Preliminary Report
Environmental Studies Program
Hawaii Geothermal Project

Project Director:

Dr. Robert Kamins
Department of Economics
University of Hawaii, Manoa

Project Coordinator:

Dr. Michael J. Chun
School of Public Health
University of Hawaii, Manoa

Contributors:

Mr. William Bonk
Department of Anthropology
University of Hawaii, Hilo

Mr. Thomas Speitel
Department of Botany
University of Hawaii, Manoa

Dr. Robert Buddemaier
Department of Chemistry
University of Hawaii, Manoa

Dr. Peter Kroopnick
Department of Oceanography
University of Hawaii, Manoa

Dr. Michael J. Chun
School of Public Health
University of Hawaii, Manoa

Dr. Barbara Z. Siegel
Department of Microbiology and
and Pacific Biomedical Research
Center

Dr. Sanford M. Siegel
Department of Botany
University of Hawaii, Manoa

Dr. Theodorus Hufen
Hawaii Institute of Geophysics
University of Hawaii, Manoa

Dr. Steven Lau
Department of Civil Engineering and
Water Resources Research Center
University of Hawaii, Manoa

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Introduction

The Hawaii Geothermal Project, a coordinated research effort of the University of Hawaii, funded by the County and State of Hawaii as well as by the federal government, was initiated in 1973 in an effort to identify, generate, and utilize geothermal energy on the Big Island of Hawaii. In developing geothermal power resources, a number of phasal stages are involved, including exploration, test drilling, production testing, field development, power plant and powerline construction, and finally, full-scale production.

Phase I of the Project began in the summer of 1973 to conduct exploratory surveys, develop analytical models for interpretation of geophysical results, conduct studies on energy recovery from hot brine, and to examine the legal and economic implications of developing geothermal resources in the state. Phase II of the Project, initiated in the summer of 1975, centers on drilling an exploratory research well on the Island of Hawaii, but also continues operational support for the geophysical, engineering, and socio-economic activities delineated above. The project to date (October 1975) is between the exploration and test drilling stages.

It is recognized that throughout the various project phases leading up to full scale production of geothermal energy, the activities of the Project must be carefully scrutinized to ascertain in a timely way if there are any adverse effects on the environment and local ecosystems, and should they occur, to identify and recommend measures to minimize these impacts.

Investigations thus far concluded have provided initial baseline data describing the existing environmental setting of the drilling site and vicinity before drilling has begun. Data gathering will continue throughout the drilling operations in order that changes to the environs of the immediate drilling area can be detected. This type of comparative data is essential to the development of mitigating measures that will provide for environmentally acceptable field operations should feasibility be demonstrated.

The immediate outcome of these initial baseline investigations is this working paper that will serve as the basis for an environmental impact assessment or statement, as one may be required for further geothermal development activities. For purposes of drilling the exploratory well, only a statement of intent to drill is required; however, anticipating successful exploration, an assessment or statement of environmental impact will be required later.

The baseline studies that have been concluded to date describe the existing environmental setting in terms of archaelogical significance (Mr. William Bonk, UH Hilo), flora (Drs. Sanford Siegel and Barbara Siegel, UH Manoa), groundwater (Water Resources Research Center, UH Manoa), air quality (Drs. Sanford Siegel and Barbara Siegel), and noise (Dr. Mike Chun, UH Manoa).

Description of Environment

The exploratory drill site is located in a 4-acre parcel in the Puna District of Hawaii, approximately three miles east of Pahoa on Pohoiki Road and about 3 miles from the coast; see Figure 1. This district is an area of marked environmental contrast with good soil fertility and lush vegetation occurring over the older, lower lying lands, while the upper slopes include large areas of land dotted with spaced lehua trees. Elsewhere, there is virgin forest on dry desert and in other areas recent lava flows have blackened the land, giving it a desolate and empty feeling. Along the coast, the ocean more often meets with black lava cliffs and offshore waters rapidly deepen. If there are pockets of sand, these too are normally black, produced by the explosion of hot lava meeting the sea.

Presently, the district is utilized for cane cultivation and papaya and orchid farming, with considerable growth in large land subdivisions occurring over the last decade or so.

Archaeology. Historically, Puna has played a relatively insignificant role in the centuries of seesaw relationships that had marked the political power and control activities on the island. During all of this time Puna produced no great family or chief whose support was crucial in deciding control over lands or districts by the many warring factions. Why it was that this district never developed strong leadership and/or a political power base is not known. Perhaps the size of the population was inadequate, or perhaps local ecological conditions were disadvantageous and would not allow for the necessary logistical support of a sufficiently strong army. Or perhaps time alone was a negative factor in the required socio-economic development of the culture prevalent in the region. Whatever the reasons, the fact remains that in place of any strong internal control of power within the area one is only able to note that the political control of Puna was wielded by the bordering districts of Hilo and Ka'u.

