action having the most direct effect on East Honolulu would be the extension of the morning contraflow HOV lane eastward onto the H-1 Freeway to Kapiolani Boulevard. This extension would provide a number of benefits:

1. The extension would continue through the stacking area of the H-1 Freeway "bottleneck" in the Manoa area, thus increasing the time savings for users of the HOV lane, and increasing the attractiveness of carpooling or using express buses.

2. It would eliminate the HOV lane crossover at Ainakoa Avenue, thus increasing the traffic capacity and safety in this segment.

3. The removal of the HOV lane crossover would allow normal functioning of the traffic signal at Ainakoa Avenue during the morning peak period, which should improve conditions for vehicles entering or exiting Ainakoa Avenue and Waikui Street.

4. The "contraflow" HOV lane would increase the ewa direction traffic-carrying capacity of the H-1 Freeway during the morning peak period.

ANALYSES ASSUMPTIONS

The additional westbound lane between Laukahi Street and the Kilauea Avenue off-ramp would increase roadway capacity through this segment. The effectiveness of this capacity would be determined by the number of vehicles continuing through the Kalaniiki Street intersection in this lane. Given near-capacity conditions, most of the weaving traffic would likely use this lane through the intersection. Since the weaving volumes would approximate[(2)] one-quarter of the traffic, the Kalaniiki Street analyses was made using normal capacity, but using a lane utilization factor of 1.10 to reflect lower volumes in the additional lane.

The transit, HOV, and other TDM actions would primarily affect the volume of traffic travelling in the peak traffic hours. These elements are intended to reduce peak hour vehicle trips through encouraging ridesharing (carpools, vanpools, and transit), encouraging bicycle use, and encouraging a shift of trips to periods outside the peak hours.

The Oahu RTP provides two sets of year 2020 travel forecasts, with a "Baseline" forecast reflecting conditions without implementation of the transportation plans, and a "With Plan" forecast reflecting a reduced volume of vehicle travel with implementation of the transit and TDM elements, as well as the highway improvements. For the East Honolulu corridor, the Oahu RTP provides morning peak hour and weekday forecasts at two locations, at Kapakahi Stream on the ewa side of Kalaniiki Street, and at Niu Valley. Based on travel forecasts presented in the Oahu RTP for the Baseline and With Plan scenarios, the Plan is projected to result in the following reductions to future traffic volumes along Kalanianaole Highway

	At Kapakahi Stream	At Niu Valley
Morning Peak Hour		
Eastbound	-3.4%	-3.1%
Westbound	-6.9%	-6.9%
Total Weekday	-4.2%	-5.0%

The year 2017 traffic conditions presented without and with the Hawaii Kai development *"Project"* (Chapters 3 and 4, respectively) reflect traffic forecasts based on a continuation of existing travel characteristics, comparable to the Oahu RTP "Baseline" forecasts. Therefore, successful implementation of the regional transit and TDM plans and programs would result in lower levels of future travel growth than those analyzed in Chapter 3 and 4.

(2) Op. Cit., Tables 2-6 and 2-7.

To evaluate the effects of the transit/TDM programs on the year 2017 conditions, the "baseline" morning traffic volumes in Chapters 3 and 4 were reduced by the same percentage as the differences forecast for Kalanianaole Highway in the Oahu RTP. Since no afternoon peak hour forecasts were provided in the Oahu RTP, the daily reduction of 5.0 percent was assumed to apply to the afternoon peak hour, peak direction traffic. The off-peak direction was reduced by 2.5 percent, since the morning peak hour Oahu RTP forecasts indicate the off-peak direction reduction is about one-half of the peak direction.

PEAK HOUR TRAFFIC VOLUMES

The year 2017 peak hour traffic volumes, with the lower traffic volumes from the implementation of the transit and TDM improvements included in the Oahu RTP, are depicted in Figures 5-1 and 5-2 for Without and With the Hawaii Kai Project, respectively. The volumes are depicted only along Kalanianaole Highway since that is where the largest changes should occur. The reduction due to transit/TDM actions were applied to through traffic along Kalanianaole Highway, and cross street traffic turning to/from the ewa direction.

In the morning peak hour, the transit/TDM plans are estimated to result in peak direction traffic volumes 200 to 460 vehicles lower than those discussed in Chapters 3 and 4. The reductions in the afternoon peak direction volumes would be 130 to 270 vehicles below those analyzed in Chapters 3 and 4.

INTERSECTION CONDITIONS

The combination of the additional westbound lane and the lower traffic volumes would greatly improve morning peak hour conditions at the Kalanianaole Highway intersections with Laukahi and Kalaniiki Streets. As summarized in Table 5-1, the lower 2017 traffic volumes would use 85 percent or less of the intersection capacity in the morning.

Afternoon conditions would also improve at the Kalaniiki and Laukahi Street intersections, but to a much lesser extent than in the morning. The additional westbound lane provides little benefit in the afternoon period, so the improvement results from the lower traffic volumes. The Laukahi Street intersection would be the one location with a very high volume-to-capacity rate, with the afternoon traffic equal to about 96 percent of capacity.

With only the additional westbound lane, without any traffic reduction, morning traffic conditions at the Kalaniiki and Laukahi Street intersections would be at acceptable levels. At Laukahi Street, the higher 2017 volumes (Chapter 4) would use 90 percent of capacity and operate at LOS B with the Hawaii Kai Project. Traffic at the Kalaniiki Street intersection would use 81 percent of capacity and operate at LOS B for With Project scenario. Therefore, the provision of the additional lane would be sufficient to alleviate capacity problems at these two intersections in the morning.

The other intersections along Kalanianaole Highway would all operate at 90 percent of capacity or less in both peak hours.

Table 5-1

KALANIANAOLE HIGHWAY INTERSECTION CONDITIONS
YEAR 2017 WITH OMPO REGIONAL TRANSPORTATION PLAN[1]
Hawaii Kai Properties EIR

Intersection	Scenario	Morning Peak Hour: Volume-To-Capacity Ratio [2]	Morning Peak Hour: Average Delay Per Vehicle (Sec)[3]	Morning Peak Hour: Level of Service	Afternoon Peak Hour: Volume-To-Capacity Ratio [2]	Afternoon Peak Hour: Average Delay Per Vehicle (Sec)[3]	Afternoon Peak Hour: Level of Service
Kalaniiki St.	Without Project	0.704	7.2	B	0.852	4.4	A
	With Project	0.746	6.5	B	0.905	5.7	B
Laukahi St.	Without Project	0.791	6.9	B	0.888	13.8	B
	With Project	0.855	8.1	B	0.962	32.5	D
West Hind Dr.	Without Project	0.804	14.2	B	0.787	6.9	B
	With Project	0.906	16.2	C	0.855	7.2	B
East Halemaumau St.	Without Project	0.714	10.3	B	0.740	6.9	B
	With Project	0.823	12.7	B	0.817	7.6	B
Kawaihae St.	Without Project	0.678	7.7	B	0.664	5.6	B
	With Project	0.785	8.2	B	0.742	6.0	B
Hawaii Kai Dr.	Without Project	0.726	21.4	C	0.572	9.2	B
	With Project	0.809	24.3	C	0.636	10.1	B
Keahole St.	Without Project	0.804	26.0	D	0.750	18.4	C
	With Project	0.907	31.5	D	0.878	21.9	C

(1) Intersection conditions reflect traffic reductions due to regional transit and travel demand management actions, plus additional westbound lane from Laukahi Street to Kilauea Avenue off-ramp.
(2) Proportion of intersection capacity used by projected traffic volumes.
(3) Average delay per vehicle, in seconds, for all vehicles passing through the intersection.

Wilbur Smith Associates; March 1996

294022

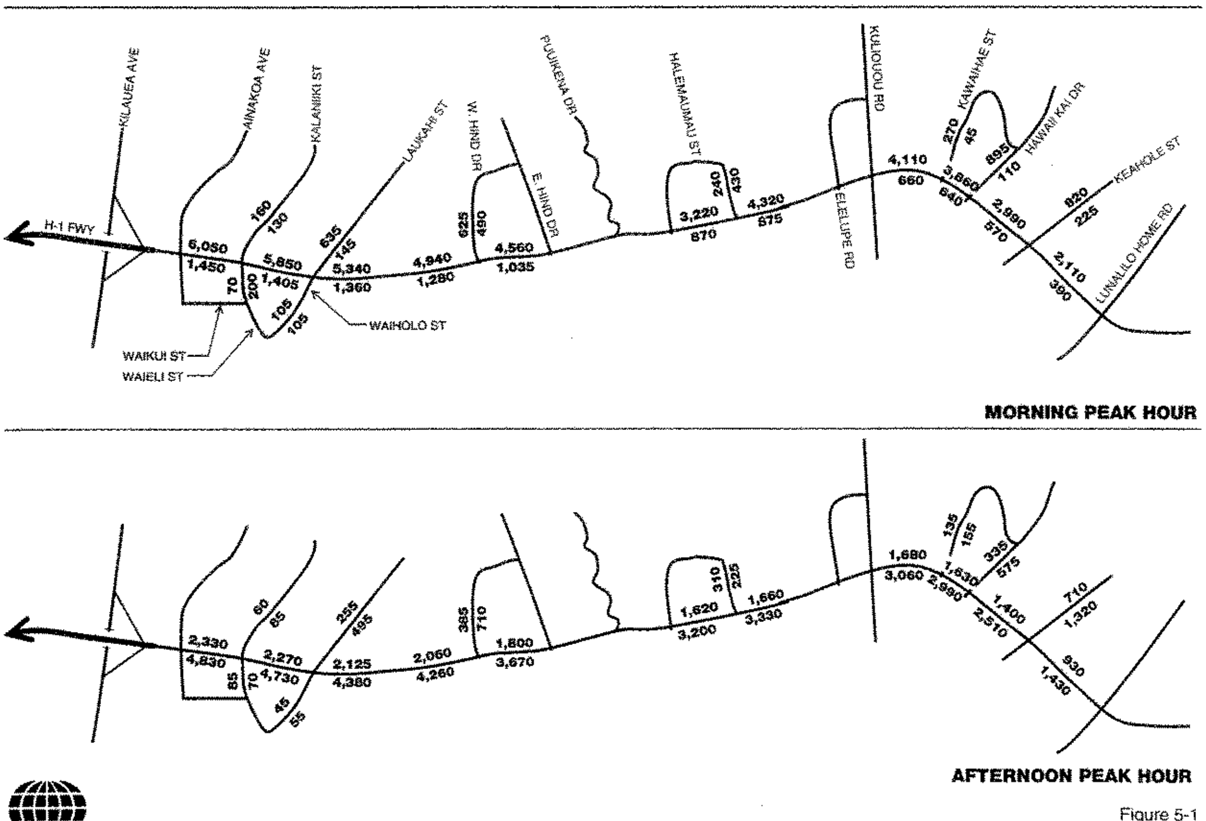


Figure 5-1

2017 PEAK HOUR TRAFFIC ON KALANIANAOLE HWY WITHOUT PROJECT WITH REGIONAL TRANSPORTATION PLAN

WSA WILBUR SMITH ASSOCIATES

PEAKHR-4/15/96C

6. MITIGATION ACTION

The traffic impact analyses, as summarized in Chapter 4, indicate that the existing or planned capacity of most of the area's roadways and key intersections is sufficient to accommodate the weekday and weekend travel volumes forecast with completion of the *Project*. These *Project* forecasts represent the buildout of the Hawaii Kai community. The forecasts reflect the estimated travel increases from other sources through Year 2017. Very limited development would be likely in East Honolulu beyond the levels reflected in this analyses.

The traffic analyses with the longer-range improvements identified in the Oahu Regional Transportation Plan (RTP) as discussed in Chapter 5, indicate that the westbound widening between Laukahi Street and the Kilauea Avenue off-ramp would result in very acceptable travel conditions along the ewa end of Kalanianaole Highway during the morning peak period. Also, the transit improvements and TDM actions included in the Oahu RTP are likely to result in fewer vehicle trips in both the morning and afternoon peak periods as compared to the forecasts presented in Chapter 4.

Based on these analyses, traffic mitigation actions may be needed to address three types of problems. These are:

1. Access to/from several of the approved and *Project* parcels in Hawaii Kai;
2. Traffic operations or capacity problems at several intersections in Hawaii Kai, primarily along the major Hawaii Kai Drive-Keahole Street route between Kalama Valley and Kalanianaole Highway; and
3. Capacity constraints at the intersections of Kalanianaole Highway with Laukahi Street and, to a lesser extent, Kalaniiki Street during the afternoon peak hour.

ACCESS TO *PROJECT* PARCELS

Modifications to several *Project* driveway connections and/or adjacent roadways are recommended to minimize potential disruption of traffic flow.

Marina 1/Strip 1 - Planned access for this commercial development is a new driveway along Kalanianaole Highway restricted to right-turns in/out, a new driveway connection to Hawaii Kai Drive, and use of the existing park-and-ride facility driveway to Keahole Street opposite Gas Express.

- The left-turn movement out of the Hawaii Kai Drive towards Kalanianaole Highway should be prohibited; left-turns-in can be allowed. This restriction is appropriate given the likely difficulty in making a left-turn due to traffic volumes and sight distance restrictions, and the availability of reasonable alternative routings.

- Convenient park-and-ride facility access via traffic signal-controlled driveway(s) must be maintained to assure reasonable bus and automobile circulation for the facility.
- The relocation of the park-and-ride facility should not reduce the number of parking stalls or bus loading bays.

Queen's Rise - This residential subdivision would have a mauka-side local street connection to Kalanianaole Highway near the bottom of the hill section south of Makapuu Lookout.

- A left-turn storage lane should be provided on Kalanianaole Highway for northbound vehicles turning into the new access roadway to minimize any delays and safety problems for northbound through traffic.
- A short deceleration lane and/or channelization to allow right-turns into the parcel access roadway without these vehicles having to slow substantially while in the southbound through lane.

Queen's Beach Golf Course - The Golf Course access roadway would intersect Kalanianaole Highway near the bottom of the hill section south of the Makapuu Lookout, just south of the curve near the Lighthouse access road.

- A left-turn storage lane should be provided on Kalanianaole Highway for southbound vehicles turning left into the new access roadway in order to minimize delays and safety problem for southbound through traffic.
- Adequate sight distance should be provided relative to the horizontal and vertical curves along both roadways.

Kaluanui 2/3 Residential (Approved Project) - Driveway access for this approved development could adversely affect traffic flow along Hawaii Kai Drive, particularly with increased traffic to and from Kamilonui Valley.

- The major driveway to this development should be located approximately midblock between the Wailua Street and Keahole Street intersections.
- Hawaii Kai Drive should be restriped to provide a left-turn lane for northbound vehicles turning into the project driveway.
- Since future traffic volumes at the Hawaii Kai Drive-Wailua Street intersection are expected to approximate 90 percent of intersection capacity, either no driveway connection should be provided to this T-intersection, or movements should be restricted to right-turns in and out, and Wailua Street movements into parcel. These movements should not adversely affect the capacity of the major movements at the intersection.

HAWAII KAI INTERSECTIONS

Local intersection modifications would be needed to improve traffic operations at several intersections.

Hawaii Kai Drive/Kealahou Street

The analyses indicate that this intersection may experience future operation problems with the addition of a Mauuwai access road as the fourth leg on the intersection, based on continuation of all-way STOP sign controls. The analyses indicate that the intersection would likely operate at LOS E in the afternoon with two-way STOP sign controls. Since the future volumes may not warrant installation of a traffic signal, the following actions are proposed:

1. Restripe the southbound Kealahou Street approach to provide a combined through/left-turn lane and a right-turn lane. If the new Mauuwai access roadway is eventually extended to provide a "through route" to Kalanianaole Highway, it would be desirable to provide a third approach lane for left-turn vehicles, which may require widening of this approach.

2. Restripe the existing northbound Kealahou Street approach to provide a separate left-turn lane and a combined through/right-turn lane.

3. Monitor traffic volumes and operating conditions at the intersection to identify if and when traffic signal controls may be appropriate to improve traffic operations.

Hawaii Kai Drive/Lunalilo Home Road

With the *Project*, traffic volumes at this intersection would approximate 95 percent of capacity during both peak hours due to increases to the large volume of vehicles turning left from westbound Hawaii Kai Drive. The connection of Hawaii Kai Drive through the Kamilonui area would divert some of this left-turn traffic, but mitigation action would still be necessary. The proposed mitigation actions include the following:

1. Sign and restripe the westbound approach to allow left-turns to be made from both of the existing approach lanes.

2. Revise the traffic signal phasing to provide separate signal phases for the eastbound and westbound approaches of Hawaii Kai Drive.

3. Restripe the existing eastbound approach to provide two lanes:
   - A combined left-turn/through lane; and
   - A combined right-turn/through lane.

4. Restripe the existing southbound approach to provide two lanes, with through traffic permitted to use either lane.

With these modifications, the intersection would operate at LOS C and at approximately 63 and 79 percent of capacity with the forecast Year 2017 morning and afternoon peak hour traffic, respectively.

Hawaii Kai Drive/Kaluanui Road

The present two-way STOP sign controls should provide acceptable service levels with the estimated *Project* and diverted through traffic volumes.

1. To minimize delays and improve safety, the northbound approach should be restriped to provide a separate left-lane for vehicles turning left onto Kaluanui Road. The left-turn lane can be provided within the existing pavement width.

