FINAL REPORT

ENVIRONMENTAL OVERVIEW PROGRAM FOR ALTERNATE ENERGY DEVELOPMENT

Toward a Data Base for Regional Environmental Baseline Establishment

HAWAII NATURAL ENERGY INSTITUTE

PROJECT 2708-40

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TABLE OF CONTENTS

Figures

Introduction

The first energy resource development related environmental baseline study carried out in the state of Hawaii, and certainly one of the first of its kind anywhere, was conducted at the site selected for HGP-A over the Kapoho hydrogeothermal reservoir in May, 1975. That baseline condition was highlighted in the Revised Environmental Impact Statement for the Hawaii Geothermal Research Station, Island of Hawaii Department of Planning and Economic Development, State of Hawaii (1978) pp. 22-46, and discussed in detail in the 7-volume Hawaii Energy Resource Overview: Geothermal, B.Z. Siegel, ed. (1980), Vol. 3 The Environment (Siegel, S.) and Vol. 4 Impact (Siegel S. and Siegel B.).

It was this overview document prepared for the Department of Energy under contract with the Lawrence Livermore Laboratory of the University of California, that prompted us to initiate an environmental overview project for the state of Hawaii.

The original Livermore concept linked overview to areas such as Geysers and other western states geothermal prospects. While our emphasis has also been placed on Big Island geothermal areas for historic reasons, we have also included a major Oahu area committed to wind resource development and a special composite energy resource program on Molokai.

In all of these areas, the emphasis has been placed on development of baseline data as appropriate to the location and energy source.

In the Puna District of Hawaii our baseline data at HGP-A (AREA 0) and the geothermal prospects designated as AREAS 1,2 and 3, consist of

1. Aerometry
   a. Fixed gases (H_2S, SO_2,)
   b. Mercury
   c. Particulates/aerosols
2. Soil Analysis
   a. Mercury
   b. Arsenic
   c. Other trace metals
3. Plant Analysis
   a. Tissue Mercury
   b. Plant/soil ratio
4. Botanical Survey
   a. Vegetation
   b. Species list

AREA 4 differed in the replacement of detailed air and plant chemistry with a more detailed examination of the soil.

1. Soil Analysis
   a. pH patterns
   b. Toxicants
   c. Nutrients
2. Botanical Survey
   a. Vegetation
   b. Species list

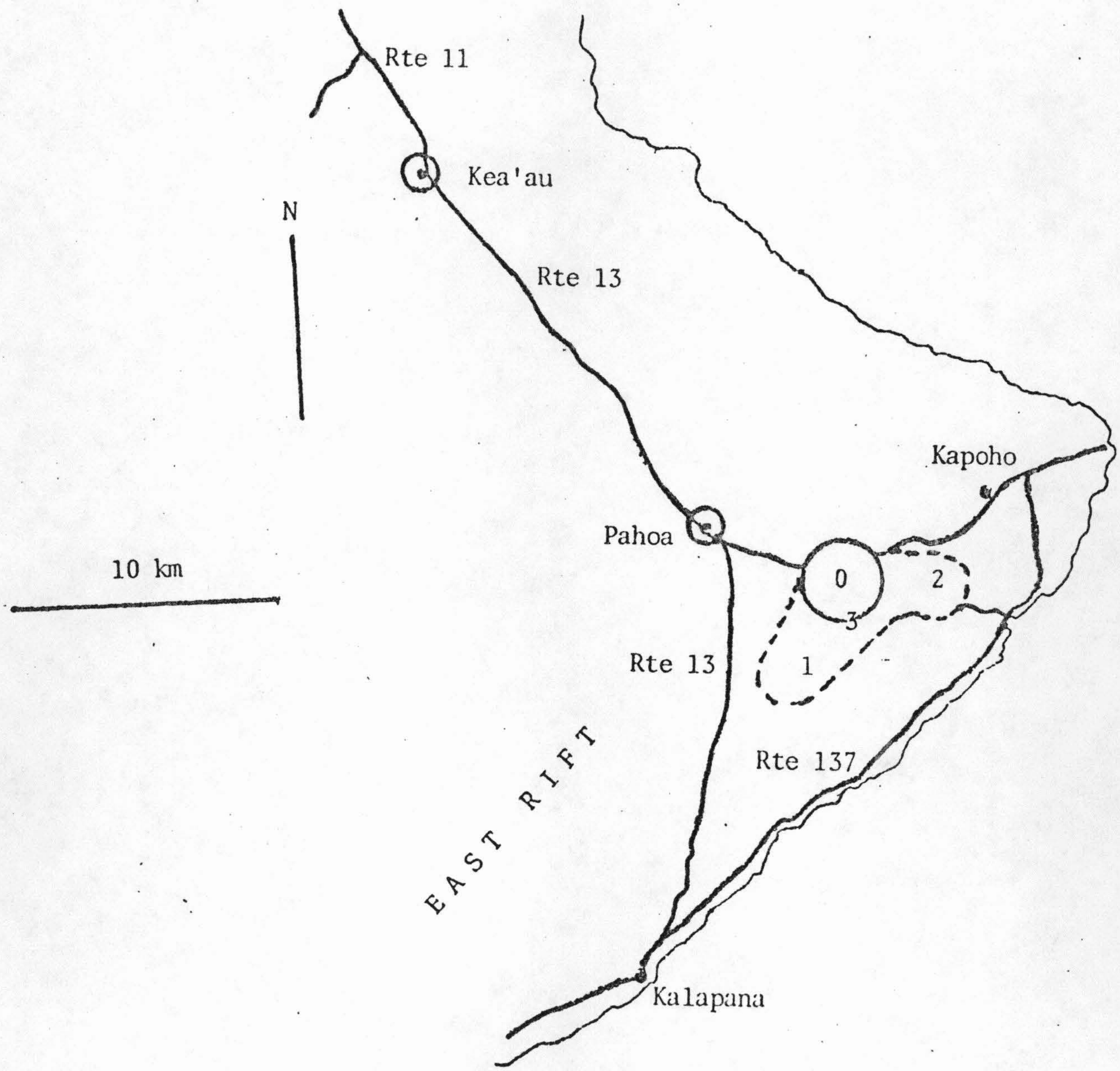
AREAS 4A and 5 together constitute a study on the Island of Molokai that was distinctive for several reasons. First, the wind test area was an individual rural residence; second,the Molokai Electric power station at the Palaau site is a multi-model station to include conventional diesel-electric, solar thermal and biomass resources ; and third, the work done and summerized here was carried out with the help of a Molokai High school teacher and his students. The data here include air, soil and plant analyses, and must only be taken as an exploratory study, but one suggesting that active cooperation in the field between professionals and community residents is feasible.

In all, the data and brief narratives presented here, although incomplete, constitute a first compilation of its kind all representing energy prospect areas as they were prior to the introduction of technology.

Most properly, this report should bear the title "Data Resource Related Regional Environmental Baselines" because that is indeed the goal we must attain if alternate energy systems are to be developed properly with minimal environmental impact.