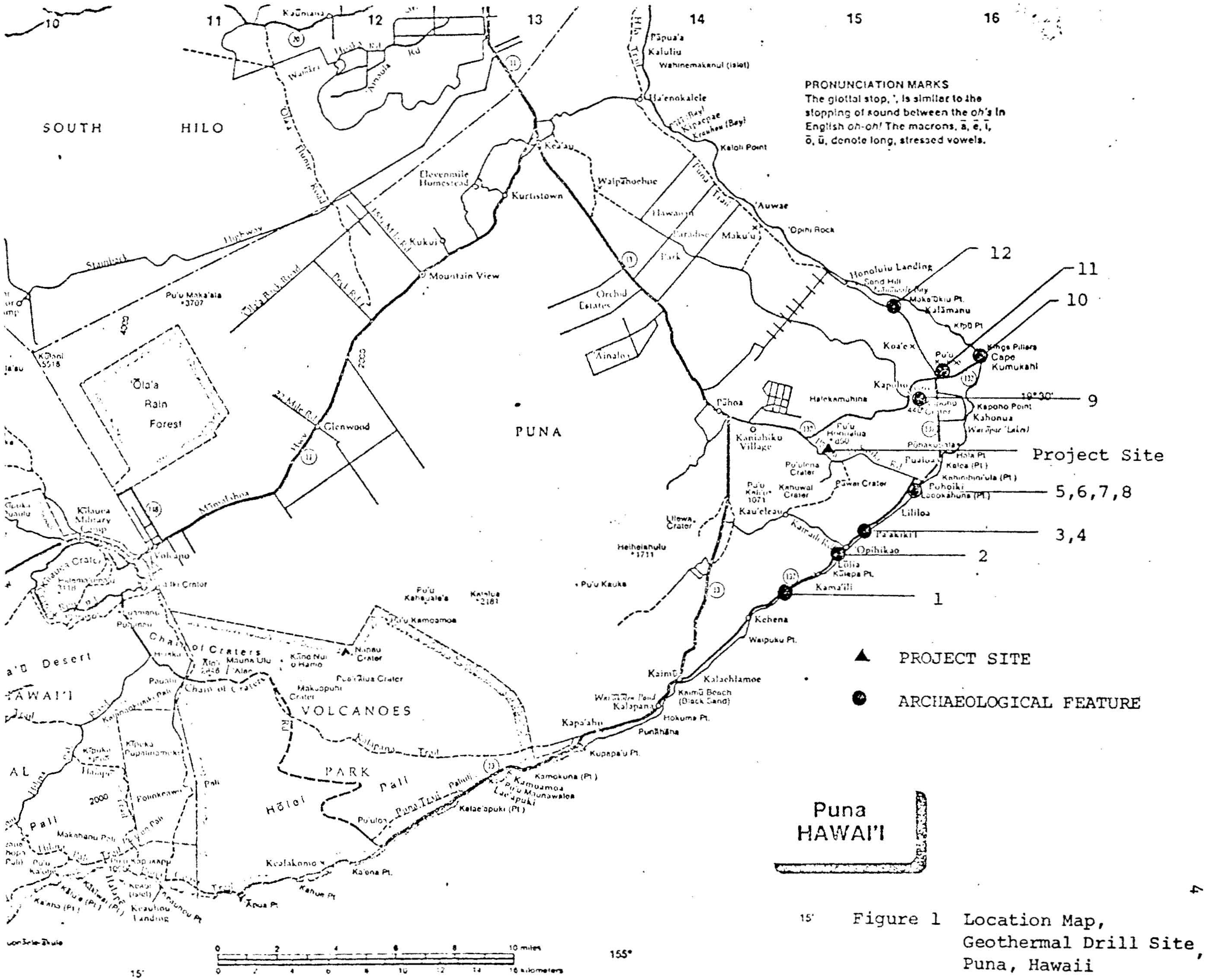


Figure 1 Location Map, Geothermal Drill Site, Puna, Hawaii

The area immediately surrounding the exploratory drilling site, hereinafter referred to as the study area, consists of recent as well as prehistoric lava flows. The 1955 eruption of Kilauea volcano broke through the earth's crust approximately one-quarter mile from the drilling site and as a result of this relatively recent volcanic activity any such archaeologically significant material in the study area, or for that matter within the region covered by this flow, has been obliterated, if indeed any was ever present prior to this environmental change.

Examination of this lava covered region, as well as the older ground cover within the study area, failed to uncover any evidence of archaeological sites, artifacts, or other data that would indicate prehistoric occupation or activity in this tract of land. If this area of Puna was altered in any way by man it certainly does not show evidence to this effect. Perhaps agricultural plots may have been developed at some time in the prehistoric past, but these too, if present, do not show existence at the present time.

Although the contemporary flora consisting generally of scrub ohia trees, brush, some ferns and a fair amount of grass and weed overlay, is not ideal for the differentiation and location of archaeological remains, it is sufficiently traversable so as to allow confidence in those conclusions.

Although no archaeological features or evidence were found within the study area, there are a number of sites in the northeastern portion of the District. The location of these sites are shown in Figure 1 and brief descriptions of each feature are given in Appendix A.

Within about one-half mile west of the project site, near the intersection of Highway 132 and Pahoiki Road, is located the State Lava Tree Park, a feature not of archaeological significance but of geological interest. This 17-acre park, known locally as Kanakaloloa, consists of about 75 standing lava tree casts formed during historic flows through this originally forested area. These tree casts were formed when the lava encapsulated standing trees, followed by burning of the trees, leaving an almost perfect mold of each tree.

Flora. Within the study area, sampling for estimation of floral species density was performed, as shown in Figure 2. A complete species list, along with frequency and cover of individual species for each transect and quadrat, are given in Table 1 and Figures 3 and 4.

In addition to identification of species, limited investigations in geo-toxicology were performed. In these baseline investigations, mercury was given high priority. Principal indicators selected were the staghorn fern (*Dicranopteris sp*.), ohia (*Metrisideros collina*, var. polymorpha), and nut grass (*Cyperus rotundus*). Where these indicator species were not present, alternative indicators were used and included guava (*Psidium sp*.), Boston fern (*Nephrolepsis exaltata* var. Bostoniensis) and lycopodium (*Lycopodium cernvum*).