Hawaii Kai Drive/Wailua Street

This intersection is projected to accommodate future traffic volumes approximating 92 percent of capacity during the afternoon peak period. To minimize any potential worsening of conditions, the following actions are recommended:

1. Either no driveway access should be permitted at this intersection for the Kaluanui 2/3 development, or, if access is provided, the movements to/from the driveway should be restricted to those that would not require special signal phasing or interfere with or delay the major traffic movements at this intersection.

2. It would be desirable to restripe Hawaii Kai Drive to provide a second northbound lane through this intersection. The additional lane could be provided within the present pavement width.

Kalanianaole Highway/Keahole Street

The State DOT widening of Kalanianaole Highway to three through lanes in each direction ends between Hawaii Kai Drive and Keahole Street, with only two through lanes provided in each direction through the Keahole Street intersection. For this study, the intersection analyses are based on the extension of the present contraflow HOV lane operation to Hawaii Kai during the morning peak period, with the proposed new terminus on the kokohead side of Keahole Street.

With the contraflow HOV lane, the Keahole Street intersection is projected to operate at 96 percent of capacity during the morning peak hour. If the contraflow HOV lane is not extended through this intersection, the estimated 2017 traffic volumes (Chapter 4) would exceed the intersection capacity. With the forecast volumes in Chapter 4 (without transit and TDM reductions), mitigative actions would be necessary. Potential actions would include one of the following two options:

1. Remark the makaibound approach lanes of Keahole Street to allow right-turns from all three lanes. To receive traffic from the three right-turn lanes, Kalanianaole Highway would have to be widened by one lane along the mauka side from Keahole Street to the beginning of the three-lane section near Hawaii Kai Drive.

2. Widen the mauka side of Kalanianaole Highway to begin the third ewabound through lane on the kokohead side of Keahole Street and continue the widening to the beginning of the three-lane section near Hawaii Kai Drive.

Either approach would require additional right-of-way from the Marina 1 parcel. Therefore, the site plan should provide building set-backs to allow for this widening if necessary in the future.

KALANIANAOLE HIGHWAY AT LAUKAHI STREET

The forecast volumes, as presented in Chapter 4, would slightly exceed the capacity of the Laukahi Street intersection in both the morning and afternoon peak hours. Traffic at Kalaniiki Street would equal 95 and 97 percent of intersection capacity in the morning and afternoon peak hours, respectively.

As indicated in Chapter 5, the planned widening of Kalanianaole Highway by one westbound lane would result in acceptable traffic conditions at both intersections in the morning peak hour. Any reduction to traffic growth through transit and TDM measures would further improve conditions.

In the afternoon, the westbound lane would have little effect on traffic conditions at these two intersections. Potential reduction from transit/TDM actions would reduce traffic to 90 percent of capacity at Kalaniiki Street, but traffic at Laukahi Street would approximate 96 percent of capacity.

Several alternative approaches were assessed relative to addressing afternoon peak hour conditions at Laukahi Street, and to a lesser extent at Kalaniiki Street.

"Do Nothing" Approach

If no mitigation action is taken, the Year 2017 capacity-level traffic volumes would result in increased congestion and delay at the ewa end of Kalanianaole Highway during the afternoon peak hour. The increased delay per vehicle would average about 22 seconds at these two intersections.

The increased delay at these two intersections would add only a small incremental increase to the total trip time. The average travel time from Keahole Street to the H-1 Freeway would increase to about 11.87 minutes with the *Project*, versus 10.76 minutes in 2017 without the *Project*, and 10.56 minutes for present conditions.(1) This would be an even smaller proportional increase when compared to the total home-to-destination trip time which, at present, is approximately 20 minutes for a trip from Downtown Honolulu to Hawaii Kai.

The study traffic forecasts and the estimate of delay times all reflect the continuation of existing patterns regarding choice of travel mode, time of departure, and choice of whether to make a trip or not. Those who wish to avoid the increased delay time could modify their pattern by one of the following actions.

(1) Present travel times reflect February, 1992 conditions as determined in OMPO travel time studies, documented in *1992 Peak Period Travel Times for Three Selected Routes on Oahu*, prepared for Oahu Metropolitan Planning Organization (OMPO) by the Hawaii Bicycling League and Julian Ng, Inc., June 1992.

1. Shift travel to TheBus or carpooling, which also would reduce the magnitude of the future traffic increase and allow use of the HOV lane in the morning;

2. Shift their departure time to the half-hour period before or after the peak hour, when traffic volumes are at only about 80 percent of the levels during the peak hour; or

3. Eliminate the trip by working at home.

In general, a travel time differential of at least 5 minutes or more is needed to encourage a commuter to change their travel pattern. Given the relatively smaller 1 to 2 minute increase in the estimated future travel time, few peak hour commuters would be likely to change.

Roadway Modifications

Several alternative roadway and traffic operational modifications were evaluated relative to improve afternoon traffic conditions.

1. Widening Kalanianaole Highway by one eastbound lane from the Kilauea Avenue on-ramp to kokohead side of Laukahi Street.

   a. **Description** - The future widening to add the westbound lane would affect the options available for providing a fourth eastbound lane.

      1) The widening could be accomplished by reducing the median width, reducing lane widths, and reducing the paved shoulder width, without taking property.

         - This would affect safety of bicyclists.
         - Buses would stop in the added fourth lane, which would not be a major negative in that less traffic would be likely to use this lane since it ends just beyond Laukahi Street (situation similar to that at West Hind Drive before the continuation of the six-lane roadway).
         - This would require removal of many of the trees.
         - This approach may not be possible if the "extra" median width is used for the additional of the fourth westbound lane.

      2) The widening could be accomplished by acquisition of an additional 8 to 10 feet width from the adjacent properties.

         - This would result in large right-of-way acquisition costs.
         - This would reduce the yard areas for the homes along the widened segment.

b. **Traffic Impacts** - With the widening, the projected "baseline" traffic would amount to 79 percent of capacity at Laukahi Street, and 74 percent at Kalaniiki Street.

2. Minor Widening at Laukahi Street. In the morning, the eastbound left-turn movement to Laukahi Street is prohibited. Residents and visitors enter Laukahi Street by turning right on Waiholo Street, making a U-turn, and travelling northbound from Waiholo Street onto Laukahi Street. Although the left-turn is not prohibited, field counts indicate that many residents also make this same maneuver in the afternoon, amounting to three-quarters of the Waiholo Street traffic. The left-turn phase provides enough time to clear the waiting traffic, an average of about 10 vehicles per cycle, with the time extending to accommodate up to 20 to 22 vehicles per cycle. On some cycles, the left-turn vehicles were blocked from reaching the left-turn lane by the queue of through traffic, and thus forced to wait through an entire cycle. Many motorists apparently use the Waiholo Street maneuver to avoid this occasional delay. The additional green time allocated to the Waiholo Street traffic reduces the green time for the peak-direction through traffic.

a. **Description** - Local improvements to afternoon conditions could be made by:

1) Widen Waiholo Street to provide two maukabound lanes. The 28-foot wide street could be widened by taking 2 feet from the park strip between the curb and sidewalk on each side.

2) Extend the length of the eastbound left-turn lane. The present 360 foot long lane could be extended to 425 feet to minimize blockage by through traffic, and to accommodate waiting left-turn queues.

b. **Traffic Impacts**

1) Widening Waiholo Street would improve the volume-to-capacity ratio by 0.04 (to .976).

2) Extending the eastbound left-turn lane would improve the volume-to-capacity ratio by 0.037 (to .979) if used by most of those now using Waiholo Street to turn onto Laukahi Street.

3) A combination of the two modifications would improve the volume-to-capacity ratio by 0.059 (to .957).

3. Minor Widening at Kalaniiki Street. Provision of an eastbound right-turn lane would be the only minor widening that would significantly affect conditions.

a. **Description** - The lane could be provided within the present right-of-way by use of the paved shoulder, decreasing width of the other eastbound lanes, and taking several feet from the landscaped median.

b. **Traffic Impact** - The right-turn lane would result in afternoon peak hour traffic equalling 93.8 percent of capacity. This small improvement does not appear to warrant the addition of the right-turn lane since these vehicles could turn right at Waikui Street in advance of this intersection.

Encourage Alternatives to Driving

Ridesharing - As part of the mitigation plan for the development of the Marina Zoning parcels, a series of programs were initiated since the late 1980s to encourage ridesharing by Hawaii Kai residents, particularly workers and students who commute into Honolulu. These programs include:

1. Development of the park-and-ride facility, with about one-half of its all-day stalls currently being used on weekdays;

2. Provision of rideshare coordination to promote and facilitate formation of carpools and use of bus services;

3. Provision of a free bus pass for one year to occupants of each new residential unit to encourage the formation of a bus-commuting habit when relocating to Hawaii Kai; and

4. Sponsorship of a privately-operated express bus service for students and staff at private schools not well-served by TheBus.

Although these programs were actively used by residents, their effect was overwhelmed by the improvements to vehicular traffic flow along Kalanianaole Highway. The traffic signal timing changes and the opening of the HOV lane to two-person carpools resulted in a net decrease in bus usage by 27 percent between 1987 and 1991, and a 33 percent reduction in the number of 3- and 4-person carpools. Vehicular traffic in the morning peak hour increased by over 1,100 vehicles, with about 10 percent of the increase resulting from more development and 90 percent resulting from shift to driving in the peak hour because of the reduced congestion and travel times.

The increased traffic from future development would reduce in part the travel time savings that have encouraged more people to drive in the peak hour. An even larger factor in increased travel times would be the increasing congestion beyond Kalanianaole Highway, particularly in the University and Downtown Honolulu areas. Choice of travel mode to these areas, as well as to Wakiki and Kakaako, would also be greatly influenced by employer trends towards providing less employee parking and by reducing or eliminating subsidy of employee parking.

These factors may result in a meaningful combination of increased travel time, reduced convenience, and increased costs for driving to work or school. If these factors were sufficient to return Hawaii Kai commuter travel modes to the 1987 levels, it would reduce Hawaii Kai peak hour traffic by approximately 8 percent, or about 350 vehicles. The levels of capacity use may also be further reduced if these factors also reduce the number of vehicle trips from other East Honolulu communities, or encourage area residents to travel at earlier or later times. These reductions in traffic growth could exceed those reflected in the Oahu RTP forecast for transit/TDM improvements.

As part of the *Project*, ridesharing should be encouraged by the following:

1. Reinstate the earlier ridesharing programs and extend the programs to the new developments.

2. Participate with City and State to promote travel demand management (TDM) programs to employers and employees, such as flexible work hours.

3. Support future programs to encourage ridesharing on a regional basis, such as an increase to 3 occupants to allow use of HOV lanes.

Telecommuting - Telecommuting is an approach for reducing home-to-work trips, and potentially some school trips, by allowing employees to work at home or in a suburban telecommute satellite office. Telecommuting employees (and high school or college students) could work at home several days a week, or all week, and travel into Honolulu for periodic meetings and conferences with managers, co-workers or clients. The primary opportunity for telecommuting is with employees in information-based jobs.

Telecommuting has been increasing at a rapid rate in recent years. Hawaii Kai offers a very high potential for telecommuting given the large proportion of its labor force who are in jobs compatible with use of communications in lieu of commuting for one or more days a week. There is insufficient information to permit a projection of telecommute potential in Hawaii Kai, but it is very likely to be at least equivalent to a reduction of at least five percent of present and new peak hour trips. A daily reduction of five percent would offset the number of peak hour vehicle trips that would be added to Kalanianaole Highway by the *Project*.

The use of telecommuting could be promoted within the community by one or more of the following actions:

1. Work with local telephone and cable companies to ensure that multimedia lines are installed in the new subdivisions that will allow high-quality video and graphics transmission.

2. Ensure that a business services center is available within Hawaii Kai to provide printing services, special transmission services, and possibly teleconferencing facilities and computer servicing resources.

3. Provide a local bulletin board on-line network with no charge for use within Honolulu.

4. Work with insurance companies to make available low-cost coverage for business and liability coverage for Hawaii Kai telecommuters.

5. Pay for costs of second (business) telephone line to homes of telecommuters, and/or work with local telephone service providers to establish lower-cost area rate.

6. Promote dialogue between the City, the State, private employers, and representatives of employee groups to identify and reduce barriers to increased use of telecommuting by public and private organizations.

Queen's Beach Golf Course

Appendix

N

Grading and Drainage Report

(Sam O. Hirota, Inc.)

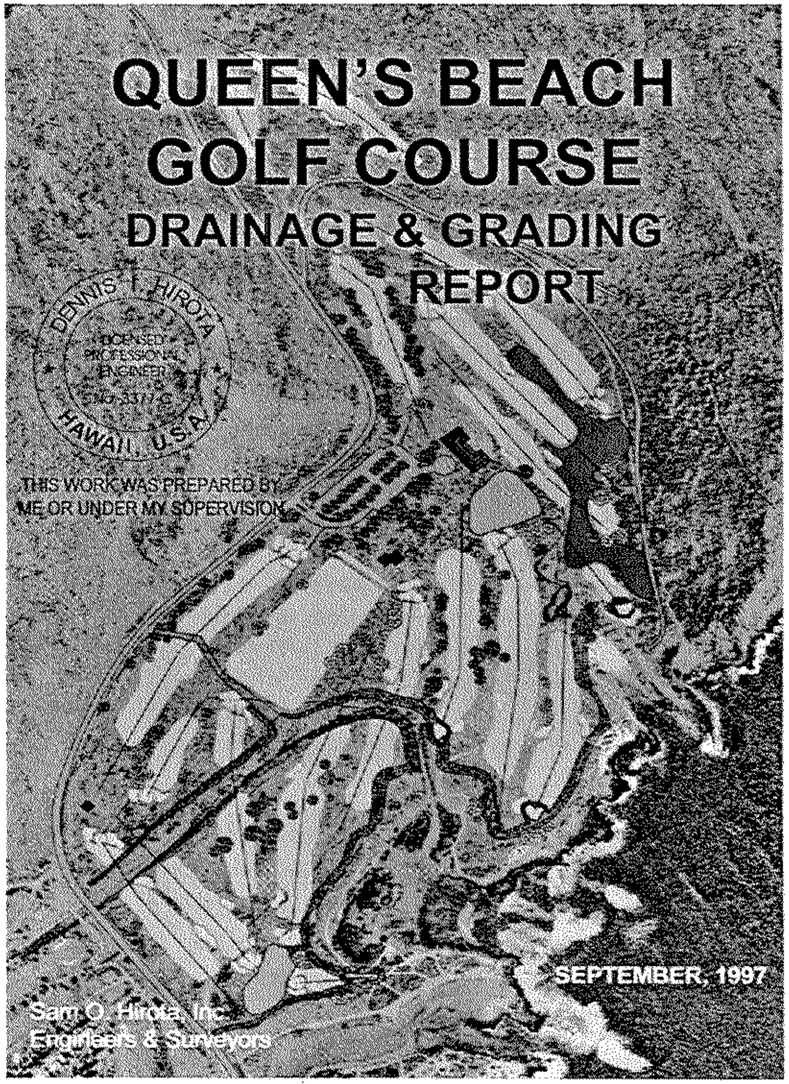


Table of Contents

I. INTRODUCTION

Kaiser Aluminum & Chemical Company is proposing to develop an 18-hole golf course in the area known as Queen's Beach. The property is currently owned by Bishop Estate and leased by Kaiser. The proposed project site is 166 acres, encompassed by Kalanianaole Highway on the west and southwest, Makapu'u Point to the north, and the Pacific Ocean to the south (see Exhibit 1- Project Vicinity Map, Exhibit 2 – Project Location Map). This report focuses on the grading and drainage impacts for the proposed project. Issues including the protection of the Hawaiian cotton plant, the Ma'o and the Marsilea Villosa fern, along with water quality have been addressed. A detailed grading plan and drainage plan have been designed for the project to minimize impacts both on and off-site. A Best Management Practices plan (BMP) for reduction of pollutant and sediment laden runoff describes the methods by which construction impacts will be kept to a minimum, along with a permanent erosion control plan.