GEOTHERMAL RESOURCE

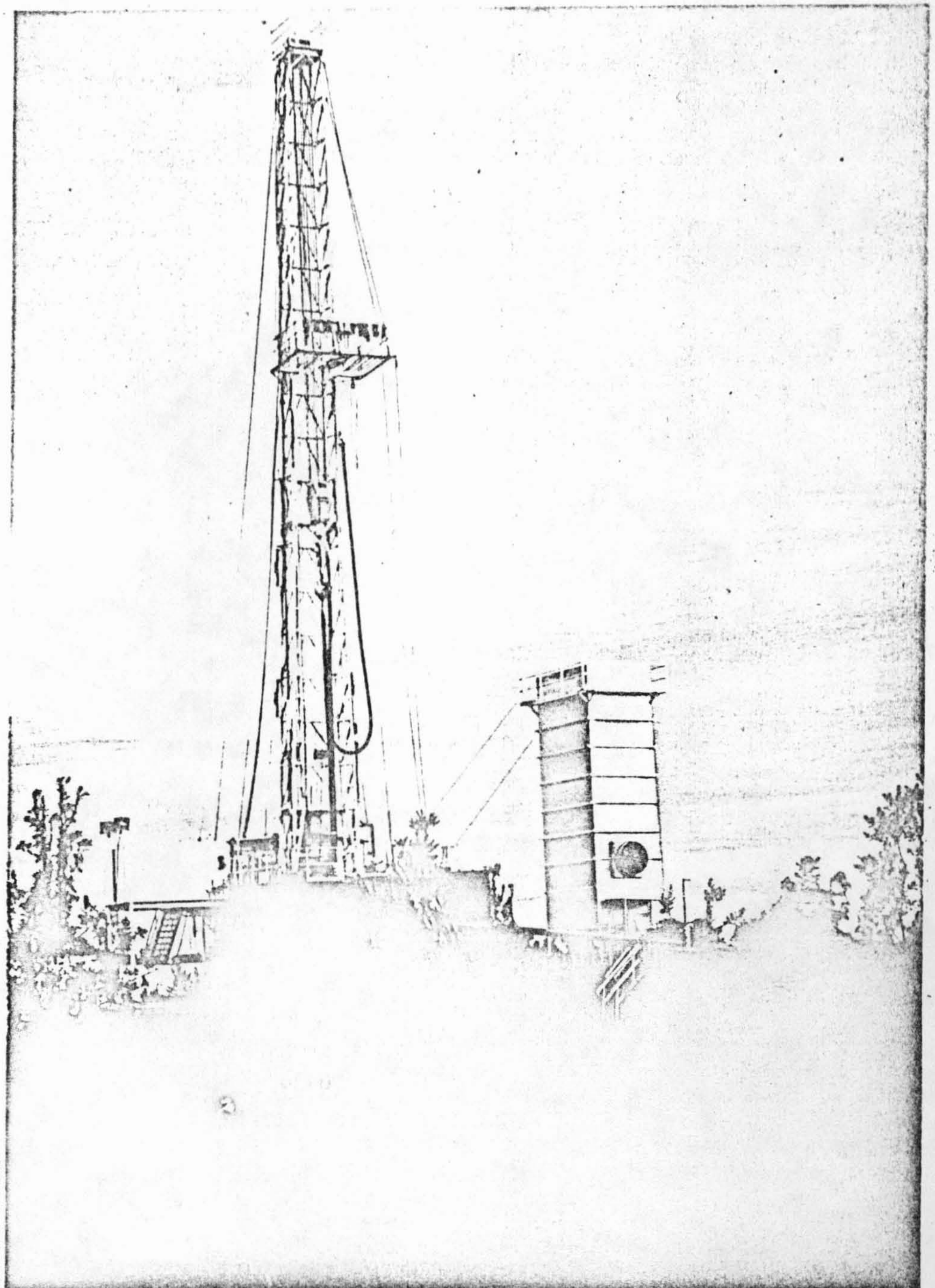
AREA 0 - 3

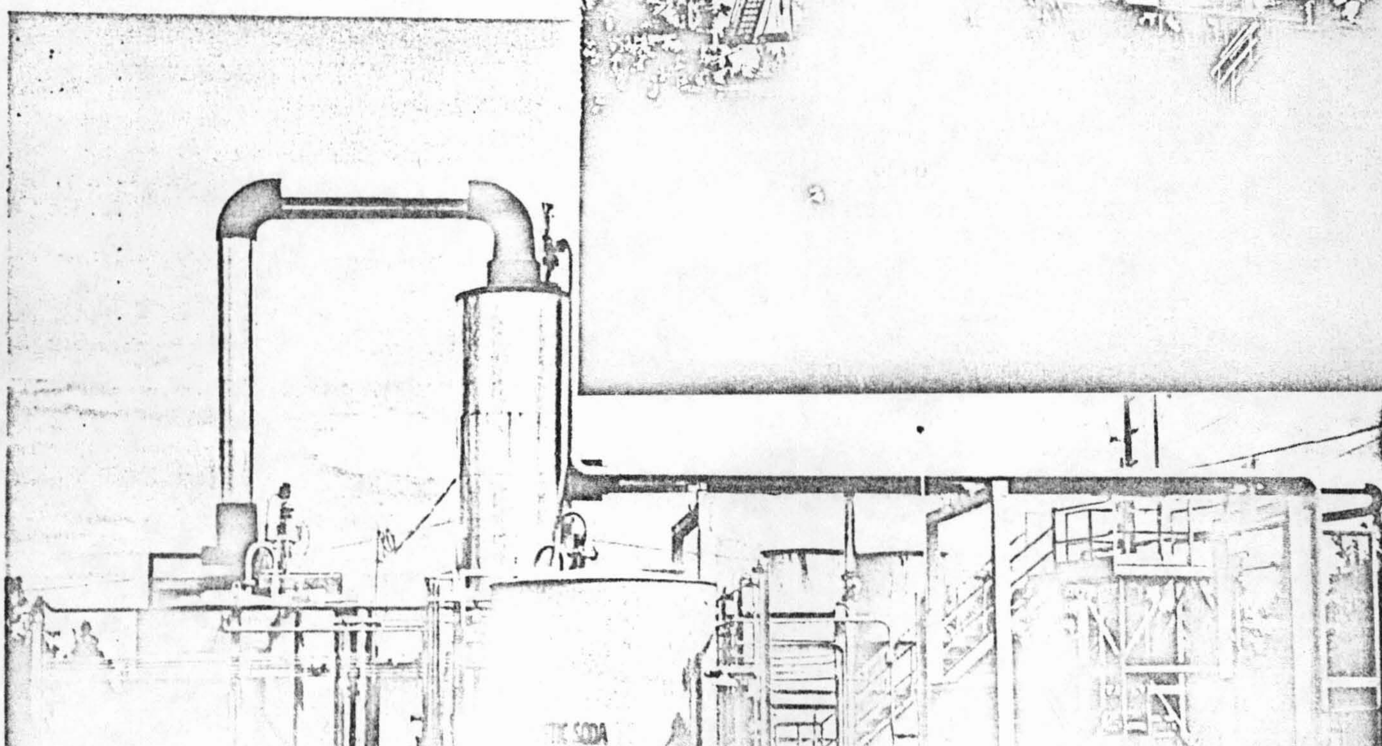


PUNA, HAWAII: AREAS 0 (in circle), 1, 2, 3 (Geothermal).