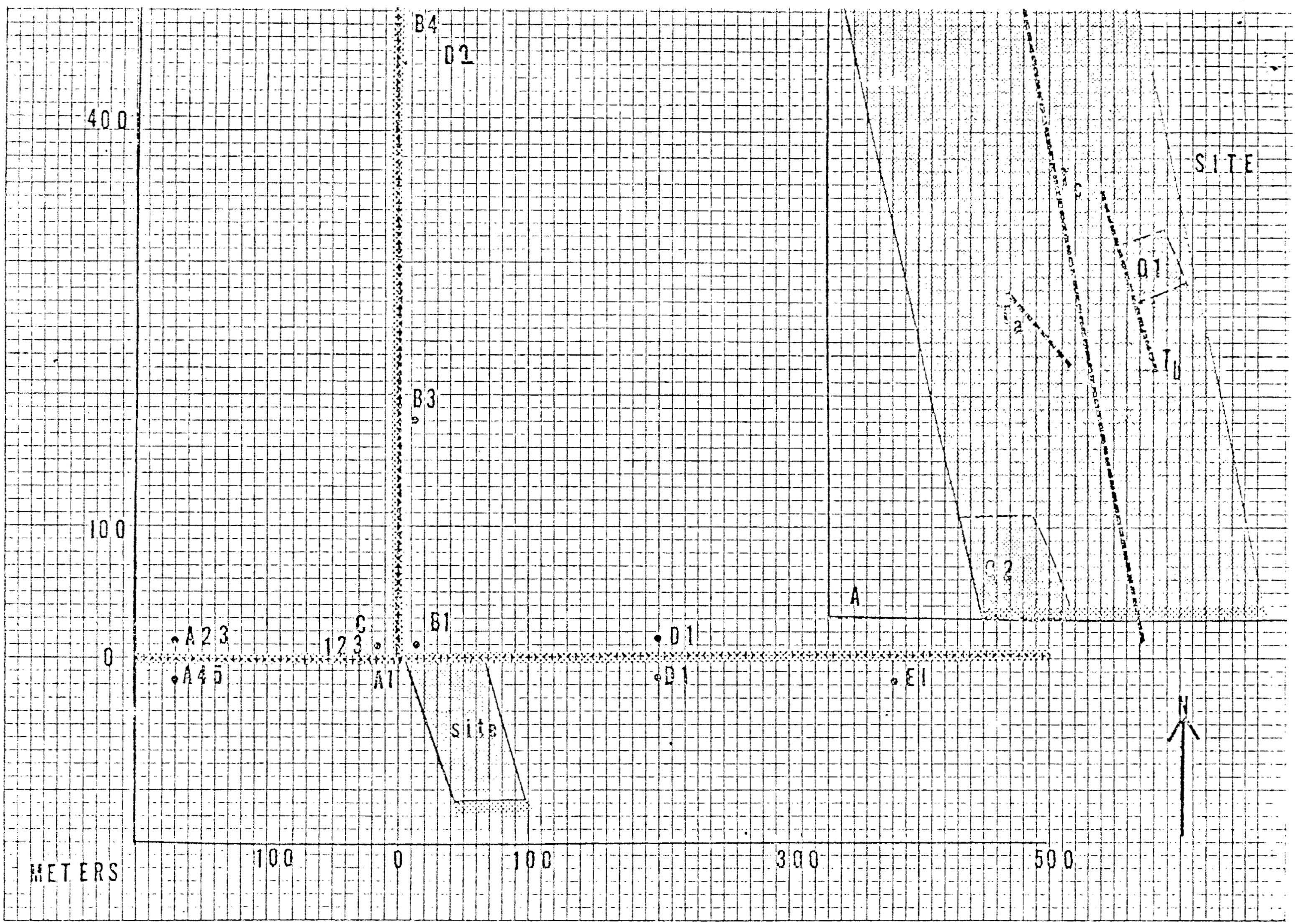
Relatively speaking, the staghorn fern showed a remarkedly uniform mercury content over the entire area sampled, as shown in Figure 5. Most values were between 150 and 210 ppb, although ohia in a stand to the rear of the drill site gave an unusually high value, circa 500 ppb. Again, most representative samples of this species yielded mercury contents of 150-200 ppb.

In each case the data for any species at any site were based upon tissue collection representing at least 5, and more commonly 8-12 individual plants. For the entire sample population shown in Figure 5 and representing over 120 assorted individual plants, the mean mercury content was 159 with a standard error of only 19 ppb, which amounts to only 12% of the mean. This speaks for the remarkedly low degree of variability in mixed population.

For purposes of comparison, ohia and Boston fern collected near Volcano House in a steam zone yielded 180-250 ppb of mercury and lycopodium collected at the Sulfur Banks contained 187 ppb.

The nut grass transect shown in Figure 6 involved an extended linear

Fig. 2 Drill Site and Its Environs in Semi-diagramatic Form. Shown are Pohoiki Bay Drive (Route 132) and its intersection with Leilani Street near one edge of the site. Each small square within the coordinate system is (10 meters)^2. Locations designated by letter and number are sample sites. Inset A provides a 4 x 4 fold expanded view within the drill site area per se. Shown at Q1 and Q2 are vegetation quadrats; at T_a and T_b are transect lines for general floristic purposes; and at T_c a transect for soil and samples of nut grass *(Cyperus rotundus)*.


B4
D2
400
SITE
C
D1
B3
100
C2
A
C
B1
A23
123
D1
0
A45
A1
D1
E1
N
site
100
0
100
300
500
METERS

7a

Table 1. Flora Species and Extent of Cover

	Quadrat 1	Quadrat 2	Transect 1	Transect 2
Total area (m^2)	4.0	14.5	1.1	2.7
Fraction of total area with plant cover	.31	.39	.36	.28
<u>Species list</u>	n/frequency/fraction of total cover			
	Quadrat 1	Quadrat 2	Transect 1	Transect 2
ASCLEPIADACEAE				
Asclepias curassavica L.	27/.44/.34	19/.23/.10	6/.08/.41	17/.21/.31
BURNAMMIACEAE				
Emilia javanica (Burm. l.) C.B. Robins			1/.01/<.01	
COMPOSITAE				
Ageratum haustaneanum Mill				
Erichtites valerianefolia (Wolf) D.C.	4/.06/.03		7/.09/.01	6/.07/.02
Erigeron bonariensis L.	2/.03/.02	1/.01/.01		1/.02/.01
Pluchea odorata (L.) Cass		1/.01/.01		
Vernonia cinerea (l.) Less	1/.02/<.01		4/.05/<.01	5/.06/<.01
CYPERACEAE				
Cyperus rotundus L.	1/.02/<.01	6/.07/.03	19/.24/.09	13/.16/.02
Rhychospora lavarum Gaud.	1/.02/<.01	3/.04/.02	5/.06/.01	6/.08/.02
Carex sp.	3/.05/<.02		2/.03/<.01	5/.06/.07
FELICINEAE				
Spheriomeris chiensis (L.) Maxon		2/.02/.02		
GRAMINEAE				
Andropogon virinicus L.	19/.31/.46	10/.12/.10	17/.21/.28	23/.29/.48
Brachiaria mutica (Forsk.) Stapp				
Melinis minutiflora Beauty				
Saccolepis indica (L.) Chase			11/.14/.04	