II. PROJECT BACKGROUND

A. Proposed Project

The proposed project is the construction of a par 72, regulation 18-hole golf course. Along with the course, the project also includes a clubhouse, 7-acre driving range, parking lot, and a maintenance building (see Exhibit 3). The course would be privately owned and operated, however, open daily to the public. (Reference 1)

B. Project Goals

Certain aspects of the proposed site are very important to maintain, such as water quality. Temporary and permanent measures are detailed within this

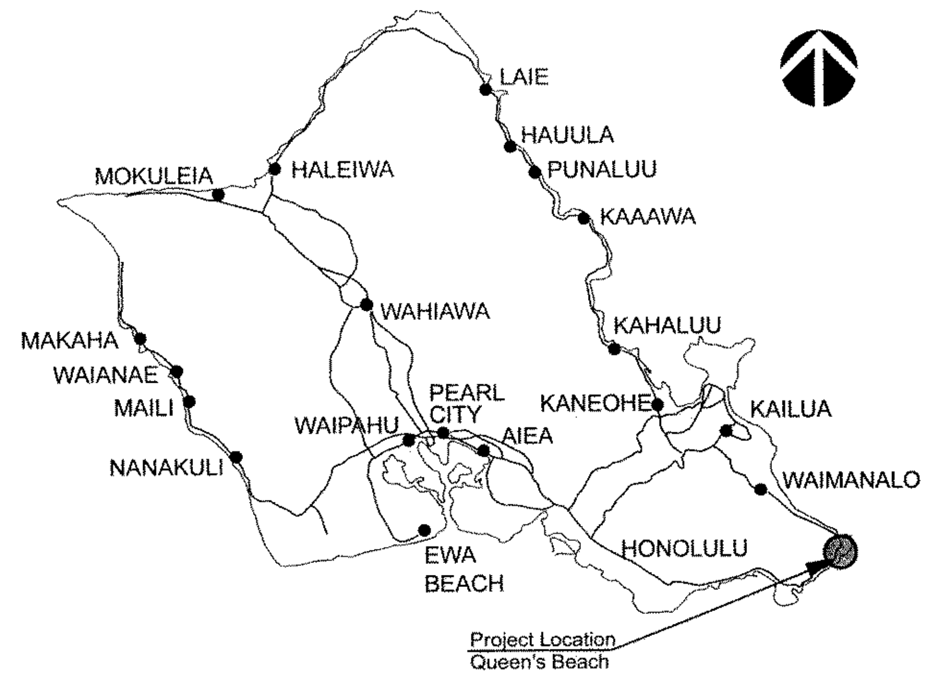


EXHIBIT 1: PROJECT VICINITY MAP
Queen's Beach Golf Course
NOT TO SCALE

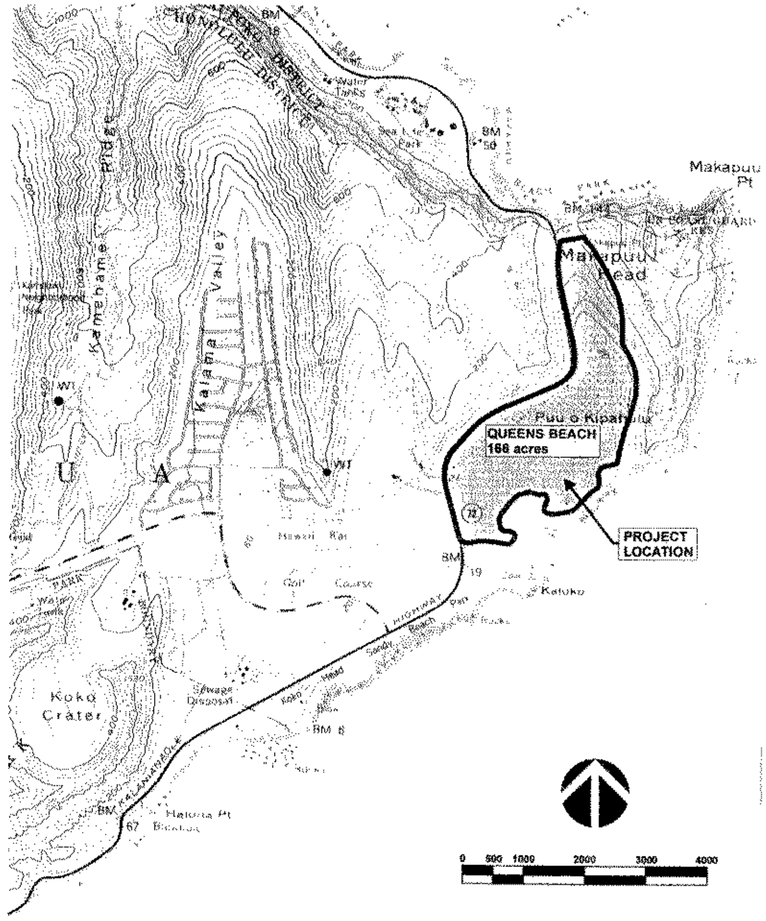


EXHIBIT 2: PROJECT LOCATION MAP
Queen's Beach Golf Course

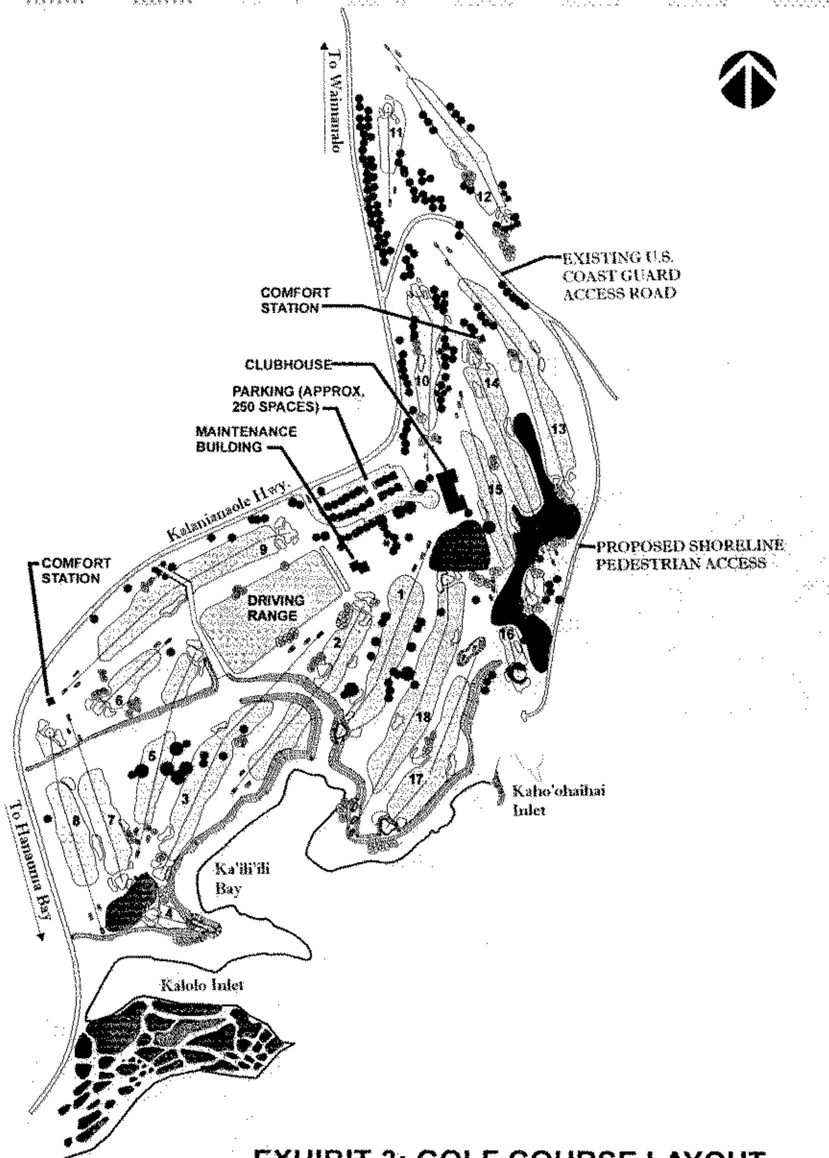


EXHIBIT 3: GOLF COURSE LAYOUT
NOT TO SCALE

report that will minimize the amount of pollutant-laden sediment leaving the site that could damage marine habitat along the coastline.

A plan has also been created to protect plant life that exists on the site. Areas have been designated where the Hawaiian cotton plant (the Ma'o), and Marsilea villosa will be cultivated (see Exhibit 4).

Along with the protection of native plants and the marine ecosystem, residents and visitors will still be able to enjoy the coastline and surrounding waters. A series of footpaths and bridges, along with the existing U.S. Coast Guard access road, will allow people to hike within the property to the coastline and Makapu'u Point.

III. EXISTING SITE

A. Site Conditions

Presently, the site is in a poor condition. During the years of development in Hawaii Kai, boulders and construction debris were scattered throughout the site. For many years, the site has been used by off-road vehicles, which have eroded away large paths. Along with construction debris, individuals have abandoned vehicles, appliances, and other trash within the property.

There are no current structures on the site. The last known building, owned by a rancher, Alan Davis, was destroyed in the 1946 tsunami. Since that time, the site has been uninhabited, other than for recreational uses (Reference 2).

The site contains four (4) easements. The first is a 2,700 ft. long, 10 ft. wide utility easement that includes overhead lines for GTE Hawaiian Tel and HECO. The City and County of Honolulu has 2 – 70 ft. wide drainage easements noted

EXHIBIT 4: PROTECTED AREAS
Queen's Beach Golf Course
NOT TO SCALE

as D-7 and D-8. Easement D-7 starts at Kalanianaole Hwy and connects to D-8, which outlets into Kaho'ohaihai Inlet. Adjacent to Easement D-8 is an additional 200 ft. wide flowage easement designed to relieve the channel during peak flows. Although Easement D-8 was originally thought to drain into Kaho'ohaihai Inlet, existing topography shows that the 15 ft. wide drainage channel drains into the eastern side of Ka'ili'ili Bay (see Exhibit 5).

B. Soils

In October of 1994, a series of soil borings were taken around the site. The borings and the USGS Soil Survey of Oahu (Reference 3) show that four (4) types of soils are predominate on the site: Jaucus series (JaC), Rock Land (rRK), Koko series (KsB), and the Lualualei (LuA, LPE) series (see Exhibit 6). A description of each series is included in Table 1.

The Jaucus series was found in areas covering 4% of the site, primarily the beach areas, usually in depths 60 in. and greater. Its workability is poor, but is found in small amounts on the site and is not relevant to the development of the golf course. Rock Land soils are predominant in the eastern portion of the project site. It can be unstable to build structures on. However, it is manageable for construction of the proposed golf course. The Koko series is found on the western portion of the site, east of the Wawamalu Ranch wall to the stone bridge at the mouth of Kaloko Inlet. The Lualualei series is found on a majority of the site. It is located both along Kalanianaole Highway and the makai side of the property.

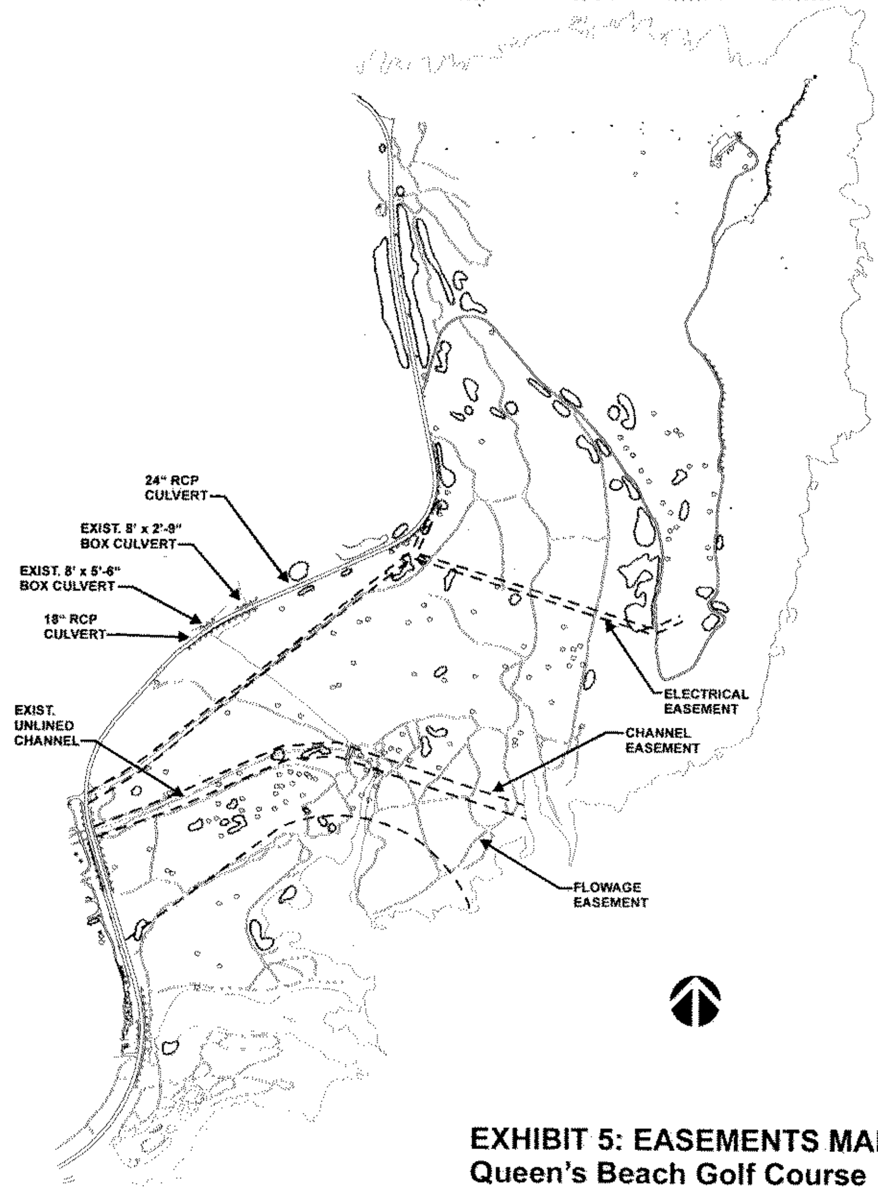


EXHIBIT 5: EASEMENTS MAP
Queen's Beach Golf Course
NOT TO SCALE

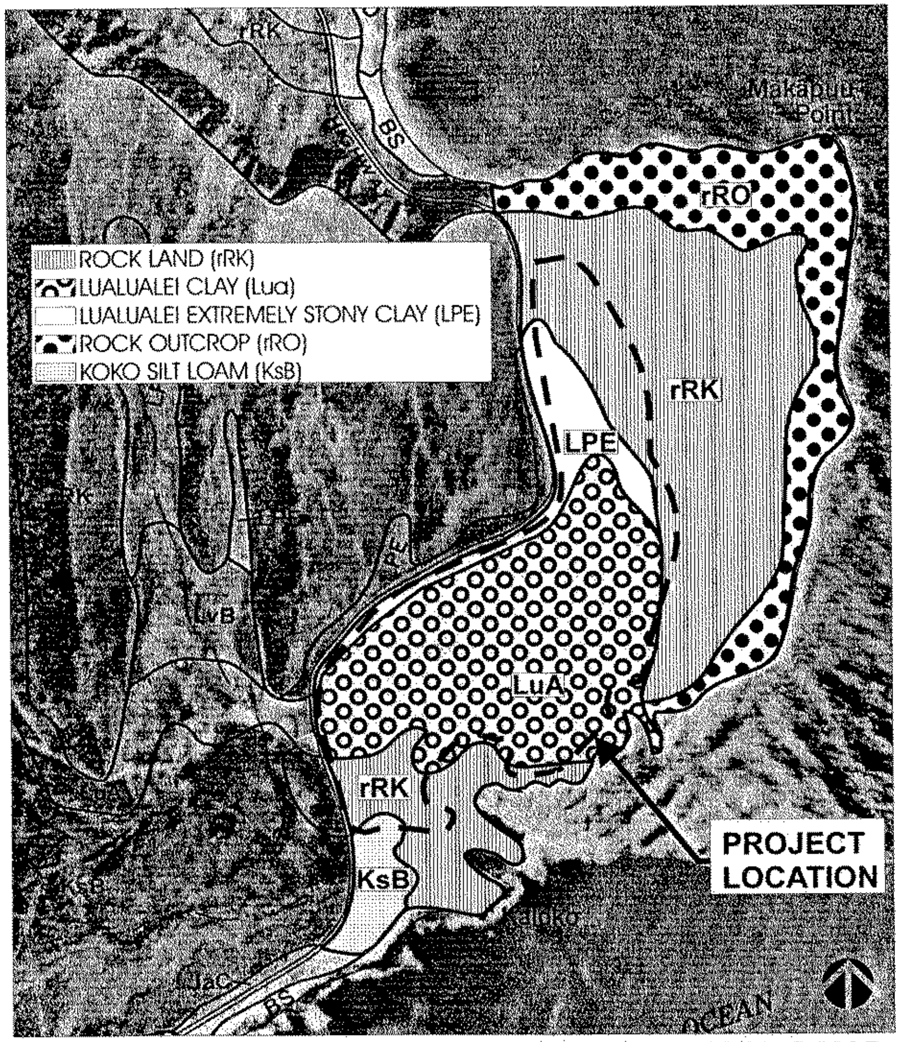


EXHIBIT 6: EXISTING SOILS MAP
Queen's Beach Golf Course

NOT TO SCALE
Reference: "Soil Survey of Islands of Kauai, Oahu, Maui,...," Soil Conservation Service, U.S. Dept. Of Agriculture, 1972.

Soil Series	Description
Jaucas Sand (JaC)	Soil has a slow to very slow runoff and rapid permeability. Water erosion hazard is slight, however, the wind erosion hazard is severe where vegetation is removed.
Rock Land (rRK)	Includes areas where exposed rock covers 25" – 90% of the surface. In many areas, the soil material associated with the rock outcrops is very sticky and platic and is susceptible to high shrink-swell potential.
Koko silt loam (KsB)	Soil occupies smooth slopes. Permeability is moderate and runoff is slow, with a slight erosion hazard.
Lualualei Clay (LuA) and extremely stony clay (LPE)	The Clay occupies 0-2% slopes and has a slow permeability. The erosion hazard is slight and shrink swell potential is high. The stony clay is similar to the LuA, however contains many stones. Runoff is medium to rapid, with a moderate to severe erosion hazard

Table 1
Soil Types

C. Topography

The existing site can be broken up into four (4) distinct regions: a coastal plain, a valley (Kealakipapa Valley), a rocky headland (Makapu'u Head), and a coastal bench trail.