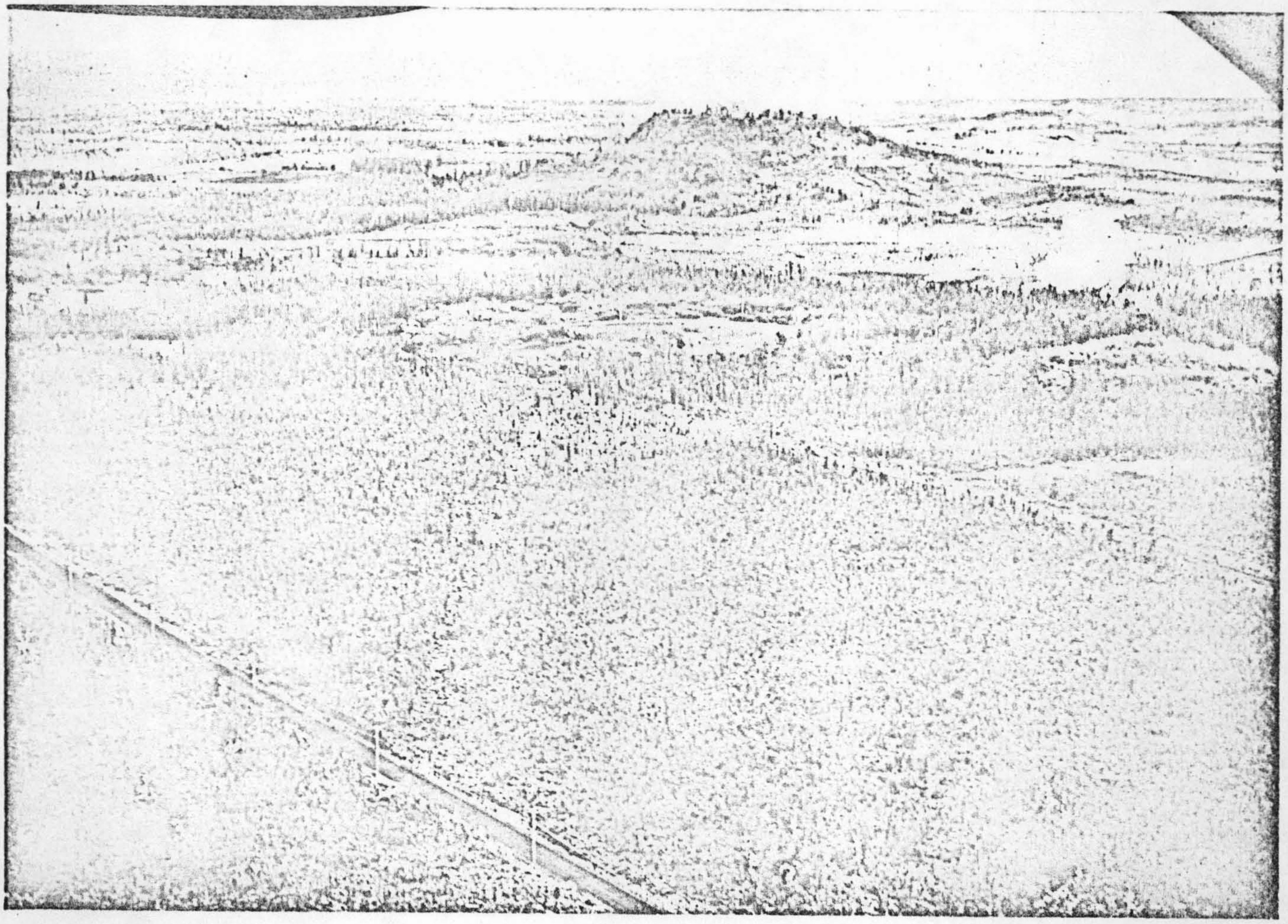
UPPER RIGHT: Drill rig in Opihikao over open Ohi'a forest (1980).

LOWER LEFT: At HGP-A, part of the H_2S abatement system showing caustic soda storage tank in foreground (1980).





Kapoho Area, Puna, Hawaii, looking eastward.
Aerial Photograph taken on 28 July, 1978
Showing Plume from HGP-A Flashing at
Upper Right. Puu Honualula is Upper Center.



Aerometry

As a vehicle, air obviously provides the most effective means for natural dissemination processes. Both mobility and penetrance must be considered in any effective regional baseline development. As we learned during the development of HGP-A from a prospect to a producing steam well, these same pervasive features can complicate greatly efforts at point-source or site specific measurement. Thus, when the well was first flashed on July 22, 1976, the air mercury level rose to ca 9.9 $\mu g/m^3$ and persisted at that level. Prior measurements from May 1975 (pre-drilling) through June 1976 flow tests fell into the range of ca 1 $\mu g/m^3$, a high world value, but normal for a great part of Hawaii (see attached Air-Soil-Rain mercury map of Hawaii below for pattern of "norms"). The fact that 5 months later the air mercury had risen even higher although the well had by then been shut down for months would probably have been misinterpreted even if we had foreknowledge of such a fact.

Resolution, however, came from a then unexpected source (cf Revised Environmental Impact Statement for the Hawaii Geothermal Research Station, Department of Planning and Economic Development, March 1978, pp. 33-38). To quote:

> The upsurge of air mercury levels during flashing was originally thought to have been a "burst" releasing accumulated mercury at depth. During the July 1977 testing, it was not known that a new East Rift Zone emission center -- the Heiheiahulu spatter cone about eight miles to the east of the well -- had been active for some months. When that was made known, the cone was tested and found to be a highly

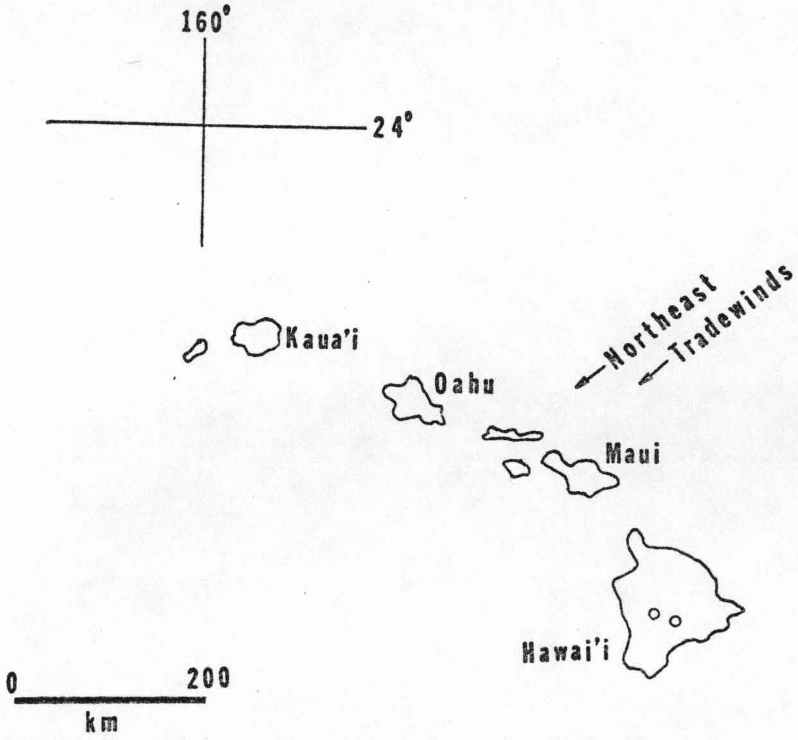
intensive mercury emitter and the probable source of the relatively high level recorded at the flashing of HGP-A. Subsequent measurements, made in July-September 1977, show the presence at the well site not only of air mercury but also of SO_2 and H_2SO_4 -- although the well itself had been shut down since May 1977. The presence of these toxic gases can only be ascribed to natural area contamination, not emanating from the well itself.

Tests conducted since drilling of HGP-A began have yielded no evidence of a sustained build-up of mercury or any other potentially toxic elements at or around the well site that can be attributed to geothermal energy development operations. The conclusion reached by the researchers is that "there is no reason to assume that HGP-A itself has any negative emission features beyond nuisance value H_2S and noise, but is (itself) influenced by its proximity to natural geotoxicant sources."

It is especially important, in terms of naturally high mercury baselines in Hawaii, that one be able to distinguish natural processes in volcanic-fumarolic regions from human activities generating potentially similar chemistries.