IRADACEAE				
Tritonia crocosmiflora		11/.07/.04		
LAURACEAE				
Metrosideros collina subsp. polymorpha (Gaud) Rock		3/.04/.02		
LEGUMINOSAE				
Cassia eschenaultiana				
Desmodium triflorum (L.) D.C.			1/.01/<.01	2/.02/.39
LYDOPODIACEAE				
Lydopodium Sp.				
LYTHRACEAE				
Cuphea carthagenesis (Jacq) MacBride				
MELASTOMACEAE				
Melastoma malabathnicum L.	1/.02/.11	4/.05/.03		
ORCHIDACEAE				
Arundima bambusaefolia (Roxb.) Lindl.				
Spatholglottis plicata Bl.				
PARKERIACEAE				
Nephrolepis exaltata (L.) Schott				
POLYDODIACEAE				
Pteridium sp.		11/.13/.52		
ROSACEAE				
Rubus penetrans Bailey	2/.03/.01	7/.08/.04		2/.03/.01
SCROPHULARIACEAE				
Castilleja arvensis Schlect & Chom		5/.06/.04		
VERBENACEAE				
Lantana camara L.				
Stachytarpheta cayennensis (L.C. Rich) Vahl				
Stachytarpheta urticaefolia (Salish) Sims		3/.04/.02	3/.04/.03	

Fig. 3 Detailed Illustration of Quadrat 1. The plant species and the extent of their coverage are shown. Species a is *Asclepias currassavica*; species b is *Andropogon virginicus*; species c is *Cassia eschenaultiana*; species d is *Cyperus rotundus*; species e is *Cassia* sp.; species f is *Erigeron bonarienses*; species g is *Erechtites valerianefolia*; species h is *Iris* sp.; species i is *Metrosideros collina*; species j is *Melinis minutiflora*; species k is *Pteridium* sp.; species l is *Rhychospora lavarum*; species m is *Rubus penetrans*; species n is *Stachytarpheta cayennensis*; species o is *Stachytarpheta urticaefolia*; species p is *Vernonia cinerea*.

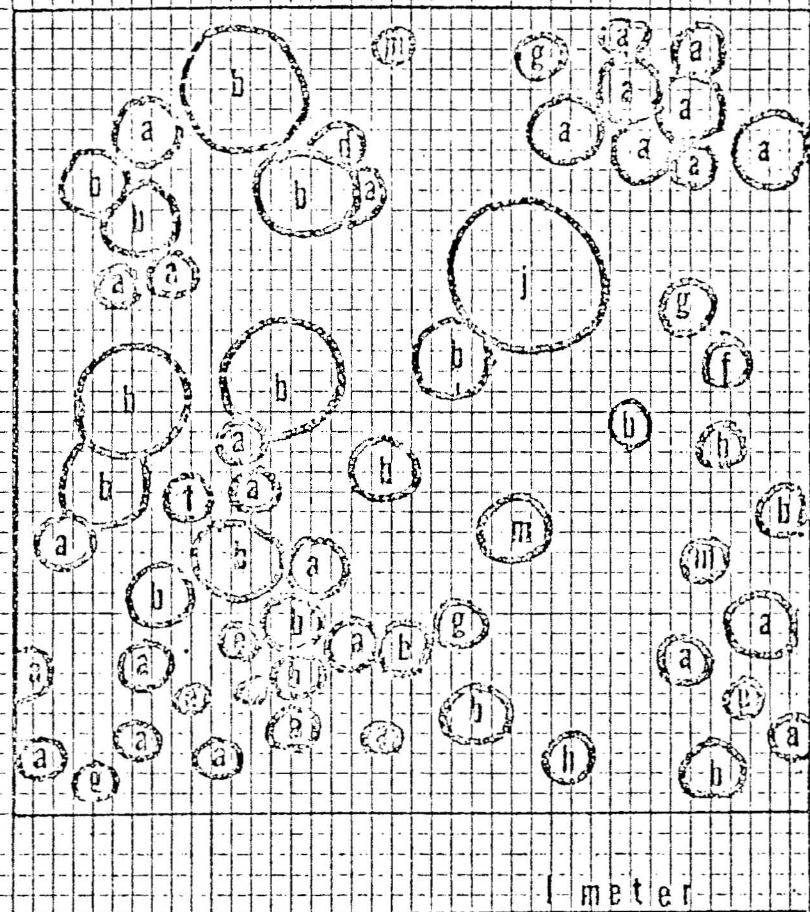

1 meter

Fig. 4 Detailed Illustration of Quadrat 2. The plant species and the extent of their coverage is shown. Species a is *Asclepias currassavica*; species b is *Andropogon virgenicus*; species c is *Cassia eschenaultiana*; species d is *Cyperus rotundus*; species e is *Cassia* sp.; species f is *Erigeron bonarienses*; species g is *Erechtites valerianefolia*; species h is *Iris* sp.; species i is *Metrosideros collina*; species j is *Melinis minutiflora*; species l is *Rhychospora lavarum*; species m is *Rubus penetrans*; species n is *Stachytarpheta cayennesis*; species o is *Stachytarpheta urticaefolia*; species p is *Veronia cinerea*.