The coastal plain makes up more than 50% of the project site. The slopes range from 0 to 5%. Variations in the slope are due to drainage ways. Maximum elevation in this area is 24 ft. above MSL. A majority of the boulders and construction debris on the site are located within this area. Depositing of the materials has altered the topography within the site. During previous attempts at development of the site, dredging was done along the coastline to expand the Kaloko Inlet and Ka'ili'ili Bay, and create Kaho'ohaihai Inlet.

Kealakipapa Valley extends along the northwest portion of the property and makes up approximately 20% of the project area. Slopes range from 5 to 10%, with a maximum elevation around 160 ft. above MSL. Scattered boulders also exist within this region.

The summit of Makapu'u Head is at 669 ft. above MSL. Slopes range from 10-60% on its west face, with slopes exceeding 60% on north facing cliffs. The terrain is very rugged. This area of the property is excluded from the project, other than for calculation purposes.

The coastal bench trail extends along the eastern edge of Makapu'u Head. The trail is fairly level and is 4,500 ft. in length. Currently, hikers and fishermen use the bench.

D. Drainage Patterns

Off-Site

The total tributary drainage area for Queen's Beach is 1,684 acres. Included in this area are potential project sites which total 367 of the 1,684 total acres. Storm water runoff from the tributary area reaches the project site by either the unlined drainage channel or culvert crossings under Kalanianaole Highway (see Exhibit 7).

A detailed report by Community Planning entitled "Proposed Hawaii Kai Developments, Preliminary Engineering Report Off-Site Improvements", calculates the existing and proposed runoff leaving each of these development

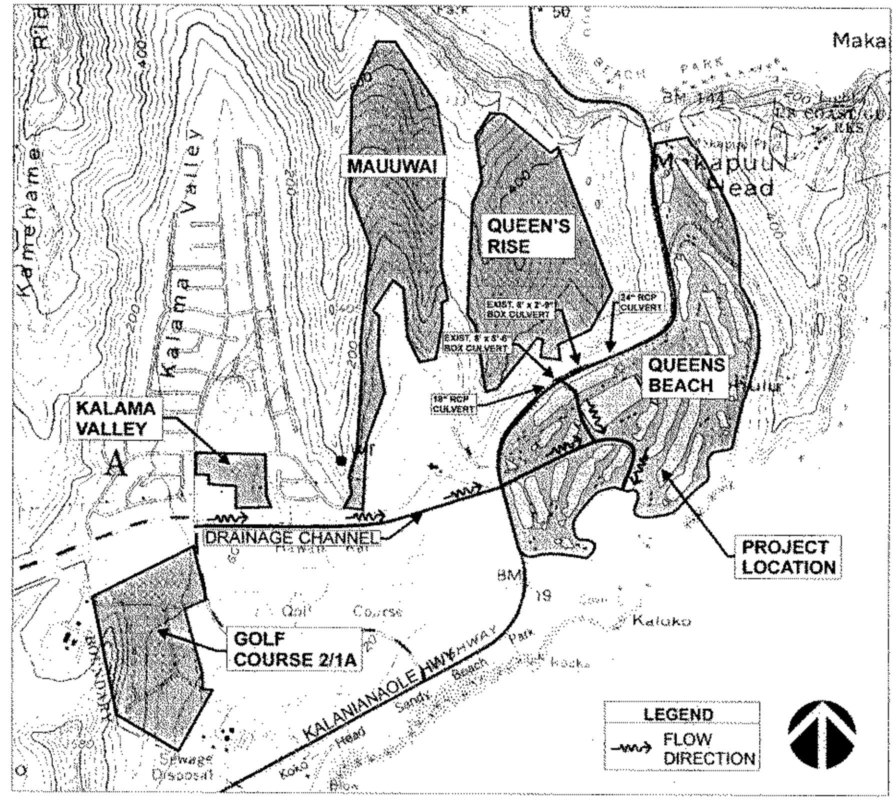


EXHIBIT 7: OFF-SITE DRAINAGE
Queen's Beach Golf Course
NOT TO SCALE

areas. Table 2 includes the calculated runoff quantities for 10 and 50 year storm frequencies.

Proposed Development	Q_{10} (undeveloped)	Q_{50} (undeveloped)	Q_{10} (developed)	Q_{50} (developed)
Kalama Valley	17	24	29	38
Mauuwai	638	893	752	1003
Queen's Rise	350	490	439	553
Golf Course 2/1A	12	16	20	27
Total	1017	1423	1240	1621

Table 2
Off Site Runoff Quantities

On-Site

The drainage patterns on the site can be broken down into similar regions as the topography.

Runoff from the Makapu'u Head sheet flows down the ridge until it reaches the old Coast Guard access road. A concrete lined rectangular channel captures the runoff, and outlets it at various points through a series of culverts.

Portions of the Kealakipapa Valley are located above the Coast Guard access road. The runoff from this area travels underneath the road through a 4'x4' box culvert. Once below the access road, the runoff flows across the site in a series of wheel ruts and artificially created channels.

Once the stormwater has outletted from the culverts, located under Kalanianaole Highway, it flows into the coastal plain. Within the coastal plain, stormwater will take one of several paths and eventually outlet into Kaloko Inlet, Ka'ili'ili Bay, or Kaho'ohaihai Inlet.

Storm runoff was estimated using the rational method as outlined in the City and County of Honolulu "Storm Drainage Standards" (Reference 6), and the SCS

method. The existing site was divided into 14 subbasins (see Exhibit 8). Calculations for peak flows and volumes can be found in Appendix A.

IV. PROPOSED CONDITIONS

A. Improvement of Soils

The project site is made up of 4 types of soils, with the majority of the area consisting of Lualualei clay (LuA) and Lualualei extremely stony clay (LPE). These clays are located in the coastal plain and valley areas of the site. Due to the high shrink swell characteristics of this series, it would be difficult to maintain greens and fairways.

To improve the soil conditions on site, soil amendments, that include peat and sand, will be necessary. During grading, these two materials will be mixed with the native topsoil, in the areas containing greens and fairways (Reference 4). Along with a subdrainage system, this will help to properly drain the course while minimizing erosion and sediment-laden runoff.

B. Grading

The project site consists of 134 acres that will be graded. Major grading will include definition of the greens and tees along with the addition of detention basins, channels, and two (2) irrigation ponds (Exhibit 9). The following table includes the amount of embankment/excavation.

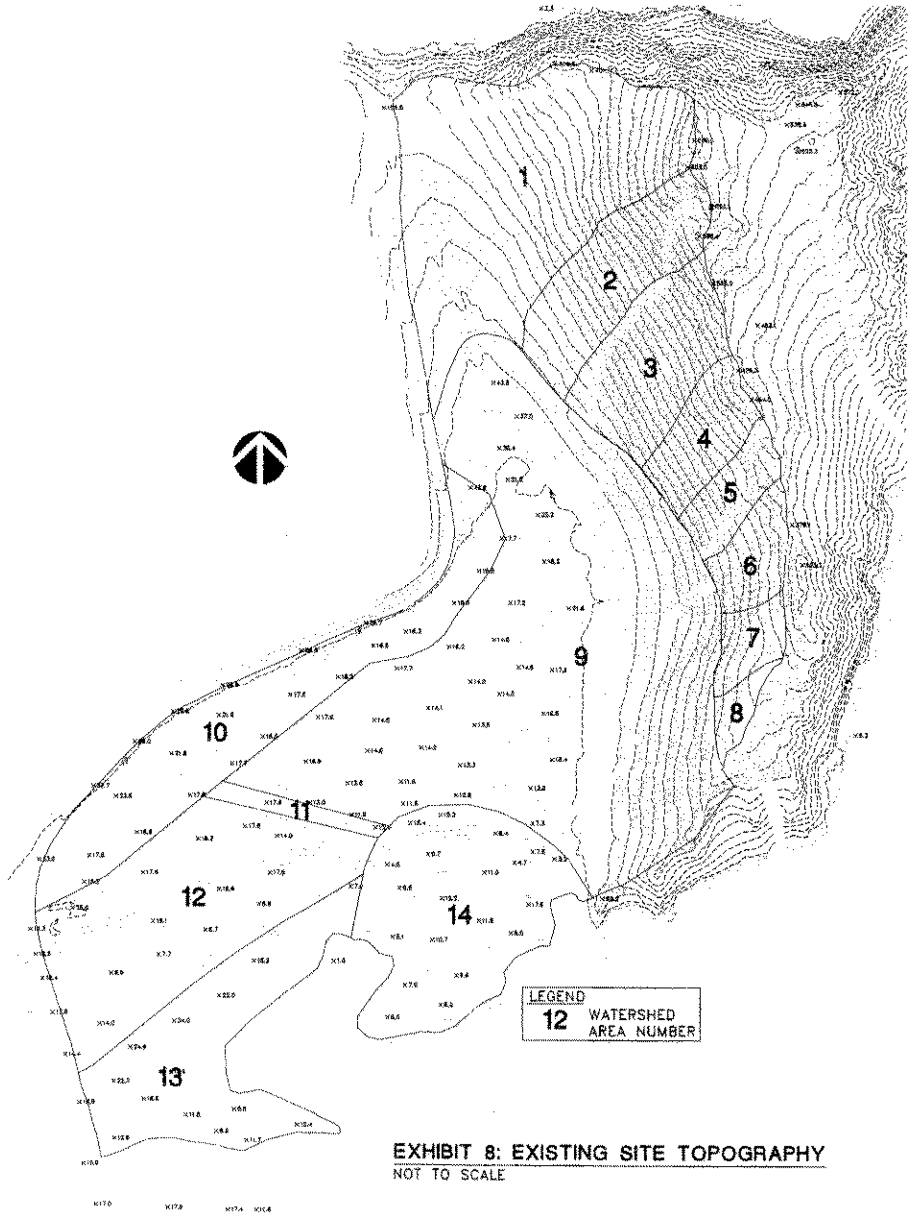


EXHIBIT 8: EXISTING SITE TOPOGRAPHY
NOT TO SCALE

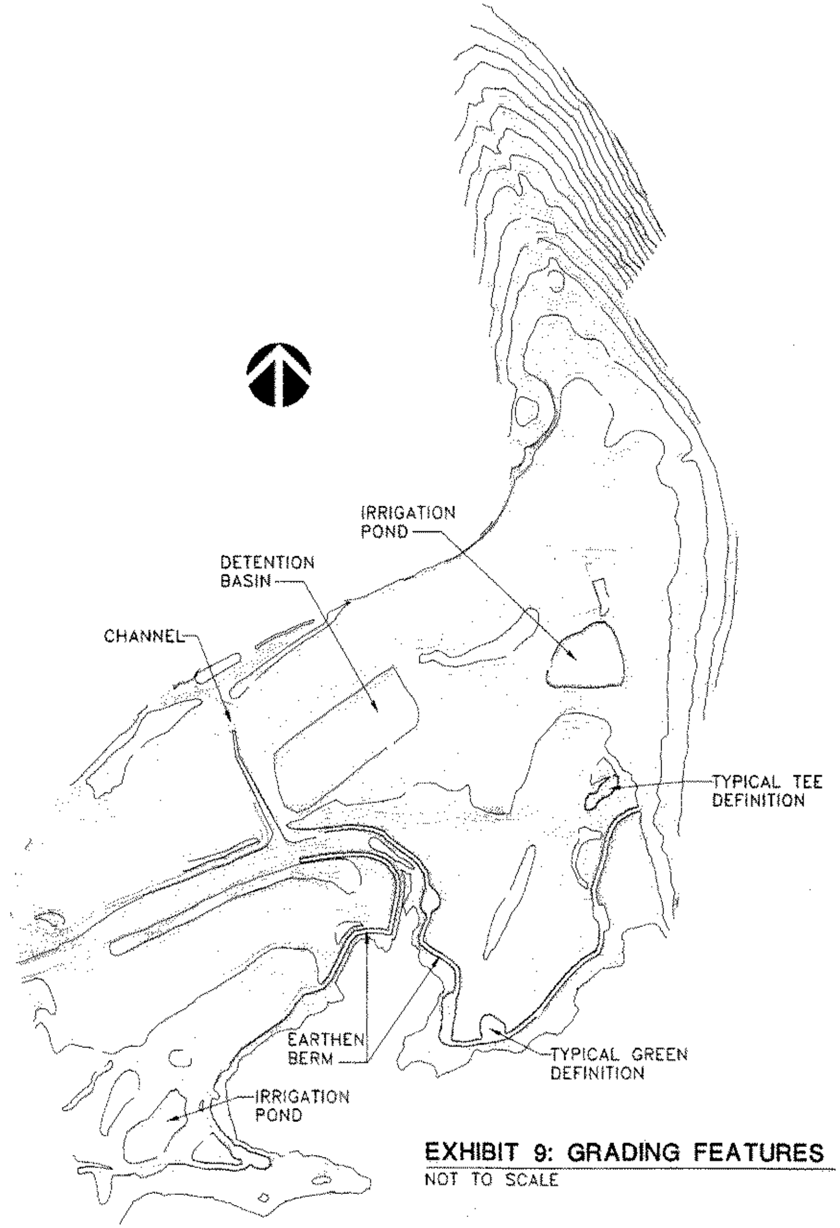


EXHIBIT 9: GRADING FEATURES
NOT TO SCALE

	QUANTITY(CY)
Excavation	180,821
Embankment	163,290
Difference (cut)	17,531*

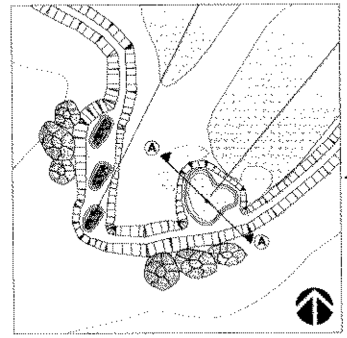
* The amount of addition excavation is equal to 0.83 in. spread over the project site

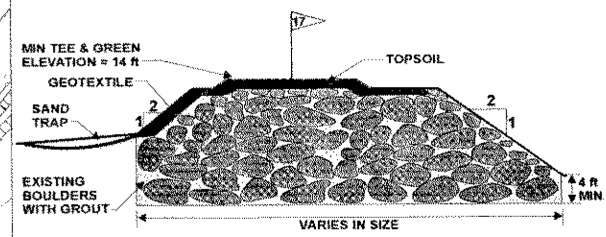
Table 3
Cut/Fill Quantities

During the first stage of construction, the site will be cleared and grubbed. During that time, the boulders will be relocated to the makai perimeter of the site for construction of an earth berm, which will retain stormwater runoff and serve as protection for the site. Once the boulders have been placed, a cementatious grout will be used to anchor them in place. To provide an anchor for the topsoil, a geotextile material will be placed between the boulders and a layer of topsoil. An erosion control mat will be used to protect the topsoil while the grass is germinating and establishing a root system (Exhibit10).

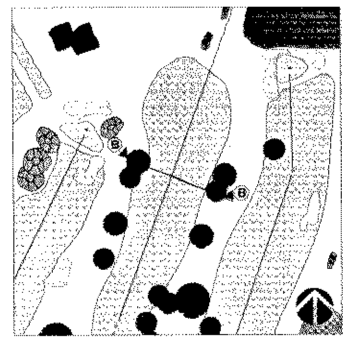
Once the berm has been completed, first phase mass grading will begin in the coastal plain area of the site. The detention basin areas will be excavated to reduce the transport and sediment off site. Included in this area is the clubhouse, maintenance building and parking areas, along with the two irrigation ponds. Each of the tees and greens will be defined, along with excavation for the bunkers and swales (Exhibit10).

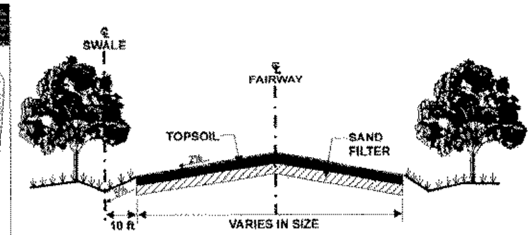
During the second phasing, grading will take place in the valley and along the coastal bench trail. The emphasis will be on the definition of the greens and tees, and reduction of the cross slopes along the fairways.