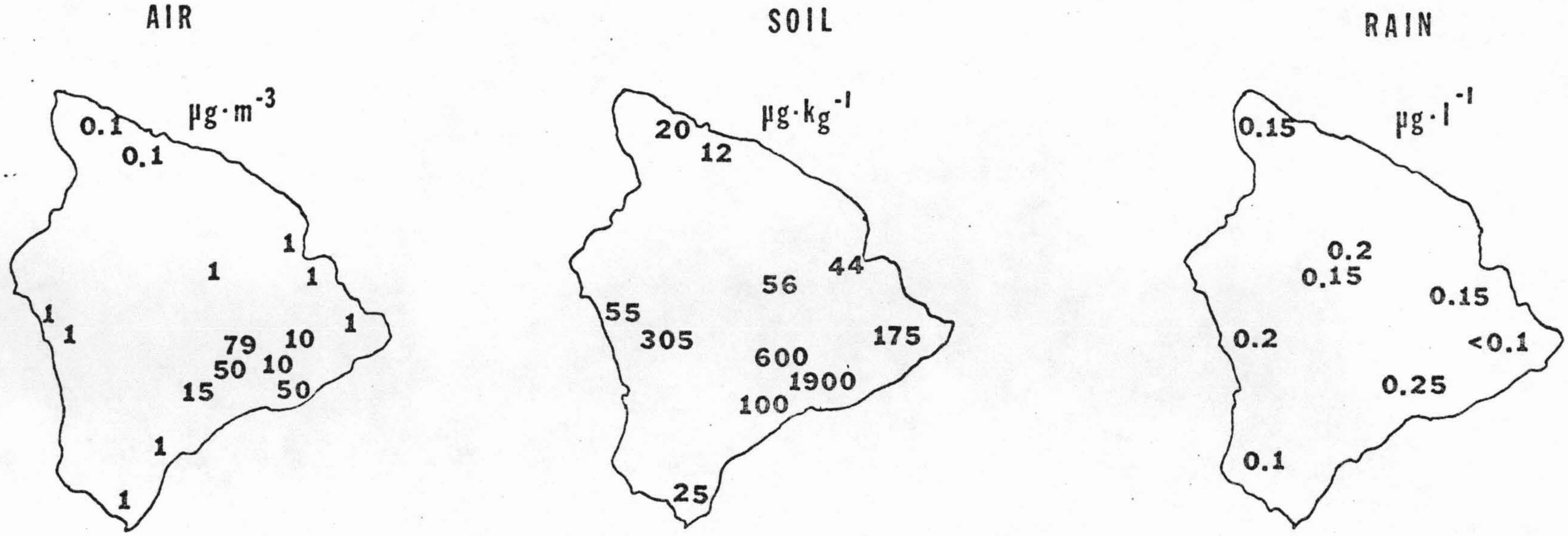
Generally speaking, our baseline measurements in Puna over 5 years and in HVNP over 12 years show the Hawaiian "norm" to be perhaps 30-50 fold above levels generally associated with clean air.

Outline Map of the Major Hawaiian Islands
Showing Orientation Relative to Tradewinds and Location
(Lower Right, on Hawaii, open circles)
of Primary Volcanic Emission Sources,
Kilauea and Mauna Loa.


160°
24°
Kaua'i
Oahu
Maui
Hawai'i
Northeast
Tradewinds
0
200
km

Island of Hawaii Showing Mean Values for

Air, Water and Soil Mercury.


AIR
µg·m-3
0.1
0.1
1
1
1
1
1
1
79
10
50
10
15
50
1
1
SOIL
µg·kg-1
20
12
44
56
55
305
175
600
1900
100
25
RAIN
µg·l-1
0.15
0.2
0.15
0.15
0.2
<0.1
0.25
0.1

AEROMETRY I: AREA 1

Fixed Gases and Mercury

Gas		Procedure	Level
		A. Fixed Cases	
H_2S		Rotec Spinning Disc	
		Rig Platform	ppb <5
		Base	<5
		Colortec Cards	
		Rig Platform	<5
		Base	<5
SO_2		Gastec tubes By Rig	ppm <0.05
CO		MSA tubes By Rig	ppm <10
CO_2		MSA tubes By Rig	% 0.037
NO_x		MSA tubes By Rig	ppm <0.025
		B. Mercury	
Hg		Acid traps/Atomic Absorpt. Drill Site Cleared Area	
	#1	N. Corner	μg/m^3 0.94
	#2	N.E. Corner (by tank)	0.50
	#3	S. Corner	3.22
	#4	S.W. Corner (entry road)	0.63

AEROMETRY II: AREA 2

Drillsite Fixed Gases

Gas	Procedure	Level Found Site		
		A	ab3	B
H_2S (ppb)	Colortec Cards	<5	<5	<5
		<5	<5	<5
	Rotec Spinning Disc	<5	<5	<5
		<5	<5	<5
SO_2 (ppm)	Gastec Tubes	<0.05	<0.05	<0.05
		<0.05	<0.05	<0.05
CO (ppm)	MSA Tubes	<10	<10	<10
		<10	<10	<10
CO_2 (Vol. %)	MSA Tubes	0.035	--	0.038
		0.036	--	0.037
NO_x (ppm)	MSA Tubes	<0.03	<0.03	<0.03
		<0.03	<0.03	<0.03

AEROMETRY III: AREA 2

Fixed Gases Downwind (Pohoiki Road)

Gas	Procedure	Level Found
H_2S (ppb)	Rotec Spinning Disc	<5 <5
SO_2 (ppm)	Gastec Tube	0.05 0.05
CO (ppm)	MSA Tubes	<10 <10
CO_2 (Vol. %)	MSA Tubes	0.037 0.033
NO_x (ppm)	MSA Tubes	<0.035 <0.037

AEROMETRY IV: AREA 2

Mercury

Station	Sample Volume (m^3)	Air Content $\mu g/m^3$
1. On Site		
A	0.36	0.47
		0.53
B	0.36	0.53
		0.61
ab1	0.36	0.56
		0.50
ab3	0.36	0.50
		0.56
ab5	0.36	0.50
		0.44
2. Pohoiki Road Downwind		
Roadside	0.44	0.57
		0.48

AEROMETRY V: AREA 3

Fixed Gases at the Exploratory Sites

Site No.	H_2S ppb	SO_2 ppm	Gas CO ppm	CO_2 %	NO_x ppm
1	<5(3)†	<0.05(2)	<10(2)	0.033	<0.03
2	<5(3)	<0.05(2)	<10(2)	0.035	<0.03
3U*	<5(3)	<0.05(2)	<10(2)	0.037	<0.03
3	<5(3)	<0.05(2)	<10(2)	0.034	<0.03
3D*	<5(3)	<0.05(2)	<10(2)	0.034	<0.03
4	<5(3)	<0.05(2)	<10(2)	0.033	<0.03
5	<5(3)	<0.05(2)	<10(2)	0.034	<0.03
6	<5(3)	<0.05(2)	<10(2)	0.035	<0.03

*3U and 3D are respectively, 300 m upwind and downwind of Site 3.

**During this peroid, temperatures of 22-25°C and light trades of <u>ca</u> 5 knots were recorded. Sky <10% cloud cover.

†() = No. of replications.

AEROMETRY VI: AREA 3

Air Mercury, Sites as in Aerometry V

Site No.	Sample a	Sample b	Ave $\mu g \cdot m^{-3}$
1	0.68	0.92	0.80
2	0.60	0.72	0.66
3U	0.52	0.56	0.56
3	0.48	0.52	0.50
3D	0.60	0.48	0.54
4	0.56	0.48	0.52
5	0.55	0.50	0.52
6	0.50	0.53	0.51

Air samples are ca 2 hr, averages and represent minimum sample volumes on 0.2 m^3, more typically 0.35-0.5 m^3.

Soil Analysis

At its interface with the atmosphere soil acts as a two-dimensional system with respect to a host of matter and energy fluxes and exchanges. The third dimension, often forgotten, consists of fluid-filled spaces, with either aqueous liquid or gas contents, and "protruding" into these capillary (or larger) spaces are complex organic-mineral particles with a host of ions and molecules adsorbed on their surfaces.