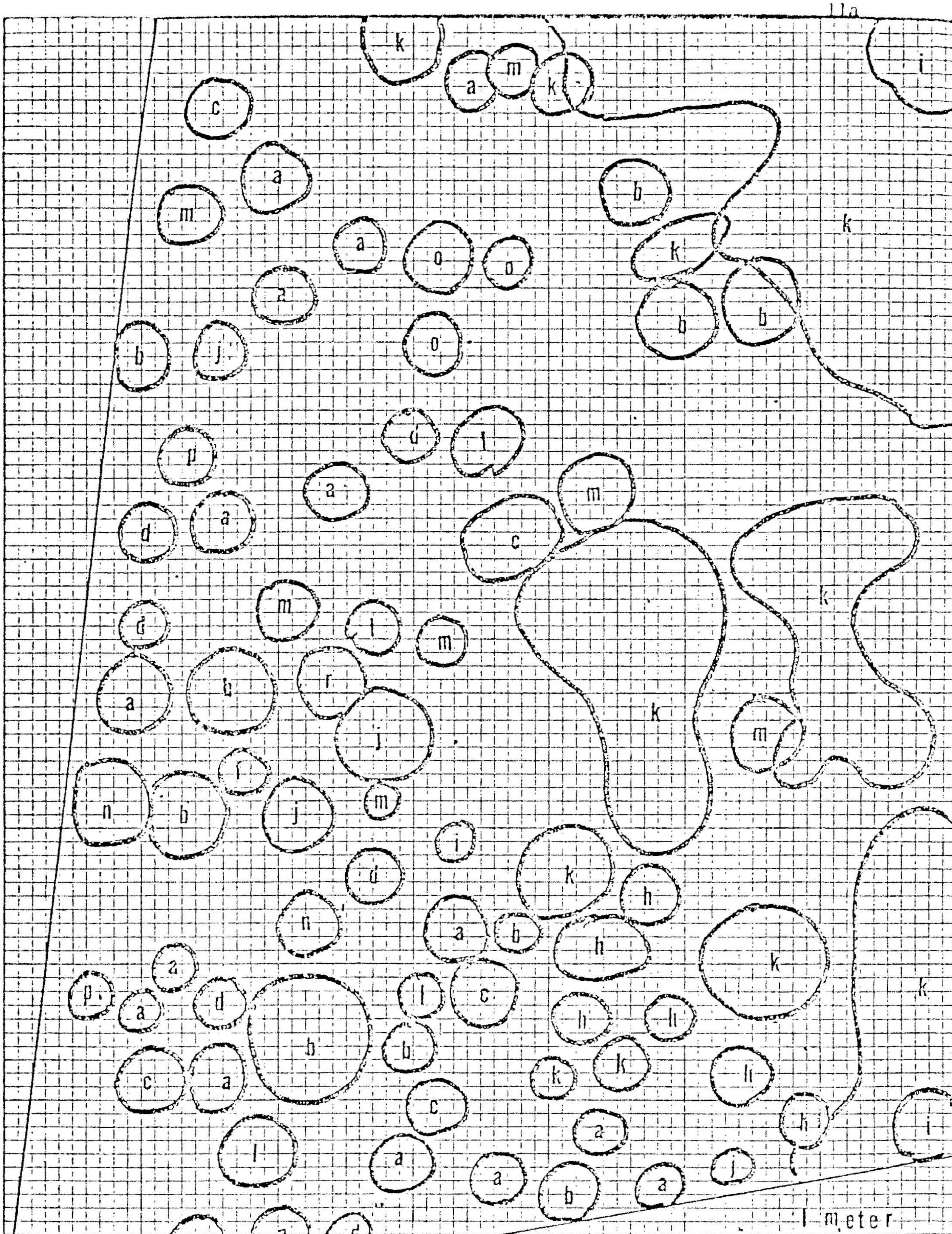
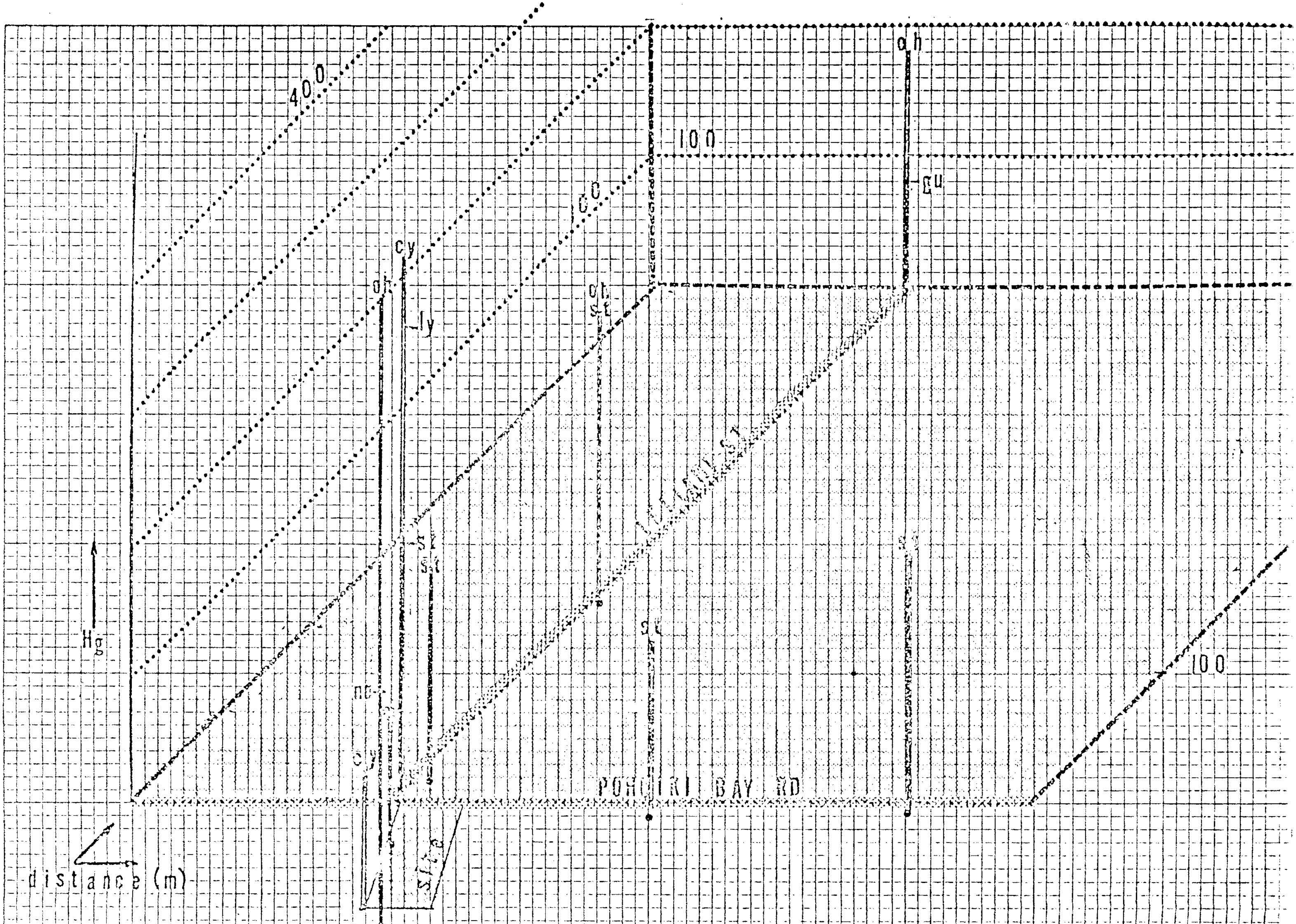
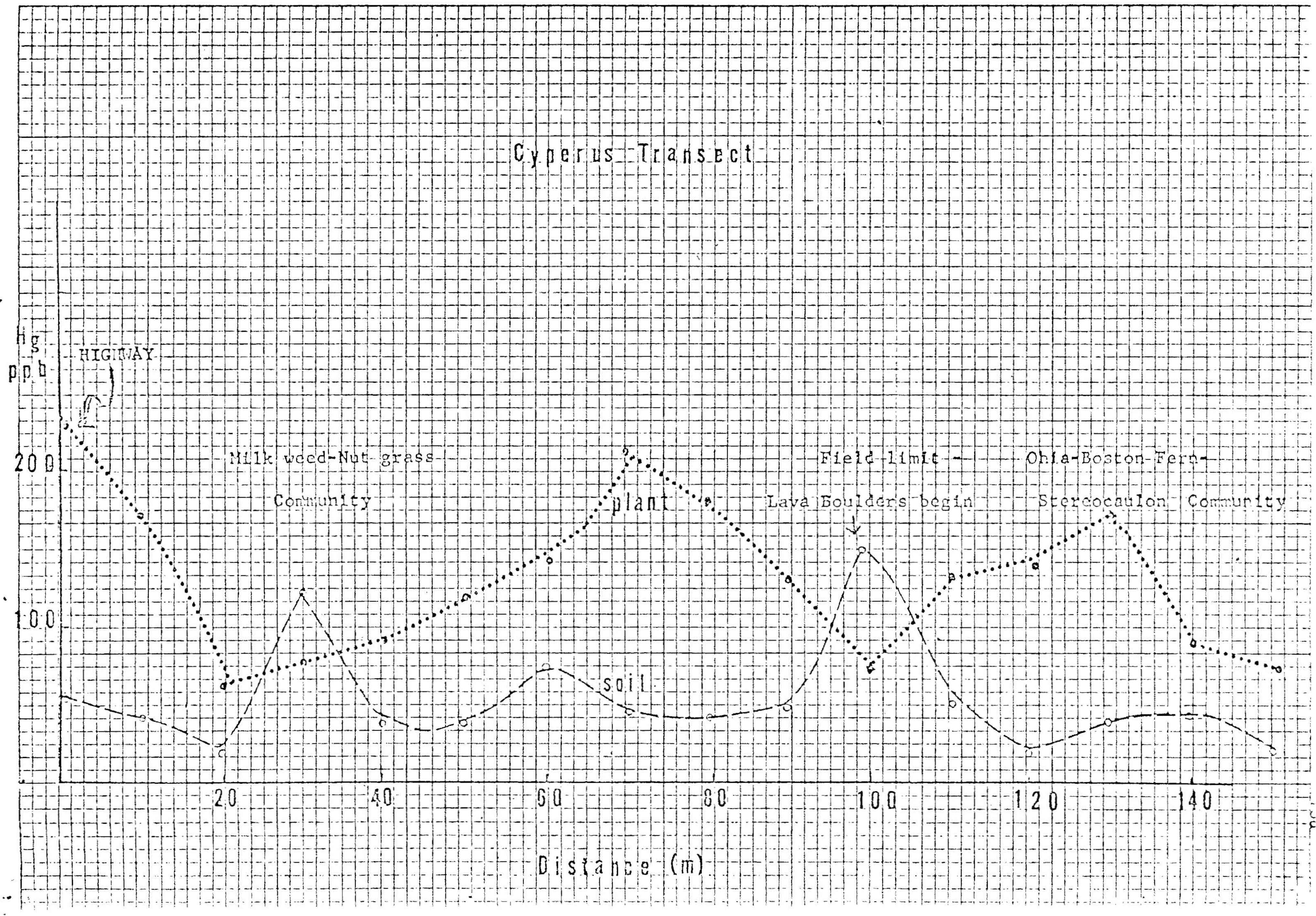