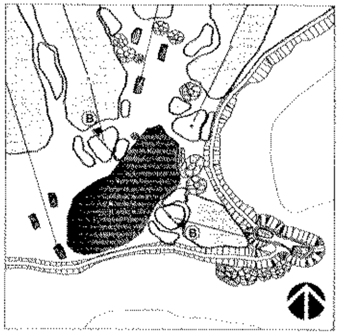
SECTION A-A: TYPICAL BERM SECTION
NOT TO SCALE

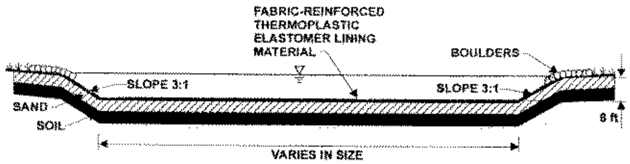




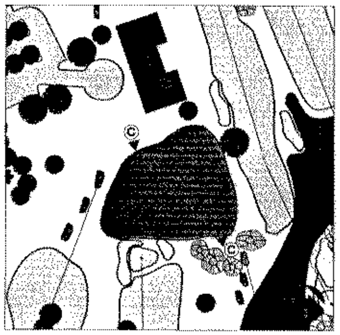
SECTION B-B: TYPICAL FAIRWAY SECTION
NOT TO SCALE

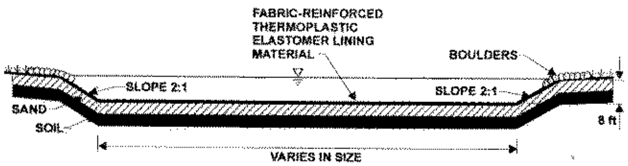
EXHIBIT 10: TYPICAL GOLF COURSE SECTIONS





SECTION B-B: TYPICAL IRRIGATION POND SECTION
NOT TO SCALE





SECTION C-C: TYPICAL IRRIGATION POND SECTION
NOT TO SCALE

EXHIBIT 10: TYPICAL GOLF COURSE SECTIONS

C. Drainage

Runoff reaching the site from existing Hawaii Kai developments will continue to travel through the unlined channel coming from Hawaii Kai Golf Course. Each of the four (4) culverts running underneath Kalanianaole Highway will be directed into a grass lined channel. This channel will connect into the existing unlined channel, continued in easements D-7 and D-8.

All of the runoff generated within the project site will be contained within detention basins and bunker pits. The elevated greens and tees will slope into the bunker pits. Fairways within the coastal plain will be crowned with swales on either side, while the fairways located within the valley or coastal bench trail zones will have cross-slopes that will allow runoff to drain into detention areas.

Runoff will be contained on the site by an earthen berm that is to be constructed. This berm will protect the marine habitat from stormwater runoff generated on-site. The large detention basin located within the driving range, along with low-lying areas near the berm will be drained with the use of weirs. The weirs allow for controlled release of stormwater runoff into the drainage channel, reducing the peak flow during storm events.

The proposed project site has a total of 24 subbasins (Exhibit 11). All calculations were based on City and County of Honolulu Storm Drainage Standards (Reference 6) and the SCS Method. The unit hydrograph method was used to determine volumes for each of the storm frequencies that were analyzed. Exhibit 12 shows a comparison of elevation versus volumes retained for the project site. Calculations for peak flows and volumes are included in Appendix A. The following table includes peak flows for the project site and its tributary basins:

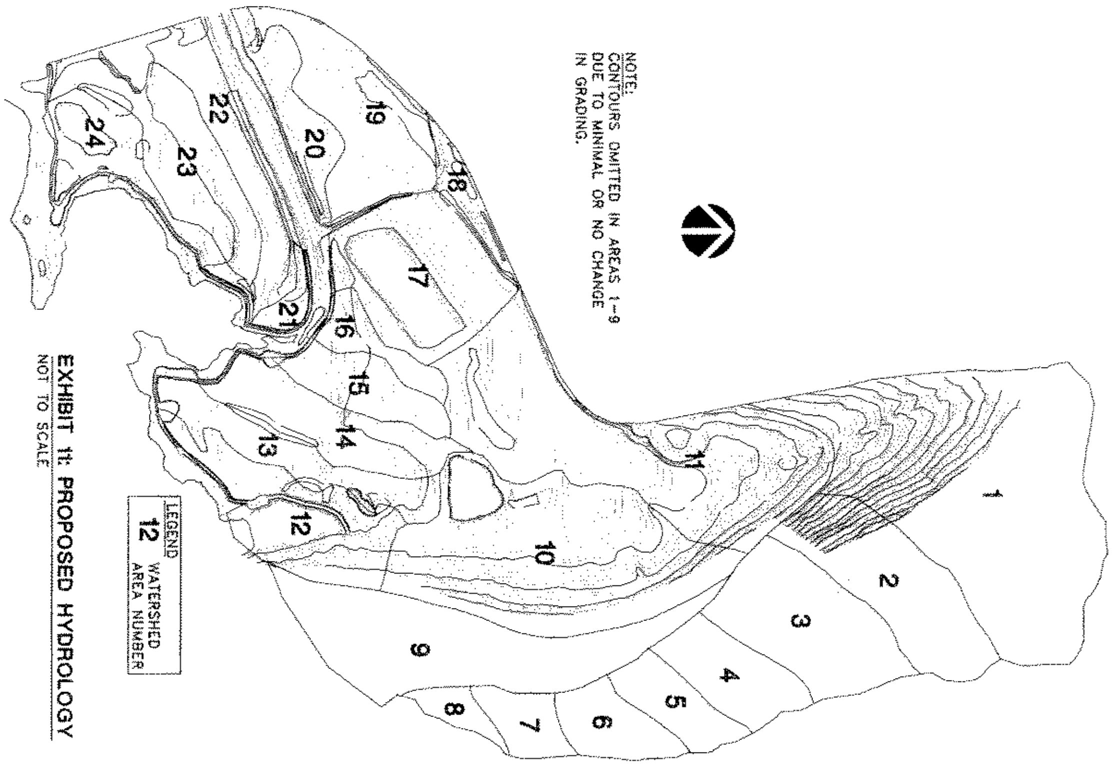


EXHIBIT 11: PROPOSED HYDROLOGY
NOT TO SCALE

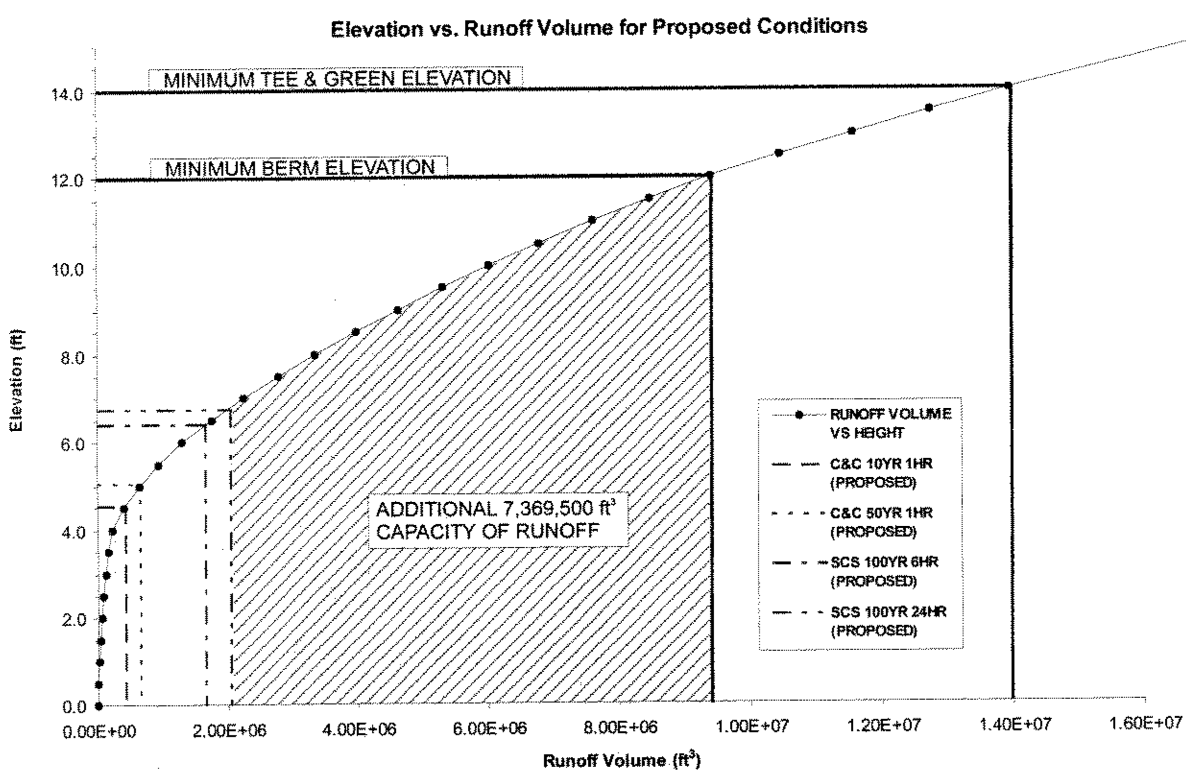


EXHIBIT 12: ELEVATION VS. DIRECT RUNOFF VOLUME

	Pre-Development (50yr-1hr)	Post-Development (50yr-1hr)
Off-Site	1423 cfs	1621 cfs
On-Site	690 cfs	595 cfs
Total	2113 cfs	2216 cfs

Table 4
Total Peak Flows

Some areas within the project site are located within the 100-year flood hazard area. Sections of the earthen berm along with greens, tees, fairways, and section of Kaloko Inlet, Ka'ili'ili Bay, and Kaho'ohaihai Inlet are subject to inundation (see Exhibit 13).

Areas within Zones AE and VE have base flood elevations determined. In addition, areas within Zone VE are described as coastal flood areas with wave velocity hazards. The remainder of the project area is located within Zone D, where flood hazards are undetermined. The State of Hawaii Office of Civil Defense has defined the Tsunami Evacuation Line for the project site to be Kalanianaole Highway (Reference 1).

As tsunamis move inland, energy dissipates due to friction and natural obstacles. Construction of the earthen berm would help to dissipate this energy force. Although damage may still occur during a tsunami, the berm would act as a protection wall for the golf course. Due to the nature of its use, it is unlikely that golfers would be at play during a tsunami or natural flood event.

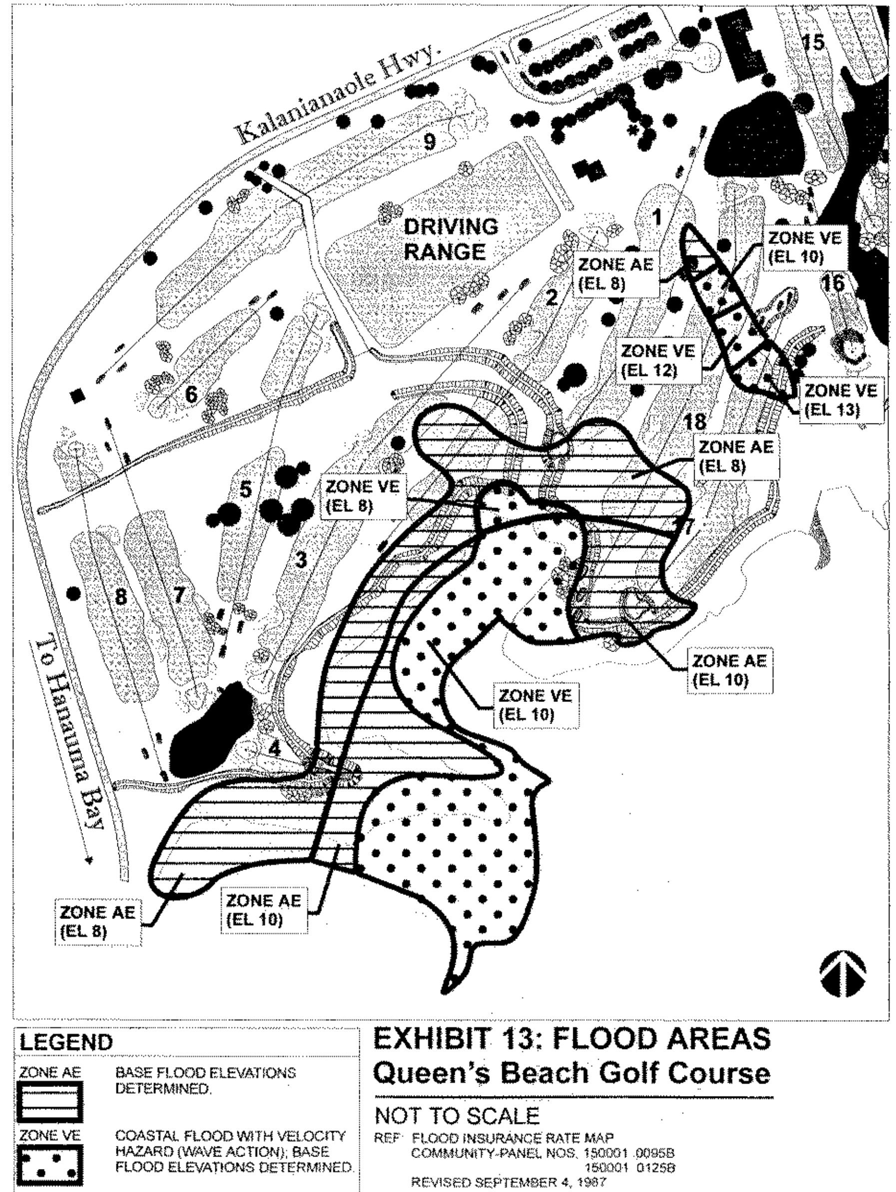


EXHIBIT 13: FLOOD AREAS
Queen's Beach Golf Course

NOT TO SCALE
REF: FLOOD INSURANCE RATE MAP
COMMUNITY-PANEL NOS. 150001 0095B
150001 0125B
REVISED SEPTEMBER 4, 1987

V. SOIL EROSION POTENTIAL AND WATER QUALITY

A. Soil Erosion Potential

The project site has been divided into 5 major basin areas, for the purpose of calculating soil erosion potential (see Exhibit 14). The areas represent sites that have differing soil erosion potential characteristics such as slope, soil type, or drainage networks.

Soil losses have been estimated using the Universal Soil Loss Equation as described in the City and County of Honolulu Soil Erosion Standards and Guidelines (Reference 5). Calculations for the severity rating number of each basin are included in Appendix A. The total calculated severity rating number for this project, under the worst case scenario, is approximately 2,330.
The standard severity rating number for Oahu is 50,000. This value of H represents the maximum amount of environmental damage considered tolerable, based on studies of stream sediment loads and analysis of the best practical and feasible control measures. No project with a severity rating number substantially above 50,000 will be approved until measures have been taken to reduce the number to meet the standard (Reference 5). Compared to the standard severity rating number of 50,000, the erosion hazard for this project is less than the maximum allowable for the Island of Oahu.

B. Construction BMP's

Planning considerations to minimize discharge and erosion of the construction site focus on two objectives: 1) increasing of water quality; and 2) minimizing the quantity of water discharged from the site (Reference 7).

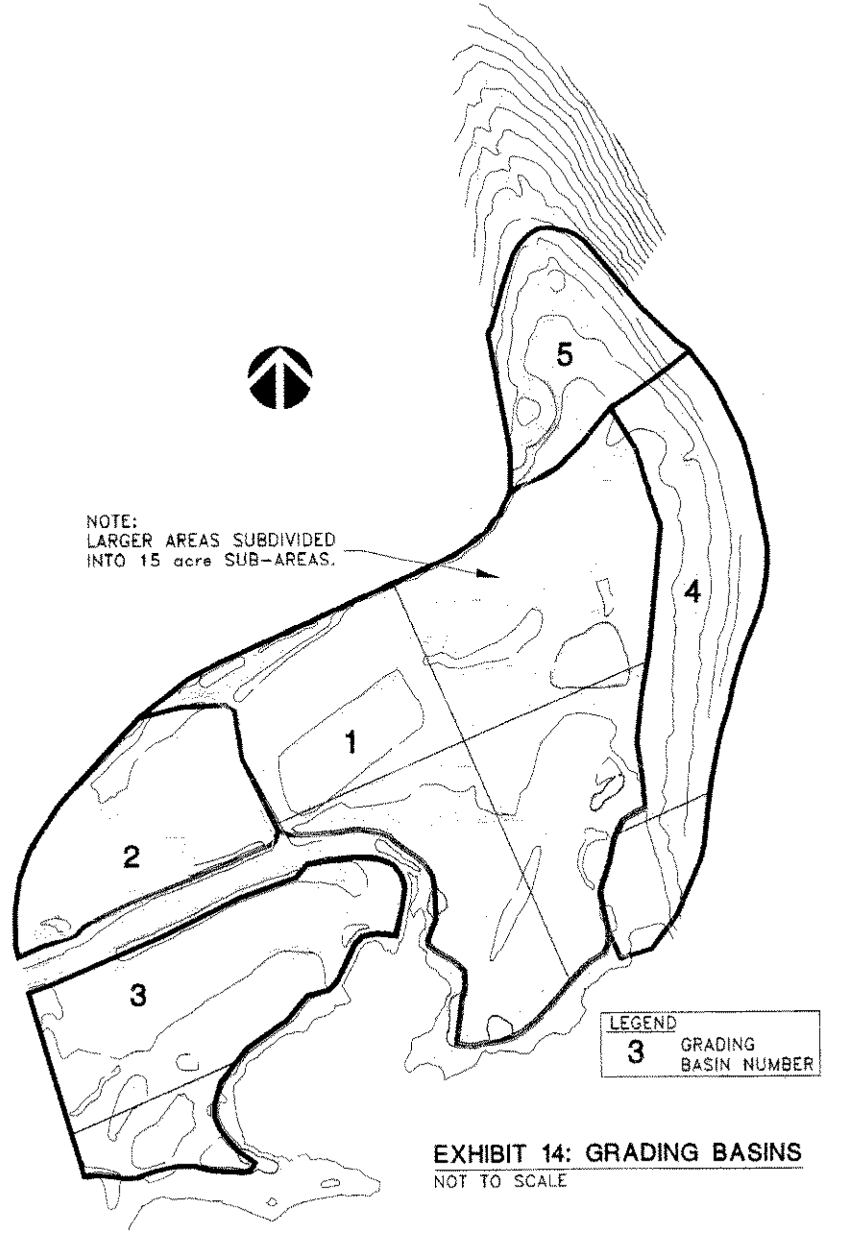


EXHIBIT 14: GRADING BASINS
NOT TO SCALE

Water Quantity: Onsite temporary detention will decrease runoff volume and reduce peak flow.