It is fair to say that the mobility of substances is lower in soil, and that it provides kinds of physiochemical environmental "buffering" that distinguish it from atmosphere.

Our concerns with soil vis-a-vis geothermal baselines are simple: the mercury and arsenic content and,to a lesser extent, trace elements of other sorts.

In other, specific non-geothermal instances (see AREA 4 below) fertility of the soil and toxicants other than mercury and arsenic may be of concern.

SOIL ANALYSIS I: AREA 0 (General)

Aggregate Mean Mercury and Arsenic
Content of Soils for Comparative Study

Sample Area	Analysis	
	Mercury $\mu g \cdot kg^{-1}$	Arsenic $mg \cdot kg^{-1}$
1. HGP-A, May-September 1975	212±66	<0.1
2. Current Wellsites within HGP-A Survey Area February 1981		
1	65±12	<0.1
2	63±3	<0.1
3	65±4	<0.1
4	60±3	0.12
3. Manoa Valley (Oahu) 1973-79	27±13	<0.1

SOIL ANALYSIS II: AREA 0 - 1, SE of HGP-A

Mercury and Arsenic

Sample Station	Mercury $\mu g \cdot kg^{-1}$	Arsenic $mg \cdot kg^{-1}$
1	57 ± 4	<0.1
2	61	<0.1
3	62	<0.1
4	65	<0.1
5	62 ± 6	<0.1
6	59	<0.1
7	67	<0.1
8	64 ± 4	<0.1
9	70	<0.1
10	62 ± 4	<0.1
11	64	<0.1

SOIL ANALYSIS III: AREA 0 - 2, SE of HGP-A

Mercury and Arsenic

Sample Station	Mercury $\mu g \cdot kg^{-1}$	Arsenic $mg \cdot kg^{-1}$
1	69	<0.1
2	60 ± 4	<0.1
3	67 ± 3	<0.1
4	67	<0.1
5	67	<0.1
6	72	<0.1
7	66	<0.1
8	56 ± 4	<0.1

SOIL ANALYSIS IV: AREA 0 - 3, SE of HGP-A

Mercury and Arsenic

Sample Station	Mercury $\mu g \cdot kg^{-1}$	Arsenic $mg \cdot kg^{-1}$
1	47 ± 5	<0.1
2	77 ± 8	<0.1
3	82 ± 13	<0.1
4	60 ± 4	<0.1
5	59 ± 2	<0.1

SOIL ANALYSIS V: AREA 0 - 4, SW of HGP-A

Mercury and Arsenic

Sample Station	Mercury $\mu g \cdot kg^{-1}$	Arsenic $mg \cdot kg^{-1}$
1	61	0.14
2	63	0.13
3	57	<0.1
4	57	<0.1
5	Lava	-
6	Lava	-
7	60	<0.1
8	64	<0.1

SOIL ANALYSIS VI: AREA 1

Mercury and Arsenic

Site	Mercury ppb	Arsenic ppm	
Rig Area Level		Gutzeit	Colorimety
#1	56	1-3	0.5-1.5
#2	54	0.5-1	0.5
#3	84	0.5-1	1.0
#4	20	0.05-0.1	0.1

SOIL ANALYSIS VII: AREA 1

Qualitative Trace Elements

Metal	At Plant Sample Area	
	#1	#4
	(Entry road at Rig Area)	(Forested Area West of Pond)
	ppm	
Antimony	<1	<1
Arsenic	Ca 1	Ca 1
Barium	<1	<1
Bismuth	<1	<1
Cadmium	tr	tr
Chromium	<1	<4
Copper	<4	<4
Lead		
Mercury	0.06	0.01
Molybdenum	<1	<1
Nickel	<1	<1
Zinc	tr	<1

SOIL ANALYSIS VIII: AREA 2

Mercury

Site	Mercury in ppb Sample 1	Sample 2
A	62	60
B	57	49
ab1	66	70
ab2	54	58
ab3	64	47
ab4	60	59
ab5	51	42

SOIL ANALYSIS IX: AREA 2

Arsenic

Site	Arsenic in ppm Sample 1	2
A	0.2	0.5
B	0.3	0.3
ab1	0.3	0.2
ab2	0.2	0.3
ab3	0.4	0.2
ab4	0.15	0.2
ab5	0.3	0.2

SOIL ANALYSIS X: AREA 2

Qualitative Trace Metals

Metal	Sample Site A	B	ab3
		ppm	
Antimony	<1	<1	<1
Arsenic	0.3	0.3	0.3
Barium	<1	<1	<1
Bismuth	<1	<1	<1
Cadmium	tr	tr	tr
Chromium	<1	<1	<1
Copper	<4	<4	<4
Lead	<1	<1	<1
Mercury	0.06	0.05	0.055
Molybdenum	<1	<1	<1
Nickel	<1	<1	<1
Zinc	<1	<1	<1

SOIL ANALYSIS XI: AREA 3

Mercury

Site	Sample a	Sample b	Ave ppb
1	48	39	44
2	42	46	47
3U	48	44	46
3	56	48	52
3D	43	47	45
4	50	46	48
5	48	58	53
6	49	59	54

Samples of 12-16 g prepared by HNO_3 digestion

SOIL ANALYSIS XII: AREA 3

Arsenic

Site	Sample a	Sample b	Ave ppm
1	0.10	0.13	0.12
2	0.18	0.12	0.15
3U	0.18	0.16	0.17
3	0.22	0.19	0.21
3D	0.19	0.26	0.23
4	0.30	0.26	0.33
5	0.35	0.33	0.34
6	0.37	0.32	0.35

Soil samples of 12-16 g prepared by HCl digestion

Soil Types in the Puna
Area*

*Excerpted and condensed from Soil Survey of the Island of Hawaii, State of Hawaii. Soil Conservation Service, United States Department of Agriculture. United States Government Printing Office, December 1973, pp. 6-150.

Lava Flows Association

Gently sloping to steep, excessively drained, nearly barren lava flows: on uplands.

This association consists of excessively drained, nearly barren lava flows and somewhat excessively drained and well-drained, coarse-textured and medium-textured soils that formed in volcanic ash, pumice, and cinders. These soils are on mountains at an elevation ranging from near sea level to 13,000 feet. They receive an annual rainfall of 10 to 250 inches. The mean annual soil temperature is between 49^{o} and 76^{o} F. The natural vegetation consists of lichen, moss, ohia, amaumau fern, mamane, naio, Kentucky bluegrass, and sweet vernal.

This soil association makes up about 50 percent of the island area, and most if it is in the saddle between Mauna Loa and Mauna Kea, near the summit of Mauna Kea, and near Pahala. Pahoehoe lava flows make up about 40 percent of this association, and Aa lava flows about 30 percent. The main soil series are Apakuie, Huikau, and Kilohana, each of which makes up about 3 percent of the association. The remaining 21 percent consists of Kilauea, Heake, and Keekee soils, and of Rock land, Rough broken land, Very stony land, Beaches, Cinder land, and Fill land.

Pahoehoe lava flows have a smooth, ropy surface. Aa lava flows are a mass of clinkery, hard, sharp lava fragment. Apakuie, Huikau, and Kilohana soils are near the summit of Nauna Kea. Apakuie soils have a dark reddish-brown and dusky-red very fine sandy loam surface layer underlain by dark reddish-brown very fine sandy loam and loamy sand. Huikau soils have a very dark brown loamy surface layer underlain by dark reddish-brown sandy loam and loamy sand and by slightly weathered volcanis ash, cinders, and pumice.