1 meter

Fig. 5 Modified Semi-diagramatic Representation of Drill Site and Its Environs. Shown are the mercury contents of selected plant species at the indicated locations. Hg contents are given as parts per billion (PPB or microgram/kg). St - staghorn fern; oh - ohia; cy - nutgrass; ly - lycopodium; gu - guava; ne - Boston fern.



400
100
100
oh
gu
cy
oh
ly
oh
st
st
st
no
Hg
POHUIRI BAY RD
site
100
distance (m)

Fig. 6 *Cyperus* (nut grass) Transect. The results of coordinate plant t and oil analysis for mercury are presented as a function of distance along a long line paralleling the long dimension of the drill site.



Cyperus Transect
Hg ppb
HIGHWAY
200
100
Milk weed-Nut grass Community
plant
Field limit - Lava Boulders begin
Ohia-Boston Fern-Stereocaulon Community
soil
20
40
60
80
100
120
140
Distance (m)

survey of soil and plant mercury over a distance of 150 meters. This line extended from Highway 132 in a relatively barren area which develops into a milkweed-nut grass community running most of the length of the drill site. The line however, was extended beyond a discontinuity created where lava boulders had been moved, apparently by bulldozing. Upon these boulders, and to some extent between them, ohia, Boston fern, and sterocanlon has become established. The boulders grade into a higher ground to the south. The mercury content of the nut grass shows three high values at roadside, and on either side of the boulder line. No obvious explanation can be offered at present for this behavior although it should be pointed out that the soil mercury associated with those same plants shows maxima that coincide almost perfectly with the plant maxima.