Water Quality: Potential to trap sediment and sediment-attached substances carried by runoff.

Temporary Construction Measures

During construction, a system of controls will be put into place to meet the objectives stated above (see Exhibit 15). The following list includes the measures that are to be implemented:

1. Construction of a perimeter berm will begin immediately. This berm will be located along the makai side of the project site at elevation 12. It will prevent runoff from leaving the site and trap sediment both during and after construction.
2. A series of silt fences and berms constructed along existing drainage channels, will be used to prevent flow from leaving the site in an uncontrolled manner.
3. Construction of sediment traps and barriers in front of and adjacent to the major discharge points of the existing drainage system. Examples of possible sediment reducing systems are illustrated in Appendix B.
4. Major construction will take place during the dry period of the spring and summer months. No mass grading will take place during the months of December through March. Grading will be implemented in 15 acre sections, with grassing to occur as sections are completed. To further control dust, watering will take place during grading and general construction.

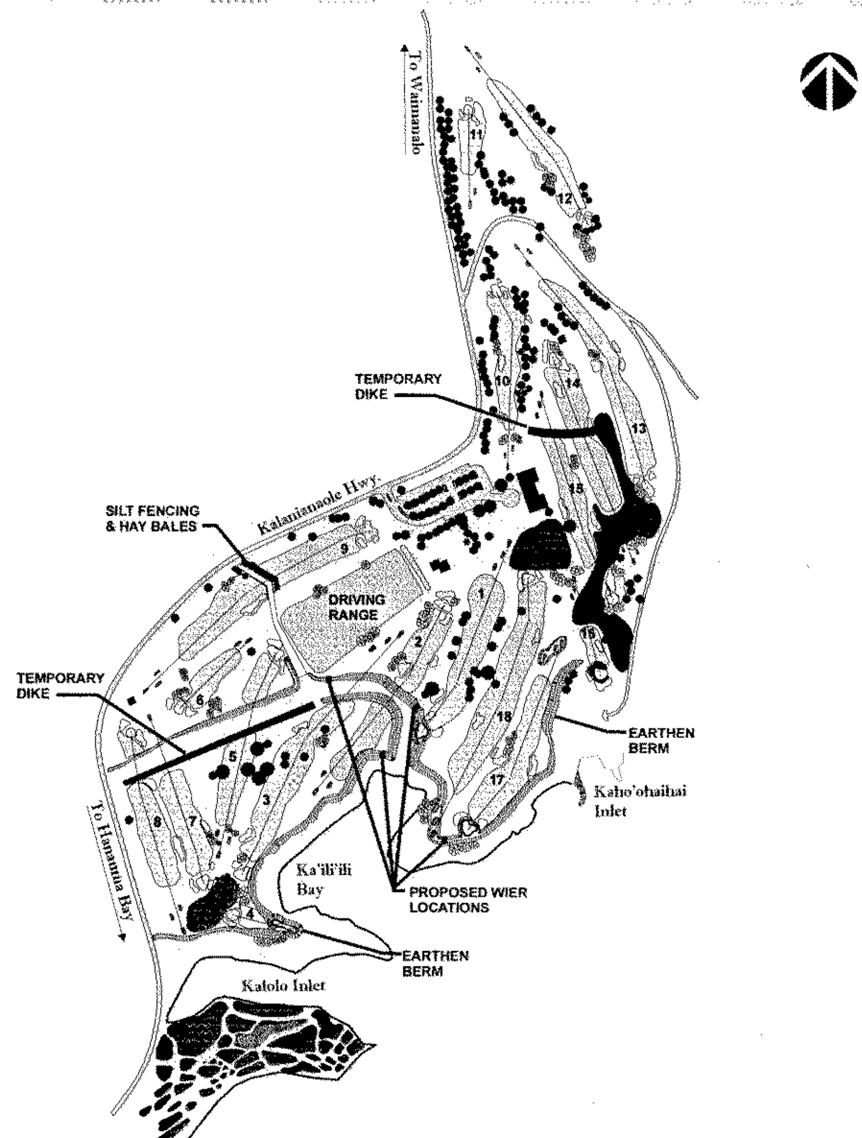


EXHIBIT 15: CONSTRUCTION BMPS
NOT TO SCALE

C. Permanent Erosion Control Measures

In planning for the Queen's Beach site, permanent erosion control measures were included to minimize the effects of runoff, sediment-laden runoff, and pollution on the surrounding marine habitat. Techniques include the following:

1. Grassing and landscaping of the site.
2. Construction of grassed berm at elevation 12 ft around the perimeter of the site, which will retain runoff on the site (see Exhibit 9).
3. Curb cuts that allow for runoff to travel over grassed or landscaped areas before reaching the final destination.
4. Cleaning of parking lots and roads to reduce the sediment load and pollutants.
5. Dry detention basins to trap suspended solids and sediment (see Exhibit 10).
6. Use of grassed swales and retention ponds that increase the time of concentration and the detention time.

D. Ordinance 96-34

Ordinance 96-34 states the following:

" The Chief engineer shall, pursuant to federal requirements, establish controls on the timing and rate of discharge of storm water runoff from any new development or redevelopment as may be appropriate to reduce storm water runoff pollution to the maximum extent practicable through the implementation of best management practices (BMP's) and engineering control facilities, designed to reduce the generation of pollutants. This may, where feasible and pursuant to City standards, include limiting peak storm water runoff rates for storms of higher frequencies to predevelopment levels."

In order to meet these requirements various measures were taken to reduce the peak flow including:

1. Construction of grass-lined swales and retention ponds to increase the time of concentration and detention time.
2. Use of landscaping and grassing.
3. Construction of earth berm to detain runoff on project site.

VI. REFERENCES

1. "Queen's Beach Draft Environmental Impact Statement, Queen's Beach, Oahu, Hawaii", Helber, Hastert & Fee, Planners, September 1996.
2. "Hawaii Kai Developments Preliminary Engineering Report Off-Site Improvements", Community Planning, Inc. August, 1996.
3. "Soil Survey of the Islands of Kauai, Oahu, Molokai, and Lanai, State of Hawaii", United States Department of Agriculture, Soil Conservation Service in cooperation with the University of Hawaii Agricultural Experiment Station, August 1972.
4. "Response to Reviewers: Proposed Golf Course, Queen's Beach, Oahu, Hawaii", William J. Walker, Ph.D., April 7, 1997.
5. "Soil Erosion Standards and Guidelines", Department of Public Works, City and County of Honolulu, November, 1974.
6. "Storm Drainage Standards", Department of Public Works, City and County of Honolulu, 1988.
7. "Runoff Management System STD 570", United States Department of Agriculture, Natural Resources Conservation Service, 1978.
8. "North American Green Version III Erosion Control Materials Design Software", North American Green, July 1995.

Appendix A

Drainage Calculations

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY RATIONAL METHOD
EXISTING CONDITIONS (10YR -1HR)

BASIN	ELEVATION		INTEN	RUNOFF	TC	TC	AREA	Q_{PEAK}	D	Tp	Tr	Tb	V	V
NUMB	UP	DN	(IN/HR)	COEFF	(MIN)	(HR)	(MI^2)	(CFS)	(hr)	(hr)	(hr)	(hr)	(cf)	(cy)
1	614	56	2	0.80	17.7	0.30	0.049	94.3	0.04	0.20	0.33	0.52	89,108	3,300
2	579	69	2	0.80	17.1	0.29	0.015	30.1	0.04	0.19	0.32	0.51	27,479	1,018
3	519	74	2	0.80	15.2	0.25	0.015	31.6	0.03	0.17	0.28	0.45	25,643	950
4	479	129	2	0.80	12.4	0.21	0.008	17.1	0.03	0.14	0.23	0.37	11,320	419
5	409	149	2	0.80	12.2	0.20	0.005	12.1	0.03	0.14	0.23	0.36	7,881	292
6	349	169	2	0.80	10.7	0.18	0.006	13.0	0.02	0.12	0.20	0.32	7,426	275
7	314	189	2	0.80	14.0	0.23	0.004	8.2	0.03	0.16	0.26	0.42	6,129	227
8	314	229	2	0.80	10.8	0.18	0.002	5.3	0.02	0.12	0.20	0.32	3,056	113
9	54	0	2	0.70	46.4	0.77	0.122	126.9	0.10	0.52	0.86	1.38	314,349	11,643
10	24	18	2	0.60	69.9	1.17	0.034	23.1	0.15	0.78	1.30	2.07	86,203	3,193
11	17	12	2	0.60	38.7	0.65	0.003	2.7	0.09	0.43	0.72	1.15	5,578	207
12	14	7	2	0.60	59.2	0.99	0.040	30.8	0.13	0.66	1.10	1.76	97,343	3,605
13	18	0	2	0.60	35.3	0.59	0.028	29.4	0.08	0.39	0.65	1.05	55,406	2,052
14	4	0	2	0.60	34.3	0.57	0.033	34.5	0.08	0.38	0.64	1.02	63,175	2,340
												Σ =	**800,096**	**29,633**

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY RATIONAL METHOD (50 YR - 1 HR)
EXISTING CONDITIONS (50YR -1HR)

BASIN	ELEVATION		INTEN	RUNOFF	TC	TC	AREA	Q_{PEAK}	D	Tp	Tr	Tb	V	V
NUMB	UP	DN	(IN/HR)	COEFF	(MIN)	(HR)	(MI^2)	(CFS)	(hr)	(hr)	(hr)	(hr)	(cf)	(cy)
1	614	56	3	0.80	17.7	0.30	0.045	141.5	0.04	0.20	0.33	0.52	133,710	4,952
2	579	69	3	0.80	17.1	0.29	0.014	45.1	0.04	0.19	0.32	0.51	41,172	1,525
3	519	74	3	0.80	15.2	0.25	0.014	47.4	0.03	0.17	0.28	0.45	38,464	1,425
4	479	129	3	0.80	12.4	0.21	0.007	25.6	0.03	0.14	0.23	0.37	16,947	628
5	409	149	3	0.80	12.2	0.20	0.005	18.2	0.03	0.14	0.23	0.36	11,854	439
6	349	169	3	0.80	10.7	0.18	0.005	19.5	0.02	0.12	0.20	0.32	11,139	413
7	314	189	3	0.80	14.0	0.23	0.004	12.2	0.03	0.16	0.26	0.42	9,118	338
8	314	229	3	0.80	10.8	0.18	0.002	8.0	0.02	0.12	0.20	0.32	4,613	171
9	54	0	3	0.70	46.4	0.77	0.112	190.3	0.10	0.52	0.86	1.38	471,400	17,459
10	24	18	3	0.60	69.9	1.17	0.031	34.7	0.15	0.78	1.30	2.07	129,491	4,796
11	17	12	3	0.60	38.7	0.65	0.003	4.1	0.09	0.43	0.72	1.15	8,471	314
12	14	7	3	0.60	59.2	0.99	0.037	46.2	0.13	0.66	1.10	1.76	146,015	5,408
13	18	0	3	0.60	35.3	0.59	0.026	44.1	0.08	0.39	0.65	1.05	83,109	3,078
14	4	0	3	0.60	34.3	0.57	0.030	51.7	0.08	0.38	0.64	1.02	94,671	3,506
												Σ =	**1,200,173**	**44,451**

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY RATIONAL METHOD
PROPOSED CONDITIONS (10YR -1HR)

BASIN NUMB	ELEVATION UP	DN	INTEN (IN/HR)	RUNOFF COEFF	TC (MIN)	TC (HR)	AREA (MI^2)	Q_{PEAK} (CFS)	D (hr)	Tp (hr)	Tr (hr)	Tb (hr)	V (cf)	V (cy)
1	614	56	2	0.65	17.7	0.30	0.049	76.7	0.04	0.20	0.33	0.52	72,477	2,684
2	579	69	2	0.80	17.1	0.29	0.015	30.1	0.04	0.19	0.32	0.51	27,479	1,018
3	519	74	2	0.80	15.2	0.25	0.015	31.6	0.03	0.17	0.28	0.45	25,643	950
4	479	129	2	0.80	12.4	0.21	0.008	17.1	0.03	0.14	0.23	0.37	11,320	419
5	409	149	2	0.80	12.2	0.20	0.005	12.1	0.03	0.14	0.23	0.36	7,881	292
6	349	169	2	0.80	10.7	0.18	0.006	13.0	0.02	0.12	0.20	0.32	7,426	275
7	314	189	2	0.80	14.0	0.23	0.004	8.2	0.03	0.16	0.26	0.42	6,129	227
8	314	229	2	0.80	10.8	0.18	0.002	5.3	0.02	0.12	0.20	0.32	3,056	113
9	179	69	2	0.80	12.7	0.21	0.023	49.6	0.03	0.14	0.24	0.38	33,629	1,246
10	88	12	2	0.35	26.6	0.44	0.034	23.8	0.06	0.30	0.49	0.79	33,798	1,252
11	57	10	2	0.70	39.4	0.66	0.035	40.3	0.09	0.44	0.73	1.17	84,768	3,140
12	50	4	2	0.35	21.0	0.35	0.014	11.2	0.05	0.23	0.39	0.62	12,557	465
13	14	6	2	0.35	47.9	0.80	0.009	4.7	0.11	0.53	0.89	1.42	12,019	445
14	14	2	2	0.35	40.6	0.68	0.011	6.0	0.09	0.45	0.75	1.20	13,005	482
15	14	4	2	0.35	33.1	0.55	0.007	4.1	0.07	0.37	0.61	0.98	7,245	268
16	16	4	2	0.35	28.3	0.47	0.004	2.6	0.06	0.31	0.52	0.84	3,928	145
17	20	4	2	0.35	22.3	0.37	0.018	13.4	0.05	0.25	0.41	0.66	15,953	591
18	20	12	2	0.35	28.1	0.47	0.003	2.1	0.06	0.31	0.52	0.83	3,150	117
19	22	14	2	0.35	37.7	0.63	0.015	8.7	0.08	0.42	0.70	1.12	17,510	649
20	18	10	2	0.35	17.0	0.28	0.006	5.4	0.04	0.19	0.32	0.50	4,901	182
21	16	2	2	0.35	20.0	0.33	0.002	1.4	0.04	0.22	0.37	0.59	1,495	55
22	14	4	2	0.35	18.2	0.30	0.012	9.6	0.04	0.20	0.34	0.54	9,328	345
23	24	4	2	0.35	15.6	0.26	0.013	11.5	0.03	0.17	0.29	0.46	9,578	355
24	24	12	2	0.35	11.9	0.20	0.008	8.3	0.03	0.13	0.22	0.35	5,273	195
												Σ =	**429,547**	**15,909**

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY RATIONAL METHOD
PROPOSED CONDITIONS (50YR -1HR)

BASIN NUMB	ELEVATION UP	DN	INTEN (IN/HR)	RUNOFF COEFF	TC (MIN)	TC (HR)	AREA (MI^2)	Q_{PEAK} (CFS)	D (hr)	Tp (hr)	Tr (hr)	Tb (hr)	V (cf)	V (cy)
1	614	56	3	0.65	17.7	0.30	0.049	115.0	0.04	0.20	0.33	0.52	108,669	4,025
2	579	69	3	0.80	17.1	0.29	0.015	45.1	0.04	0.19	0.32	0.51	41,172	1,525
3	519	74	3	0.80	15.2	0.25	0.015	47.4	0.03	0.17	0.28	0.45	38,464	1,425
4	479	129	3	0.80	12.4	0.21	0.008	25.6	0.03	0.14	0.23	0.37	16,947	628
5	409	149	3	0.80	12.2	0.20	0.005	18.2	0.03	0.14	0.23	0.36	11,854	439
6	349	169	3	0.80	10.7	0.18	0.006	19.5	0.02	0.12	0.20	0.32	11,139	413
7	314	189	3	0.80	14.0	0.23	0.004	12.2	0.03	0.16	0.26	0.42	9,118	338
8	314	229	3	0.80	10.8	0.18	0.002	8.0	0.02	0.12	0.20	0.32	4,613	171
9	179	69	3	0.80	12.7	0.21	0.023	74.5	0.03	0.14	0.24	0.38	50,512	1,871
10	88	12	3	0.35	26.6	0.44	0.034	35.7	0.06	0.30	0.49	0.79	50,697	1,878
11	57	10	3	0.70	39.4	0.66	0.035	60.4	0.09	0.44	0.73	1.17	127,047	4,705
12	50	4	3	0.35	21.0	0.35	0.014	16.8	0.05	0.23	0.39	0.62	18,835	698
13	14	6	3	0.35	47.9	0.80	0.009	7.1	0.11	0.53	0.89	1.42	18,156	672
14	14	2	3	0.35	40.6	0.68	0.011	9.1	0.09	0.45	0.75	1.20	19,724	731
15	14	4	3	0.35	33.1	0.55	0.007	6.1	0.07	0.37	0.61	0.98	10,779	399
16	16	4	3	0.35	28.3	0.47	0.004	4.0	0.06	0.31	0.52	0.84	6,043	224
17	20	4	3	0.35	22.3	0.37	0.018	20.0	0.05	0.25	0.41	0.66	23,810	882
18	20	12	3	0.35	28.1	0.47	0.003	3.2	0.06	0.31	0.52	0.83	4,801	178
19	22	14	3	0.35	37.7	0.63	0.015	13.1	0.08	0.42	0.70	1.12	26,366	977
20	18	10	3	0.35	17.0	0.28	0.006	8.1	0.04	0.19	0.32	0.50	7,351	272
21	16	2	3	0.35	20.0	0.33	0.002	2.1	0.04	0.22	0.37	0.59	2,242	83
22	14	4	3	0.35	18.2	0.30	0.012	14.4	0.04	0.20	0.34	0.54	13,992	518
23	24	4	3	0.35	15.6	0.26	0.013	17.2	0.03	0.17	0.29	0.46	14,325	531
24	24	12	3	0.35	11.9	0.20	0.008	12.4	0.03	0.13	0.22	0.35	7,876	292
												Σ =	**644,535**	**23,872**