Kilohana soils have a very dark brown loamy fine sand surface layer over dark-brown and very dark gray fine sand.

Beaches consist of coral sand, black sand, or olivine sand. Cinder land is a mixture of fine cinders, pumice, and volcanic ash. Rock land consists of very shallow soils where rock outcrop occupies 50 to 90 percent of the surface. Tough broken land is made up of very steep and precipitous areas broken by many intermittent drainage channels. Very stony land consists of very shallow soils that have stones covering 30 to 70 percent of the surface.

This soil association is used for grazing, wildlife habitat, and recreation. The carrying capacity for grazing and wildlife is low. The wildlife consists of goats, sheep, pigs, pheasants, and quails. Sheep are common near the summit of Mauna Kea. Goats are in the stony areas.

Cinder Land

Cinder land (rCL) is a miscellaneous land type consisting of bedded cinders, punice, and ash. These materials are black, red, yellow, brown, or variegated. The particles have jagged edges and a glassy appearance and show little or no evidence of soil development.

Cinder land commonly supports some grass, but it is not good pasture land because of its loose consistency and poor trafficability. This land is a source of material for surfacing roads. (Capability subclass VIIIs, nonirrigated)

Lava Flows, Aa (have possible geothermal site)

Lava flows, Aa (rLV), has been mapped as a miscellaneous land type. This lava has practically no soil covering and is bare of vegetation, except for mosses, lichens, ferns, and a few small ohia trees. It is at an elevation ranging from near sea level to 13,000 feet and receives from 10 to 250 inches of rainfall annually. It is associated with pahoehoe lava flows and many soils.

This lava is rough and broken. It is a mass of clinkery, hard, glassy, sharp pieces piled in tumbled heaps. In areas of high rainfall, it contributes substantially to the underground water supply and is used for watershed. (Capability subclass VIIIs, nonirrigated)

Lava Flows, Pahoehoe

Lava flows, pahoehoe (rLW), has been mapped as a miscellaneous land type. This lava has a billowy, glassy surface that is relatively smooth. In some areas, however, the surface is rough and broken, and there are hummocks and pressure domes.

Pahoehoe lava has no soil covering and is typically bare of vegetation except for mosses and lichens. In the areas of higher rainfall, however, scattered ohia trees, ohelo berry, and aalii have gained a foothold in cracks and crevices.

This miscellaneous land type is at an elevation from sea level to 13,000 feet. The annual rainfall ranges from 10 inches to more than 140 inches.

Some flat slabs of pahoehoe lava are used as facings on buildings and fireplaces. In areas of higher fainfall, this lava contributes to the ground-water supply. (Capability subclass VIIIs, nonirrigated)

Malama Series

The Malama series consists of well-drained, thin, extremely stony organic soils over Aa lava. These soils are undulating to rolling. They are on mountains at an elevation ranging from near sea level to 1,000 feet, and receive form 60 to 90 inches of rainfall annually. Their mean annual soil temperature is between 72° and 74° F. The natural vegetation consists of guava, waiwe, mango, hala, noni apple, and ohia. These soils and Keei, Opihikao, Puna, and Punaluu soils are in the same general area.

Malama soils are used for woodland, pasture, and orchards.

Malama extremely stony muck, 3 to 15 percent slopes (rMAD).-- This soil overlies relatively young Aa lava flows on the windward side of Kilauea Crater.

In a representative profile the surface layer is very dark brown, extremely stony muck about 3 inches thick. It is underlain by fragmental Aa lava. This soil is strongly acid.

Manu Series

The Manu series consists of well-drained silt loams that formed in volcanic ash, cinders, and pumice. These soils are nearly level to gently sloping. They are on uplands at an elevation ranging from 3,000 to 4,000 feet and receive from 80 to 120 inches of rainfall annually. Their mean annual soil temperature is between 58° and 62° F. The natural vegetation consists of ohia, tree fern, amaumau fern, and rattail. These soils and Heake, Kilauea, Kona, Puaulu, and Puhaimau soils are in the same general area.

Manu soils are used mostly for woodland. Small areas are used for pasture and truck crops.

Manu silt loam, 2 to 6 percent slopes (rMUB).-- This soil is at intermediate elevations on the windward side of Mauna Loa in the Volcano area.

In a representative profile the surface layer is very dark brown silt loam about 3 inches thick over about 5 inches of very dark grayish-brown fine sandy loam. It is underlain by stratified layers of very dark grayish-brown coarse sand, fine sandy loam, and loamy fine sand and dark yellowish-brown pumice. Hard pahoehoe lava bedrock is at a depth of about 36 inches. The profile grades from medium acid in the surface layer to neutral in the lower part of the subsoil.

Opihikao Series

The Opihikao series consists of well-drained, thin organic soils over pahoehoe lava bedrock. These soils are gently sloping to moderately steep. They are on uplands at an elevation ranging from near sea level to 1,000 feet and receive from 60 to 90 inches of rainfall annually. Their mean annual soil temperature is between 72^{o} and 73^{o} F. The natural vegetation consists of guava, waiwe, and ohia. These soils and Keei, Kona, Malama, Papai, and Puna soils are in the same general area.

Opihikao soils are in native forest or are used for pasture.

Opihikao extremely rocky muck, 3 to 25 percent slopes (rOPE).-- This soil is in the Puna district. Rock outcrops occupy 30 to 50 percent of the area.

In a representative profile the surface layer is very dark brown muck about 3 inches thick. It is underlain by pahoehoe lava bedrock. The muck is strongly acid.

The depth to pahoehoe lava bedrock is 2 to 5 inches. The hue of the 02 horizon ranges from 7.5 YR to 10 YR.

The muck is rapidly permeable. The lava is very slowly permeable, but water moves rapidly through the cracks. Runoff is slow, and the erosion hazard is slight. Roots are matted over the pahoehoe lava, but they can penetrate the cracks to a depth of 2 feet.

This soil is in native forest or is used for pasture.

Papai Series

The Papai series consists of well-drained, thin, extremely stony organic soils over fragmental Aa lava. These soils are gently sloping to moderately steep. They are on uplands at an elevation ranging from near sea level to 1,000 feet and receive from 90 inches to more than 150 inches of rainfall annually. Their soil temperature is between 72° and 74° F. The natural vegetation consists of ohia, tree fern, uluhe fern, and guava. These soils and Keaukaha, Kiloa, Olaa, Opihikao, and Panaewa soils are in the same general area.

Papai soils are used mostly for woodland. Small areas are used for pasture, orchards, and truck crops.

Papai extremely stony muck, 3 to 25 percent slopes (rPAE).-- This soil is low on the windward side of Mauna Kea.

In a representative profile the surface layer is very dark brown extremely stony muck about 8 inches thick. It is underlain by fragmental Aa lava. This soil is slightly acid.

The depth to fragmental Aa lava ranges from 3 to 12 inches. The hue of the surface layer ranges from 7.5 YR to 10 YR.

Permeability is rapid, runoff is slow, and the erosion hazard is slight.

Puna Series

The Puna series consists of well-drained, thin, extremely stony organic soils over fragmental Aa lava. These soils are gently sloping to moderately steep. They are on uplands at an elevation ranging from 1,000 to 3,500 feet and receive from 60 to 90 inches of rainfall annually. Their mean annual soil temperature is 63° F. The natural vegetation consists of ohia, guava, Christmas berry, and alapaio fern. These soils and Kona, Malama, and Opihikao soils are in the same general area.

Puna soils are used for woodland, pasture, and orchards.

Puna extremely stony muck, 3 to 25 percent slopes (rPXE).-- This soil is at intermediate elevations on Mauna Loa and Hualalai.

In a representative profile the surface layer is very dark brown extremely stony muck about 5 inches thick. It is underlain by fragmental Aa lava. This soil is neutral in reaction.