Preliminary sampling of the flora at the exploratory drilling site was carried out during the early part of the annual dry season. It is anticipated that at the onset of winter rains, the drill site proper may well show striking increase in cover and species diversity, and therefore, further sampling during the rainly season may yield additional significant information, including mercury distribution.

Groundwater. In general, groundwater occurring in the basaltic rocks underlying the Puna District is unconfined basal water, i.e. fresh water floating on salt water in a lens-like configuration. During January of 1975, eight groundwater samples were collected at selected stations, and the overall chemical quality, along with water level measurements and reported literature data, indicate that these groundwater samples were either basal water or basal water mixed with salt water. The location of the stations are shown in Figure 7, while the chemical and microbiological results are given in Tables 2 and 3.

Basal groundwater in basaltic aquifers in the Hawaiian Islands normally has low concentrations of dissolved chemical quality parameters and is typically of a sodium-bicarbonate type. In this regard the samples from Well 9-5, Well 9-7,

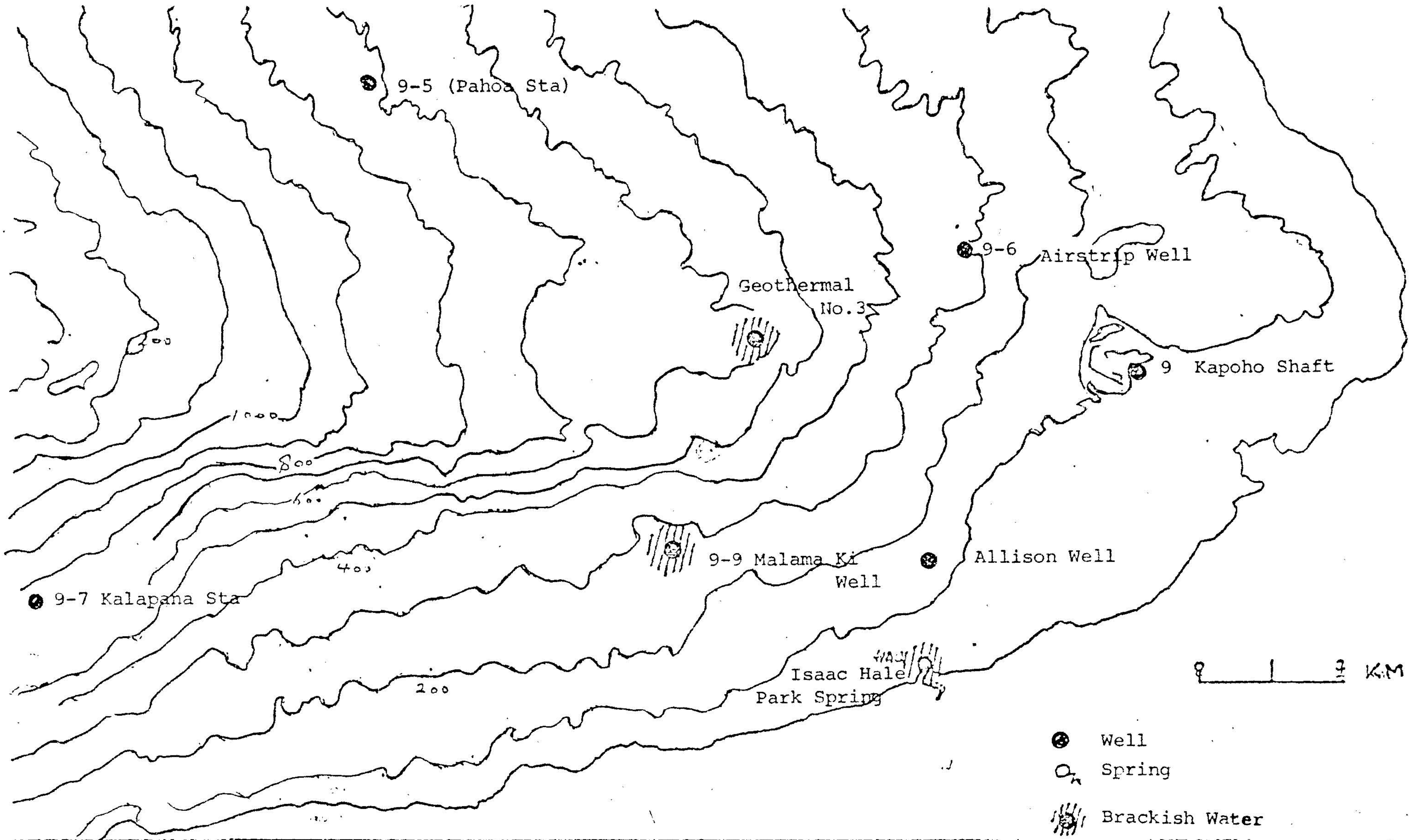


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Figure 7 Location of Sampled Wells and Spring, Puna, Hawaii

TABLE 2. CHEMICAL DATA, GROUNDWATER AND RAINWATER,

PUNA, HAWAII

OLD NO.	STATE NO.	NAME	DATE	T*	pH	Na**	K	Ca	Mg	Cl	HCO_3	SO_4	SiO_2	N***	P
9-5	2986-01	PAHOA STATION	1-6-75		7.30	36.0	2.72	1.58	2.7	13.5	48	21.1	50.0	0.252	0.078
9-7	2487-01	KALAPANA STATION	1-6-75	28.5	7.68	89.6	5.20	5.30	6.6	132.2	38	37.2	44.5	0.070	0.056
9	3080-02	KAPOHO SHAFT	1-6-75	25.5	7.80	85.8	6.60	42.4	37	16.9	372	20	53.6	0.378	0.233
9-6	3081-01	AIRSTRIP WELL	1-6-75	33.0	7.42	238	13.6	23.0	28	303.5	48	204	71.3	0.014	0.040
	2881	ALLISON WELL	1-7-75	37.5	7.35	216	10.8	13.4	15	281	132	69.2	24.1	>14	<0.002
		ISAAC HALE PARK SPRING	1-7-75	36.0	7.75	2020	86.0	32.4	200	3534	56	507	81.5	1.218	0.016
9-9	2783-01	MALAMA KI WELL	1-7-75	52.3	7.02	2105	109	66.8	210	3811	144	471	100.7	0.280	0.006
		GEOTHERMAL #3	1-7-75	93.0	6.85	2050	190	76.8	52	3274	30	314	96.6	0.003	0.006
		RAIN AT KALAPANA STATION	1-6-75			4.5	0.25	0.25	0.75	7.2		~2.5	0	0.024	<0.002