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY SCS METHOD
EXISTING CONDITIONS (100YR - 6HR)

Basin #	Tc (min)	Tc (hr)	Area (ac)	Area (sq. mi)	Soil Types	Hydrologic Class	CN	Rainfall (in)	Runoff Depth (in)	Q (cfs/in)	Slope Adjust.	Peak Q (cfs)	D (hr)	Tp (hr)	Tr (hr)	Tb (hr)	V (cf)	V (cy)
1	17.7	0.30	31.6	0.049	rRK, LPE	D	84	11.8	9.79	18.00	1.12	197.4	0.04	0.20	0.33	0.52	186,500	6,907
2	17.1	0.29	9.9	0.015	rRK	D	84	11.8	9.79	6.80	1.15	76.6	0.04	0.19	0.32	0.51	69,891	2,589
3	15.2	0.25	9.9	0.015	rRK	D	84	11.8	9.79	6.80	1.15	76.6	0.03	0.17	0.28	0.45	62,125	2,301
4	12.4	0.21	5.0	0.008	rRK	D	84	11.8	9.79	3.50	1.17	40.1	0.03	0.14	0.23	0.37	26,539	983
5	12.2	0.20	3.5	0.005	rRK	D	84	11.8	9.79	3.00	1.13	33.2	0.03	0.14	0.23	0.36	21,616	801
6	10.7	0.18	3.6	0.006	rRK	D	84	11.8	9.79	3.00	1.17	34.4	0.02	0.12	0.20	0.32	19,629	727
7	14.0	0.23	2.5	0.004	rRK	D	84	11.8	9.79	2.50	1.06	25.9	0.03	0.16	0.26	0.42	19,391	718
8	10.8	0.18	1.5	0.002	rRK	D	84	11.8	9.79	1.80	1.00	17.6	0.02	0.12	0.20	0.32	10,160	376
9	46.4	0.77	14.5	0.023	LuA, LPE	D	84	11.8	9.79	33.00	1.27	410.3	0.10	0.52	0.86	1.38	1,016,368	37,643
10	69.9	1.17	21.9	0.034	LuA, LPE	D	84	11.8	9.79	11.00	0.59	63.5	0.15	0.78	1.30	2.07	237,103	8,782
11	38.7	0.65	22.7	0.035	LuA	D	84	11.8	9.79	1.80	0.86	15.2	0.09	0.43	0.72	1.15	31,311	1,160
12	59.2	0.99	9.3	0.014	rRK, LuA	D	84	11.8	9.79	13.00	0.74	94.2	0.13	0.66	1.10	1.76	297,654	11,024
13	35.3	0.59	5.9	0.009	rRK, KsB	D, B	81	11.8	9.39	10.50	1.17	115.4	0.08	0.39	0.65	1.05	217,394	8,052
14	34.3	0.57	6.9	0.011	rRK	D	84	11.8	9.79	11.00	0.85	91.5	0.08	0.38	0.64	1.02	167,618	6,208
																Σ =	**2,383,300**	**88,270**

EXISTING CONDITIONS (100YR - 24HR)

Basin #	Tc (min)	Tc (hr)	Area (ac)	Area (sq. mi)	Soil Types	Hydrologic Class	CN	Rainfall (in)	Runoff Depth (in)	Q (cfs/in)	Slope Adjust.	Peak Q (cfs)	D (hr)	Tp (hr)	Tr (hr)	Tb (hr)	V (cf)	V (cy)
1	17.7	0.30	31.6	0.049	rRK, LPE	D	84	14	11.96	18.00	1.12	241.1	0.04	0.20	0.33	0.52	227,839	8,438
2	17.1	0.29	9.9	0.015	rRK	D	84	14	11.96	6.80	1.15	93.5	0.04	0.19	0.32	0.51	85,382	3,162
3	15.2	0.25	9.9	0.015	rRK	D	84	14	11.96	6.80	1.15	93.5	0.03	0.17	0.28	0.45	75,895	2,811
4	12.4	0.21	5.0	0.008	rRK	D	84	14	11.96	3.50	1.17	49.0	0.03	0.14	0.23	0.37	32,422	1,201
5	12.2	0.20	3.5	0.005	rRK	D	84	14	11.96	3.00	1.13	40.5	0.03	0.14	0.23	0.36	26,407	978
6	10.7	0.18	3.6	0.006	rRK	D	84	14	11.96	3.00	1.17	42.0	0.02	0.12	0.20	0.32	23,980	888
7	14.0	0.23	2.5	0.004	rRK	D	84	14	11.96	2.50	1.06	31.7	0.03	0.16	0.26	0.42	23,689	877
8	10.8	0.18	1.5	0.002	rRK	D	84	14	11.96	1.80	1.00	21.5	0.02	0.12	0.20	0.32	12,413	460
9	46.4	0.77	14.5	0.023	LuA, LPE	D	84	14	11.96	33.00	1.27	501.2	0.10	0.52	0.86	1.38	1,241,651	45,987
10	69.9	1.17	21.9	0.034	LuA, LPE	D	84	14	11.96	11.00	0.59	77.6	0.15	0.78	1.30	2.07	289,658	10,728
11	38.7	0.65	22.7	0.035	LuA	D	84	14	11.96	1.80	0.86	18.5	0.09	0.43	0.72	1.15	38,251	1,417
12	59.2	0.99	9.3	0.014	rRK, LuA	D	84	14	11.96	13.00	0.74	115.1	0.13	0.66	1.10	1.76	363,631	13,468
13	35.3	0.59	5.9	0.009	rRK, KsB	D, B	81	14	11.55	10.50	1.17	141.9	0.08	0.39	0.65	1.05	267,402	9,904
14	34.3	0.57	6.9	0.011	rRK	D	84	14	11.96	11.00	0.85	111.8	0.08	0.38	0.64	1.02	204,772	7,584
																Σ =	**2,913,391**	**107,903**

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY SCS METHOD
PROPOSED CONDITIONS (100YR - 6HR)

Basin #	Tc (min)	Tc (hr)	Area (ac)	Area (sq. mi)	Soil Types	Hydrologic Class	CN	Rainfall (in)	Runoff Depth (in)	Q (cfs/in)	Slope Adjust.	Peak Q (cfs)	D (hr)	Tp (hr)	Tr (hr)	Tb (hr)	V (cf)	V (cy)
1	17.7	0.30	34.4	0.054	rRK, LPE	D	80	11.8	9.26	17.00	1.13	177.9	0.04	0.20	0.33	0.52	168,091	6,226
2	17.1	0.29	10.8	0.017	rRK	D	84	11.8	9.79	6.90	1.17	79.0	0.04	0.19	0.32	0.51	72,152	2,672
3	15.2	0.25	10.8	0.017	rRK	D	84	11.8	9.79	6.90	1.17	79.0	0.03	0.17	0.28	0.45	64,135	2,375
4	12.4	0.21	5.4	0.008	rRK	D	84	11.8	9.79	3.60	1.12	39.5	0.03	0.14	0.23	0.37	26,131	968
5	12.2	0.20	3.8	0.006	rRK	D	84	11.8	9.79	3.00	1.09	32.0	0.03	0.14	0.23	0.36	20,851	772
6	10.7	0.18	3.9	0.006	rRK	D	84	11.8	9.79	3.00	1.09	32.0	0.02	0.12	0.20	0.32	18,287	677
7	14.0	0.23	2.7	0.004	rRK	D	84	11.8	9.79	2.60	1.00	25.5	0.03	0.16	0.26	0.42	19,025	705
8	10.8	0.18	1.6	0.003	rRK	D	84	11.8	9.79	1.80	1.02	18.0	0.02	0.12	0.20	0.32	10,364	384
9	12.7	0.21	15.8	0.025	rRK	D	84	11.8	9.79	9.50	1.08	100.4	0.03	0.14	0.24	0.38	68,103	2,522
10	26.6	0.44	23.9	0.037	rRK, LuA	D	80	11.8	9.26	13.00	1.10	132.4	0.06	0.30	0.49	0.79	188,045	6,965
11	39.4	0.66	24.7	0.039	LPE, LuA	D	83	11.8	9.66	13.40	1.08	139.8	0.09	0.44	0.73	1.17	294,059	10,891
12	21.0	0.35	10.1	0.016	LuA	D	80	11.8	9.26	6.00	1.09	60.6	0.05	0.23	0.39	0.62	67,895	2,515
13	47.9	0.80	6.5	0.010	LuA	D	80	11.8	9.26	4.30	0.86	34.2	0.11	0.53	0.89	1.42	87,568	3,243
14	40.6	0.68	7.5	0.012	LuA	D	80	11.8	9.26	4.80	1.00	44.4	0.09	0.45	0.75	1.20	96,341	3,568
15	33.1	0.55	4.5	0.007	LuA	D	80	11.8	9.26	3.00	1.05	29.2	0.07	0.37	0.61	0.98	51,544	1,909
16	28.3	0.47	2.7	0.004	LuA	D	80	11.8	9.26	2.70	1.17	29.3	0.06	0.31	0.52	0.84	44,196	1,637
17	22.3	0.37	12.4	0.019	LuA	D	80	11.8	9.26	7.00	0.93	60.3	0.05	0.25	0.41	0.66	71,768	2,658
18	28.1	0.47	2.2	0.003	LuA	D	80	11.8	9.26	2.40	1.03	22.9	0.06	0.31	0.52	0.83	34,340	1,272
19	37.7	0.63	10.4	0.016	LuA, rRK	D	80	11.8	9.26	6.20	0.96	55.1	0.08	0.42	0.70	1.12	110,930	4,109
20	17.0	0.28	4.4	0.007	LuA, rRK	D	80	11.8	9.26	2.70	0.93	23.3	0.04	0.19	0.32	0.50	21,103	782
21	20.0	0.33	1.2	0.002	LuA, rRK	D	80	11.8	9.26	2.00	0.95	17.6	0.04	0.22	0.37	0.59	18,786	696
22	18.2	0.30	8.1	0.013	rRK, KsB	D,B	78	11.8	8.98	5.00	0.94	42.2	0.04	0.20	0.34	0.54	41,009	1,519
23	15.6	0.26	9.1	0.014	rRK, KsB	D,B	78	11.8	8.98	5.50	1.07	52.8	0.03	0.17	0.29	0.46	44,013	1,630
24	11.9	0.20	5.9	0.009	rRK, KsB	D,B	78	11.8	8.98	4.00	1.09	39.2	0.03	0.13	0.22	0.35	24,874	921
																Σ =	**1,663,608**	**61,615**

SAM O. HIROTA, INC. ENGINEERS & SURVEYORS
COMPUTATION OF STORM DISCHARGE BY SCS METHOD
PROPOSED CONDITIONS (100YR - 24HR)

Basin #	Tc (min)	Tc (hr)	Area (ac)	Area (sq. mi)	Soil Types	Hydrologic Class	CN	Rainfall (in)	Runoff Depth (in)	Q (cfs/in)	Slope Adjust.	Peak Q (cfs)	D (hr)	Tp (hr)	Tr (hr)	Tb (hr)	V (cf)	V (cy)
1	17.7	0.30	34.4	0.054	rRK, LPE	D	80	14	11.42	17.00	1.13	219.4	0.04	0.20	0.33	0.52	207,300	7,678
2	17.1	0.29	10.8	0.017	rRK	D	84	14	11.94	6.90	1.17	96.4	0.04	0.19	0.32	0.51	87,997	3,259
3	15.2	0.25	10.8	0.017	rRK	D	84	14	11.94	6.90	1.17	96.4	0.03	0.17	0.28	0.45	78,220	2,897
4	12.4	0.21	5.4	0.008	rRK	D	84	14	11.94	3.60	1.12	48.1	0.03	0.14	0.23	0.37	31,870	1,180
5	12.2	0.20	3.8	0.006	rRK	D	84	14	11.94	3.00	1.09	39.0	0.03	0.14	0.23	0.36	25,430	942
6	10.7	0.18	3.9	0.006	rRK	D	84	14	11.94	3.00	1.09	39.0	0.02	0.12	0.20	0.32	22,303	826
7	14.0	0.23	2.7	0.004	rRK	D	84	14	11.94	2.60	1.00	31.0	0.03	0.16	0.26	0.42	23,203	859
8	10.8	0.18	1.6	0.003	rRK	D	84	14	11.94	1.80	1.02	21.9	0.02	0.12	0.20	0.32	12,640	468
9	12.7	0.21	15.8	0.025	rRK	D	84	14	11.94	9.50	1.08	122.5	0.03	0.14	0.24	0.38	83,059	3,076
10	26.6	0.44	23.9	0.037	rRK, LuA	D	80	14	11.42	13.00	1.10	163.3	0.06	0.30	0.49	0.79	231,908	8,589
11	39.4	0.66	24.7	0.039	LPE, LuA	D	83	14	11.81	13.40	1.08	170.9	0.09	0.44	0.73	1.17	359,507	13,315
12	21.0	0.35	10.1	0.016	LuA	D	80	14	11.42	6.00	1.09	74.7	0.05	0.23	0.39	0.62	83,733	3,101
13	47.9	0.80	6.5	0.010	LuA	D	80	14	11.42	4.30	0.86	42.2	0.11	0.53	0.89	1.42	107,994	4,000
14	40.6	0.68	7.5	0.012	LuA	D	80	14	11.42	4.80	1.00	54.8	0.09	0.45	0.75	1.20	118,814	4,401
15	33.1	0.55	4.5	0.007	LuA	D	80	14	11.42	3.00	1.05	36.0	0.07	0.37	0.61	0.98	63,568	2,354
16	28.3	0.47	2.7	0.004	LuA	D	80	14	11.42	2.70	1.17	36.1	0.06	0.31	0.52	0.84	54,505	2,019
17	22.3	0.37	12.4	0.019	LuA	D	80	14	11.42	7.00	0.93	74.3	0.05	0.25	0.41	0.66	88,508	3,278
18	28.1	0.47	2.2	0.003	LuA	D	80	14	11.42	2.40	1.03	28.2	0.06	0.31	0.52	0.83	42,350	1,569
19	37.7	0.63	10.4	0.016	LuA, rRK	D	80	14	11.42	6.20	0.96	68.0	0.08	0.42	0.70	1.12	136,805	5,067
20	17.0	0.28	4.4	0.007	LuA, rRK	D	80	14	11.42	2.70	0.93	28.7	0.04	0.19	0.32	0.50	26,025	964
21	20.0	0.33	1.2	0.002	LuA, rRK	D	80	14	11.42	2.00	0.95	21.7	0.04	0.22	0.37	0.59	23,168	858
22	18.2	0.30	8.1	0.013	rRK, KSB	D,B	78	14	11.11	5.00	0.94	52.2	0.04	0.20	0.34	0.54	50,736	1,879
23	15.6	0.26	9.1	0.014	rRK, KSB	D,B	78	14	11.11	5.50	1.07	65.4	0.03	0.17	0.29	0.46	54,452	2,017
24	11.9	0.20	5.9	0.009	rRK, KSB	D,B	78	14	11.11	4.00	1.09	48.4	0.03	0.13	0.22	0.35	30,774	1,140
																$\Sigma =$	**2,044,869**	**75,736**

Erosion Control Calculations
Queen's Beach Golf Course

Date: 6/17/1997
Prepared By: JSH

Basin #	Area (ac)	Upper Elev (ft)	Lower Elev (ft)	Length of Slope (ft)	R	K	LS	C	P	CP	E	F	T (yr)	D	H
#1 (April 1 - July 31, '99)	60.88	16	2	800	62.7	0.28	0.376	0.488	0.336	0.16	1.1	4	0.33	2	569
#2 (Aug 1 - Aug 31, '99)	14.86	18	10	300	15.96	0.28	0.04	0.9	0.336	0.30	0.05	4	0.08	2	5
#3 (Sept 1 - Oct 31, '99)	24.24	20	4	400	31.73	0.28	0.697	0.9	0.336	0.30	1.9	4	0.17	2	333
#4 (April 1 - May 15, 2000)	21.72	70	16	700	23.37	0.28	3.78	0.633	0.56	0.35	8.8	4	0.12	2	1330
#5 (May 16 - June 16, 2000)	11.85	54	20	440	13.3	0.28	1.42	0.4	0.56	0.22	1.2	4	0.07	2	92
Total	133.55														2330

Appendix B
Erosion Control

Sample Calculation of the Severity Rating Number for Basin #3

Soil loss and severity ratings were calculated for the construction area in accordance with the City and County of Honolulu "Soil Erosion Standards and Guidelines", November 1975 (Reference 5).