The depth to fragmental Aa lava is 2 to 6 inches.

Permeability is rapid, runoff is slow, and the erosion hazard is slight. Roots are matted in the surface layer, but some roots extend to a depth of 20 inches into the cracks in the lava.

This soil is used for woodland, pasture, and orchards.

HGP-A: 1975 - 1981 (AREA 0)

Save for the obvious changes attendant upon construction of a generating facility, the area around HGP-A has changed little in aspect since the original baseline study was inaugurated in 1975. Clearly, concerns about environmental degradation related to toxic emissions have not materialized. To be sure, HGP-A has only been operated intermittently; however some signs of its effects might have been perceptible.

If the injury were present but latent or hidden, a long known phenomenon with ozone and smog pollutants, it should at least show indications of exposure. Exposure to adverse but asymptomatic levels of ozone leave no analytical record in the tissue, as the oxidant is reduced to H_2O, etc. and can no longer be recognized.

In the case of Hg and other intrinsically toxic elements, an exposure, if potentially toxic, must leave a record in the form of tissue presence of the hazardous substance.

To the question "what is the mercury record in the plants now as related to the original status," the expectation (for latent injury) and reality are quite different. Aggregate mean Hg levels in plants of the HGP-A Baseline radius were 353 $\mu g \cdot kg^{-1}$ with a standard deviation of about ±18%. This was 6-fold greater than both aggregate means taken in the Manoa Valley, Honolulu. This shows clearly a position proximity factor. Yet the 1981 surveys yield aggregates of only 110 - 136 $\mu g \cdot kg^{-1}$, averaging overall about 126 $\mu g \cdot kg^{-1}$ or ca one-third of the 1975 figure. The soils picture is completely parallel.

This general situation can be accounted for readily by noting the volcanic record in comparison with soil and plant Hg content.

It is obvious that the general subsidence in volcanic activity from 1975 to the present coincides with a 3-fold reduction in soil plant concentrations.

This underscores the importance of continued surveillance at natural volcanic-fumarolic sites while developing a monitoring program as close (or seemingly remote) as HGP-A is to Mauna Kea and Kilauea.

A final comment on sample station selection. The 4 sets of tracks chosen are considered as applying to both wells, even though three are "attached" to well number 2 and only a single track to well number one. All 4 tracks cover both wells.

Chemistry of Air and Soil:

AREA 1

Chemical analyses were carried out on air and soil samples emphasizing two elements characteristic of geothermally active environments and geothermal fluids, mercury and arsenic. The Kilauea volcanic system and its vents and fumaroles produce large amounts of mercury but, unlike New Zealand, only minute levels of arsenic (see HGP-A reports, the HGP-A EIS and the Geothermal Generator Project Environmental Plan for data and details). Experience at HGP-A indicates no arsenic emission and a level of mercury far below EPA standards. Nevertheless, we do not assume that other East Rift sites, even Kapoho step-out wells,are automatically "clean" without verification. January, 1980 tests at HGP-A also demonstrated that site hydrogen sulfide and sulfur dioxide levels were below the 5ppb level. The sulfide figure involved an experimental 95% abatement procedure.

Aerometric data at the present site show , as expected, completely non-significant levels of H_2S and other fixed gases; in other words, a clean air baseline.

Air mercury appears relatively high: measurements at 4 corner locations around the drill field range from 0.50 - 3.22g/m^3, averaging 1.32g/m^3. Referring again to prior experience at HGP-A, and in Hawaii generally, this is within the normal range for all but the more tradewind-exposed locations (e.g. Kahuku, Oahu and Kukuihaele, Hawaii). A previous sampling on 5, January (during the nearby HGP-A test) also yielded 1.3/m^3, an average of duplicate samples.

It should be noted that Hawaii's "norm",except for tradewind areas as noted,is near to above the EPA recommended 30 day average ambient air quality standard. This is not an enforced level and, in much of the Island of Hawaii and elsewhere in the state, it is not enforceable. Data and details about natural levels of mercury in Hawaii (in publications of Siegel and Siegel) can be provided if desired.

In contrast with air values, soil mercury at the aerometric sites was not high compared to many Island of Hawaii volcanic zone locations: 20-84 ppb *vs* up to 62,000 ppb at the Puhimau hot spot near Puhimau Crater. The soils around the drillsite are largely cinder, low organic, hence of low Hg-holding capacity.

Arsenic, in contrast,is relatively high for this area, but not excessively so.

At two locations where plant reference areas were set up a series of qualitative tests confirmed mercuty and arsenic and indicated traces of cadmium and zinc.

AREA 2

Experience at HGP-A indicates no arsenic emissions and a level of mercury far below EPA standards. Nevertheless, we do not assume that other East Rift sites, even Kapoho step-out wells, are automatically "clean" without verification. January, 1980 tests at HGP-A also demonstrated that site hydrogen sulfide and sulfur dioxide levels were below the 5 ppb level, noted above.

Aerometric data at the present site shows, as expected, completely non-significant levels of H_2S and other fixed gases; in other words, a clean air baseline both along the trail through the proposed initial drill site and downwind along Pohoiki Road.

Air mercury appears relatively high: measurements along the trail through the site range from 0.44 to 0.01 ug/m^3, averaging 0.52 ug/m^3. This figure is lower than the average at Ashida No. 1. The figure downwind along Pohoiki Road was virtually the same. Referring again to prior experience at HGP-A, and in Hawaii generally, this is again within the normal range for all but the more tradewind-exposed locations.

In contrast with air values, soil mercury at the aerometric sites was not high compared to many Island of Hawaii volcanic zone locations: 42-70 ppb <u>vs</u> up to 62,000 ppb at the Puhimau hot spot near Puhimau Crater. Values range somewhat above those at the Opihikao prospect; the soils around the proposed drillsite are largely organic, hence of high Hg-holding capacity.

Arsenic, in contrast, is relatively high for this area, but averaging <u>ca</u> one-half of the figure found in Opihikao.

At two locations where plant reference areas were set up, a series of qualitative tests confirmed mercury and arsenic and indicated traces of cadmium. Zinc, indicated at the Opihikao site, was absent here.

AREA 3

Over the range of proposed exploratory sites fixed gases showed no variations of interest or significance, being generally below detection levels.

Air mercury levels were highest toward HGP-A (site 1) and fell to a minimum at sites 5 and 6 on the eastern edge of the prospect. This is fully consistent with previous independent aerometrics data taken over an extended period of study. The significance of the high values around HGP-A is not clear, but it is related to Kilauea East Rift activity, not to a local wellhead source of mercury.

The air mercury trend which varies from a low of 0.51 $\mu g \cdot m^{-3}$ or by 58% is not parallelled in soil levels, which seem to fluctuate randomly around a mean of 48 $\mu g \cdot m^{-3}$ by about ±10-11%.

Soil arsenic, unlike mercury, shows a possibly significant trend from sites 1 and 2 to sites 5 and 6. All arsenic values were in fact low, but the distributions of the lowest toward HGP-A are again consistent with earlier baseline studies.

Plant Analysis

The prime objective of the assessment at AREA 0 is a search for signs of change in an exploration area close to the original HGP-A.

To accomplish this, advantage was taken of extensive past experience with mercury emissions in volcanic areas of the Island of Hawaii and elsewhere as indicators of hydrogeothermal or geothermal activity and the tendency for a number of plant species to accumulate toxicants such as mercury.

Arsenic (III) was included in this study because Puna soils are highly variable in their As content. Arsenic III was at no time detected at or near HGP-A itself up to 1978. However, in 1980, As (III) was found in modest quantities in and around Opihikao (forest soils at 0.15 - 0.4 ppm), and it is a characteristic component at many of the world's geothermal centers.