*TEMPERATURE GIVEN AS °C

**CHEMICAL DATA IN mg/l

***NO_2 NO_3 as N

TABLE 3. MICROBIOLOGICAL QUALITY OF GROUNDWATER

PUNA, HAWAII

WELL/SHAFT NO.	STATE NO.	NAME	DATE OF SAMPLE	COLIFORM MPN No. per 100 ml	FECAL COLIFORM MPN No. per 100 ml	REMARK
9-5	2986	PAHOA	1-6-75	<3	<3	Unchlorinated sample
9-7	2487-01	KALAPANA	1-6-75	<3	<3	Unchlorinated sample
9	3080-02	KAPOHO SHAFT	1-6-75	460	<3	
9-6	3081	AIRSTRIP	1-6-75	<3	<3	
9-9	2783	MALAMA KI	1-7-75	<3	<3	
---	----	ISAAC HALE BEACH PARK HOT SPRING WATER	1-7-75	1500	7	
---	2881	ALLISON	1-7-75	≥24,000	93	Well bottom mud in sample

and Shaft 9 can be regarded as fairly representative of basal waters as far as their chemical composition is concerned. The bicarbonate content of Shaft 9 is anomalously high for reasons as yet unknown.

Samples from Well 9-6, Allison Well, Isaac Hale Spring, Well 9-9, and Geothermal Drill Hole No. 3 have chloride contents that are higher in varying degrees than average basal water. Salination of basal water due to intermixing with underlying salt water is a common phenomena especially in coastal areas where unconfined lenses are thinnest and easily perturbed by tidal effects or heavy pumping. As such, the slightly above normal chloride concentrations of samples from Well 9-6 and Allison Well are not too surprising considering that they are located about 5 and 1.5 km from the coast, respectively. By the same token water from Isaac Hale Spring which is located only a few meters inland from the beach can be expected to be brackish, which indeed it is.

Considering the locations of Well 9-9 and Geothermal Drill Hole No. 3 with respect to the other wells and distance from the coast, they should penetrate a layer of fresh water whose chemical composition should be comparable or superior to that of Well 9-6, Shaft 9, and Allison Well. However, samples from both wells were quite brackish with chloride contents comparable to that of water from Isaac Hale Spring. Since the temperatures of samples from Well 9-9 and Geothermal Drill Hole No. 3 are quite high, it is reasonable to conclude that basal water and salt water have been mixed (locally?) due to upward movement of heated salt water.

The heating of groundwater in the Puna area does not only induce fresh water-salt water mixing but evidently increases chemical interaction between groundwater and basaltic rock as well. Chemical composition of warm water samples (>30^{o}C) were compared with concentrations of hypothetical mixtures between basal water and salt water using chloride ion concentrations as a mixing ratio index. The brackish water samples were found to contain excess potassium and deficit magnesium concentration that change dramatically as a function of temperature indicating temperature dependent ion exhange reactions. Alteration of aquifer material is further indicated by the large excess of silica in all but one of the warm waters.

Coliform and fecal coliform analyses (Table 3) show the sample waters to be generally pollution-free. High values for the Allison Well samples are attributed to local contamination, and probably introduced during sampling.

Air Quality. To date, air quality data consists of mercury determinations on samples obtained at the drill site, Hilo, and the Sulfur Banks during the flora study, see Table 4. The highest figure was not unexpectedly obtained at the Sulfur Banks and the value found at Banyon Drive in Hilo was one-fifth of the Volcano Park figure. It was quite surprising to find that the drill site air was nearly one-half of the figure from the park thermal area. This may have been an entirely transitory result of wind movement and temperature gradient effects and only future measurements can reveal the regularity of this pattern. A fallout value for the Sulfur Banks area has been included as an example to demonstrate the kind of numbers and oxidized-reduced relationships in the thermal area for future reference.

Noise. No noise measurements have been made at the site to date. However, during a site visit the ambient noise levels were noted to be due primarily from the wind blowing through the trees and an occasional passing vehicle. Nearby, activity is limited to papaya farming and very little vehicular traffic was observed.

TABLE 4. Air and Fallout Values for Mercury,

Island of Hawaii, May 22, 1975.

Location	Measurement
Drill Site Air	$1.11 \pm 0.58\ \mu g \cdot m^{-3}$
Hilo Air	$0.44 \pm 0.27\ \mu g \cdot m^{-3}$
Sulfur Banks, Hawaii Volcanoes National Park Air	$2.6 \pm 0.51\ \mu g \cdot m^{-3}$
Sulfur Banks, Hawaii National Park Fallout	Hg^{o}, $250 \pm 80\ \mu g \cdot m^{-2}$ Hg^{2+}, $540 \pm 60\ \mu g \cdot m^{-2}$

Summary

The existing environmental setting of the exploratory drilling site and surrounding area has been described by various investigative efforts. Other than limited farming, the area has been subjected to environmental change via recent volcanic activity and large subdivision development. However, the area retains its rural character, quiet and serene, undisturbed except for occasional visitors passing through to the coastal recreational facility of Isaac Hale Park. Despite the development of large subdivisions, the area still retains its rustic atmosphere inasmuch as subdivision development has been thus far limited to site preparation.

Although considerable baseline data has been accumulated to date, this phase of the environmental studies program remains incomplete. Additional baseline data to be obtained include the following:

a. flora species identification during the annual rainy season,

b. aerometric sampling for mercury,

c. fall-out data for mercury,

d. soil and vegetation analysis for mercury, arsenic, and selenium, and

e. particulate, H_2S, and SO_2 air measurements.

Since the initial groundwater analyses conducted in January, a second set of samples has been collected by WRRC personnel in July, 1975. However, interpretation of those results including tritium data has not yet been completed. This data, along with appropriate discussion, will be presented when made available. Supplementary sampling, if proved necessary, will be undertaken prior to initiation of drilling.