1. Universal Soil Loss Equation

E   Annual Soil Loss in tons per acre
    E=RK(LS)(CP)

R   Soil Erosion Effect Factor, R, for a full year is 190 (Reference 5, Exhibit 3).
    R = (0.17)(190) = 31.73

K   Soil Erodibility Factor, K: The project is to be constructed on Lualualei Clay, LuA (Reference 3).
    K = 0.28 (Reference 5, Exhibit 5)

LS   Length and steepness of slope factor, LS: The LS factor was calculated by the formula given in Reference 5, Exhibit7, using an average slope of 4% and a typical field slope of 400 feet.
    LS = 0.697

CP   Engineering Erosion Control Factor, CP: Based on examples given in Reference 5, Exhibit 8, the following values were chosen for the CP factor.
    Grading in the winter months, C=0.9
    Incremental grading in 15 acres or smaller, P=0.7

Sediment basin installed at beginning of grading, P=0.6
Use of berms, sediment traps, and containment dikes, P=0.8
P = (0.7)(0.6)(0.8) = 0.336
CP = (0.9)(0.336) = 0.30

E = (31.73)(0.28)(0.697)(0.30) = 1.90

2. Severity Rating Number

F Potential Downstream Drainage Factor, F: Potential damage area directly below site or more than 300 feet but with stream or drainage channel through or close to lower boundary of site.
F = 4 (Reference 5, Exhibit 1, Table 1).

T Time Duration, T:
T = 0.17 year

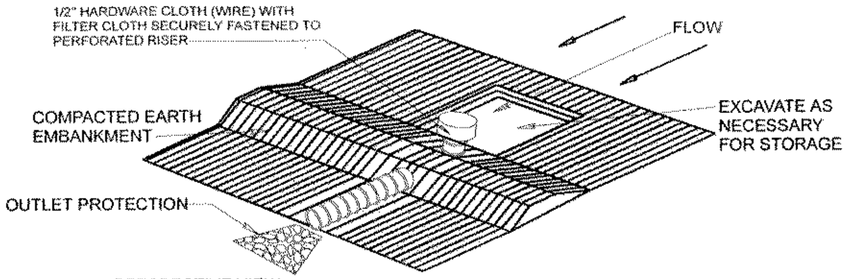
D Potential Sediment Damage Factor, D: Area classified A (Reference 5, Exhibit 1, Table 2).
D = 2

A Area of disturbance, A: The grading area is 24.24 acres.
A = 24.24 acres

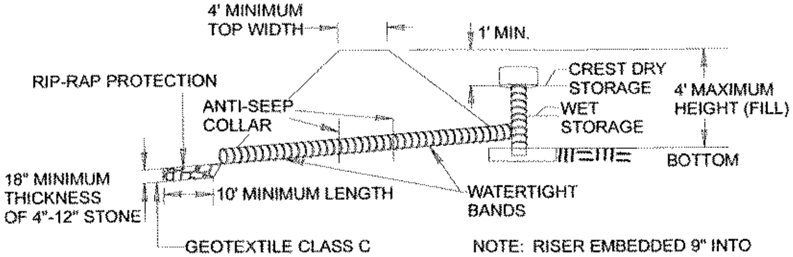
E Annual Soil Loss, E:
E = 1.90 (as calculated above)

H Severity Rating Number, H:
H = [(2)(4)(0.17) + (3)(2)] x (24.24)(1.90) = 333

Appendix C
Details



PERSPECTIVE VIEW



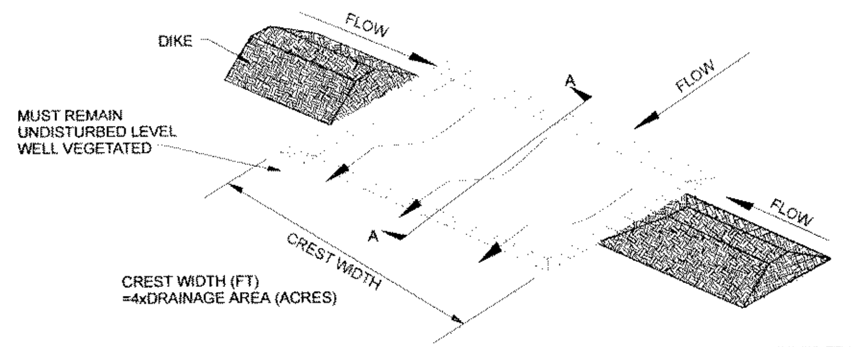
EMBANKMENT SECTION THROUGH RISER

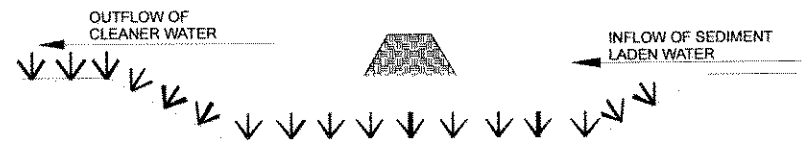
NOTE: RISER EMBEDDED 9" INTO CONCRETE OR 1/4" STEEL PLATE ATTACHED TO RISER WITH A CONTINUOUS WELD ON BOTTOM AND 2' OF STONE PLACED ON STEEL PLATE TWICE THE RISER DIAMETER (MIN.)

CONSTRUCTION SPECIFICATION

1. THE AREA UNDER THE EMBANKMENT SHALL BE CLEARED, GRUBBED AND STRIPPED OF ANY VEGETATION AND ROOT MAT. THE POOL AREA SHALL BE CLEARED.
2. THE FILL MATERIAL FOR THE EMBANKMENT SHALL BE FREE OF ROOTS OR OTHER WOODY VEGETATION AS WELL AS OVERSIZED STONES, ROCKS, ORGANIC MATERIAL, OR OTHER OBJECTIONABLE MATERIAL. THE EMBANKMENT SHALL BE COMPACTED BY TRAVERSING WITH EQUIPMENT WHILE IT IS BEING CONSTRUCTED.
3. THE TOTAL TRAP VOLUME AS MEASURED FROM THE BOTTOM TO RISER CREST ELEVATION SHALL BE 3600 CUBIC FEET PER ACRE OF DRAINAGE AREA. THE TOP OF EMBANKMENT MUST BE ≥ 1 FT ABOVE THE RISER CREST ELEVATION.
4. SEDIMENT SHALL BE REMOVED AND THE TRAP RESTORED TO ITS ORIGINAL DIMENSIONS WHEN THE SEDIMENT HAS ACCUMULATED TO ONE HALF OF THE WET STORAGE DEPTH OF THE TRAP (900 CF/AC). THE SEDIMENT SHALL BE DEPOSITED IN A SUITABLE AREA AND IN SUCH A MANNER THAT IT WILL NOT ERODE.
5. THE STRUCTURE SHALL BE INSPECTED PERIODICALLY AND AFTER EACH RAIN AND REPAIRS MADE AS NECESSARY.

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE SYRACUSE, NEW YORK	PIPE OUTLET SEDIMENT TRAP ST-I	STANDARD SYMBOL





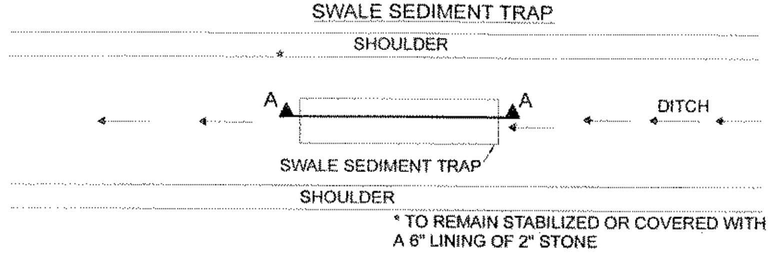
SECTION A-A

CONSTRUCTION SPECIFICATION FOR ST-II

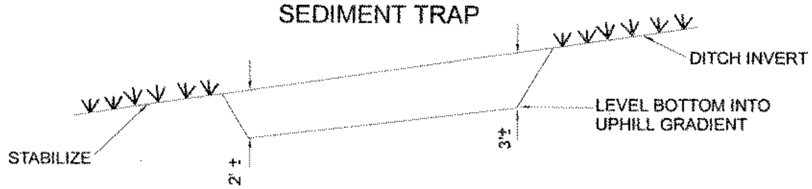
1. VOLUME OF SEDIMENT STORAGE SHALL BE 1800 CUBIC FEET PER ACRE OF CONTRIBUTORY DRAINAGE AREA.
2. MINIMUM CREST WIDTH SHALL BE 4 x DRAINAGE AREA.
3. SEDIMENT SHALL BE REMOVED AND TRAP RESTORED TO ITS ORIGINAL DIMENSIONS WHEN THE SEDIMENT HAS ACCUMULATED TO 1/2 THE DESIGN DEPTH OF THE TRAP. REMOVED SEDIMENT SHALL BE DEPOSITED IN A SUITABLE AREA AND IN SUCH A MANNER THAT IT WIL NOT ERODE.
4. THE STRUCTURE SHALL BE INSPECTED AFTER EACH RAIN AND REPAIRS MADE AS NEEDED.
5. CONSTRUCTION OPERATIONS SHALL BE CARRIED OUT IN SUCH A MANNER THAT EROSION AND WATER POLLUTION SHALL BE MINIMIZED.
6. THE SEDIMENT TRAP SHALL BE REMOVED AND AREA STABILIZED WHEN THE REMAINING DRAINAGE AREA HAS BEEN PROPERLY STABILIZED.
7. ALL CUT SLOPES SHALL BE 1:1 OR FLATTER.

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE SYRACUSE, NEW YORK	GRASS OUTLET SEDIMENT TRAP ST-II	STANDARD SYMBOL

SWALE SEDIMENT TRAP



SEDIMENT TRAP

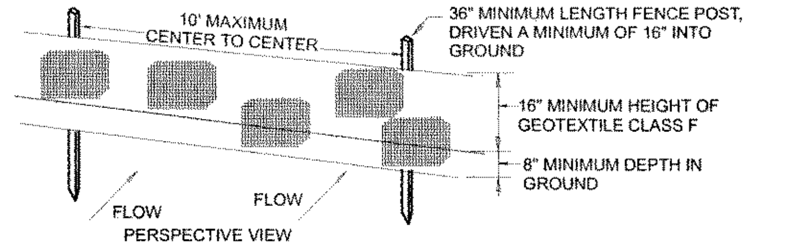


SECTION A-A

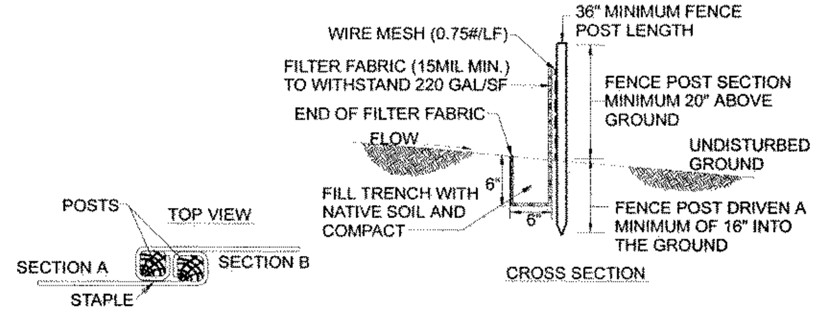
CONSTRUCTION SPECIFICATION FOR ST-IV

1. THE SWALE SEDIMENT TRAP SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE DIMENSIONS PROVIDED ON THE DESIGN DRAWINGS OR SIZED TO PROVIDE THE MINIMUM STORAGE NECESSARY 1800 CUBIC FEET OF STORAGE FOR EACH ACRE OF DRAINAGE AREA.
2. SEDIMENT SHALL BE REMOVED AND TRAP RESTORED TO ITS ORIGINAL DIMENSIONS WHEN THE SEDIMENT HAS ACCUMULATED TO 1/2 THE DESIGN DEPTH OF THE TRAP. REMOVED SEDIMENT SHALL BE DEPOSITED IN A SUITABLE AREA AND IN SUCH A MANNER THAT IT WILL NOT ERODE.
3. THE STRUCTURE SHALL BE INSPECTED AFTER EACH RAIN AND REPAIRS MADE AS NEEDED.
4. CONSTRUCTION OPERATIONS SHALL BE CARRIED OUT IN SUCH A MANNER THAT EROSION AND WATER POLLUTION SHALL BE MINIMIZED.
5. THE SEDIMENT TRAP SHALL BE REMOVED AND AREA STABILIZED WHEN THE CONTRIBUTORY DRAINAGE AREA HAS BEEN PROPERLY STABILIZED.
6. THE SWALE SEDIMENT TRAP WILL BE PROPERLY BACKFILLED AND THE SWALE OR DITCH RECONSTRUCTED.

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE SYRACUSE, NEW YORK	SWALE SEDIMENT TRAP ST-IV	STANDARD SYMBOL



PERSPECTIVE VIEW



JOINING TWO ADJACENT SILT FENCE SECTIONS

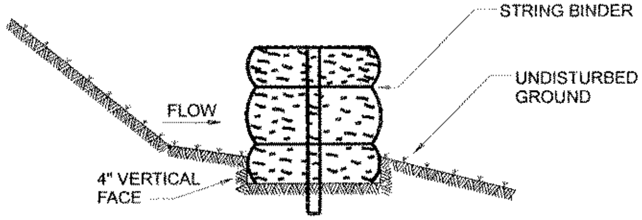
CONSTRUCTION SPECIFICATION FOR ST-IV

1. FENCE POSTS SHALL BE A MINIMUM OF 36" LONG DRIVEN 16" MINIMUM INTO THE GROUND. WOOD POSTS SHALL BE 1-1/2" X 1-1/2" SQUARE (MIN.) CUT, OR 1-3/4" DIAMETER (MIN.) ROUND AND SHALL BE OF SOUND QUALITY HARDWOOD. STEEL POSTS WILL BE STANDARD T OR U SECTION WEIGHTING NOT LESS THAN 1.00 POND PER LINEAR FOOT.
2. GEOTEXTILE SHALL BE FASTENED SECURELY TO EACH FENCE POST WITH WIRE TIES OR STAPLES AT TOP AND MID-SECTION AND SHALL MEET THE FOLLOWING REQUIREMENTS FOR GEOTEXTILE CLASS F:

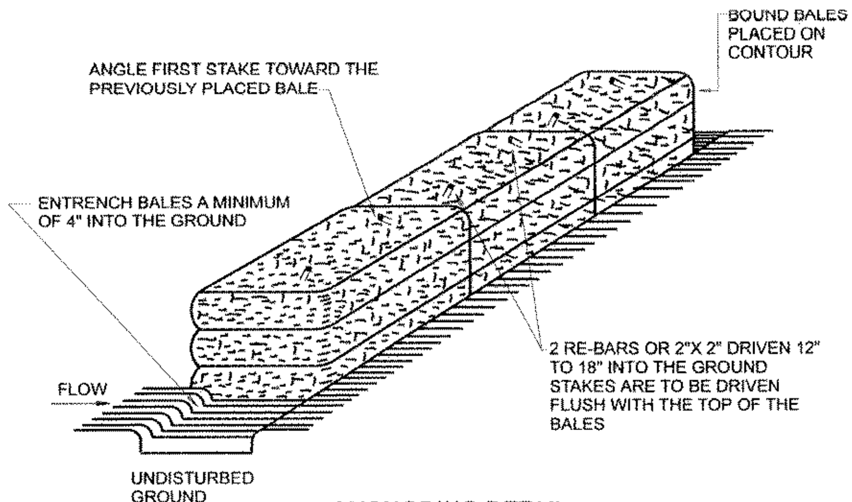
TENSILE STRENGTH	50 LBS/IN (MIN.)	TEST: MSMT 509
TENSILE MODULUS	20 LBS/IN (MIN.)	TEST: MSMT 509
FLOW RATE	0.3 GAL^2 FT/MIN. (MAX.)	TEST: MSMT 322
FILTERING EFFICIENCY	75% (MIN.)	TEST: MSMT 322

3. WHERE ENDS OF GEOTEXTILE FABRIC COME TOGETHER, THEY SHALL BE OVERLAPPED, FOLDED AND STAPLED TO PREVENT SEDIMENT BYPASS.
4. SILT FENCE SHALL BE INSPECTED AFTER EACH RAINFALL EVENT AND MAINTAINED WHEN BULGES OCCUR OR WHEN SEDIMENT ACCUMULATION REACHES 50% OF THE FABRIC HEIGHT.

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE SYRACUSE, NEW YORK	SILT FENCE	STANDARD SYMBOL



BEDDING DETAIL



ANCHORING DETAIL

U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE SYRACUSE, NEW YORK	STRAW BALE DIKE	STANDARD SYMBOL