AREA 0 - 1, SE of HGP-A

Over the approximate 1000 ft. span of this transect, there is no indication of variation or tissue Hg content with distance. There is, in fact, remarkable consistency in Hg content.

This consistency does not extend to soils analyzed(see above "SOIL ANALYSIS") as the Hg content rises with the elevation to a maximum on the top of Puu Pilau and falls toward lower disturbed lands. Arsenic, if present in these soils, is below our detection limit.

AREA 0 - 2, SE of HGP-A

Sampling along this track begins on aa supporting widely scattered individual plants of low stature and proceeds into open scrub with heavy cover of herbs and semi-woody plants, ending at a wide bulldozed area of open Ohia scrub.

None of the species sampled shows any trend toward variation in mercury content according to site. Unlike AREA 0 - 1, the soils show no sign of position related variation.

AREA 0 - 3, SE of HGP-A

Like the foregoing transect, this one begins by an open aa field with sparse cover and proceeds into an increasingly solid stand of ferns and scrubs. From station 1, Pluchea shows a slight drop in Hg, thereafter rising back to about its level as seen at Site 1. The fern Nephrolepis behaves similarly.

Both trends of the plants are highly questionable statistically. If there is any trend in soil Hg, it is seen in a drop at Station 8, the summit of the transect. Again, no arsenic was detected.

AREA 0 - 4

In this more complex layout, Stations 5 and 6 are nearest the highway; numbers 7 and 8 are most interior. Together with Station 1 they are all along the "papaya trail." Ohia leaf data suggested a possible rising trend along the trail (inward) but analytical results with other plants have no indications of this possibility.

Soil data also show no differential in Hg distribution. Arsenic was detected for the first time here at Stations 1 and 2, but only in traces.

AREA 1

Permanent plant sample reference areas were selected as indicators of toxic sulfur gas emissions and, because they accumulate mercury readily, as sensitive monitors for any mercury release. For these reasons we seek to place reference areas as closely as possible to downwind and upwind locations. It also provides fixed points of reference for the downwind region more generally.

Other areas serve as controls, reflecting for example somewhat drier locations or lack of lichen ground cover. One reference lies to the east by the rim of the small pit crater edging the drill field. It consists of tagged plants. Another location, also west of the drill site, lies within the forest margin above the fire control pond.

Additional individual trees around the area were tagged.

In addition to the simple identification of sample sites of dominant species, a more quantitative treatment of the principle sites was carried out. In these locations numbers and heights of *Metrosideros* plants and numbers of *Nephrolepis* (Boston fern) plants in an enclosed area have been recorded.

The mercury contents of tissue samples and in two cases, soil where it existed, have been taken. The procedure included immediate analysis together with freezer storage of samples (-10° C) for future reference up to *ca* 6 months.

Tissue mercury levels are within previously observed values typical of the Puna-area vegetation and these species in particular.

Soils at the principle sites were relatively rich in mercury. This may reflect a higher organic content in those locations hence higher mercury holding capacity.

AREA 2

Two plant sampling stations were extablished, respectively, "above" (west) and "below" (east) the first proposed exploratory drill site area. The plant densities were too high for counting purposes. Area A contained 6 species, Area B contained 5; of these, 4 were common to both quadrants.

The general condition of plants at these sites was good: no evidences of unusual browning, necrosis or other abnormalities indicative of nutritional, predator or microbial disturbances were noted.

The mercury content of leaf tissue and soils in areas A and B was similar as reflected in plant/soil values. At site A the ratio ranged from 0.97 to 3.02; at site B the accumulation ratio averaged somewhat lower, 0.75 - 2.13.

With respect to general aspect and condition, the two sites are fully comparable.

AREA 2 Plant Sample Stations

Sample Reference Station	Species Composition
A Approximately W. of projected first drill site Quadrat 10x60m = 60m^2 regular geometry	Pluchea Metrosideros (Ohia) Dicranopteris Psidium (Guava) Rubus Cyperus
B Approximately E. of projected first drill site Quadrat 8x5m = 40m^2 but irregular	Pluchea Metrosideros Dicranopteris Cyperus Lycopodium

AREA 3

Among the six potential exploration sites, Pluchea was found at all; guava and the fern Dicranopteris were found at 5 locations; and Ohia, with the fern Nephrolepis, was found at 3.

At station 3, indicated species are differentiated, with open ohia-guava woodland to the NE (upwind and makai) and a denser, less diversified fern and herb community on the makai (downwind and SW) side of Pohoiki road.

With respect to leaf mercury content, there is suggestion of a down-trend in ohia and in guava starting from station 1, but it is of questionable significance. Other species were clearly random.

For the same species (Pluchea, Nephrolepis) at site 3, there is only a normal variability in the range of ±5-7%.

The area of the 6 exploratory sites is known to harbor rare, threatened or endangered species in 5 families. None of these was found.

Maximum Expected Rare, Threatened or Endangered
Species in AREA 3 Geothermal Prospect

Family	Species
Apocynaceae	Rauvolfia remotiflora Deg. & Sherff
Campanulaceae	Clermontia hawaiiensis (Hbd.) Rock var. Hawaiiensis
Goodeniaceae	Scaevola kilaueae Deg. var. Kilaueae
Pittosporaceae	Pittosporium hosmeri Rock var. hosmeri
Rubiaceae	Bobea timonioides (Hock.) Hbd.

PLANT ANALYSIS I: AREA 0 - 1, SE of HGP-A

Leaf Tissue Mercury

Sample Station	Species	Mercury ($\mu g \cdot kg^{-1}$, fr. wt.)
1	Dicranopteris	92 ± 10
2	Dicranopteris	93 ± 12
	Ohia	132
	Guava	138
3	Dicranopteris	95 ± 12
	Ohia	126
	Guava	111
4	Dicranopteris	83 ± 10
	Guava	124
5	Dicranopteris	91 ± 9
	Guava	120 ± 14

PLANT ANALYSIS II: AREA 0 - 2, SE of HGP-A

Leaf Tissue Mercury

Sample Station	Species	Mercury ($\mu g \cdot kg^{-1}$, fr. wt.)
1	Pluchea	177
	Nephrolepis	80 ± 4
2	Pluchea	170
	Nephrolepis	81 ± 7
3	Pluchea	176 ± 8
	Nephrolepis	82 ± 4
4	Pluchea	151 ± 17
	Nephrolepis	80 ± 4
5	Pluchea	181 ± 4
	Nephrolepis	87
6	Pluchea	168 ± 7
	Nephrolepis	83 ± 5
7	Pluchea	170 ± 6
	Nephrolepis	77
8	Pluchea	174
	Nephrolepis	74
9	Pluchea	173
	Nephrolepis	75 ± 3
10	Nephrolepis	83
	Ohia	171
11	Ohia	170

PLANT ANALYSIS III: AREA 0 - 3, SE of HGP-A

Leaf Tissue Mercury

Sample Station	Species	Mercury ($\mu g \cdot kg^{-1}$, fr. wt.)
1	Pluchea	186 ± 10
	Nephrolepis	83 ± 5
	Ohia	166
2	Pluchea	169 ± 8
	Nephrolepis	76
	Ohia	172
3	Pluchea	176
4	Pluchea	174
	Nephrolepis	68
5	Pluchea	174 ± 10
6	Pluchea	172
	Nephrolepis	82
7	Pluchea	194 ± 8
8	Nephrolepis	89

PLANT ANALYSIS IV: AREA 0 - 4, SW of HGP-A

Leaf Tissue Mercury

Sample Station	Species	Mercury ($\mu g \cdot kg^{-1}$, fr. wt.)
1	Pluchea	170
	Nephrolepis	83 ± 5
	Ohia	179
2	Nephrolepis	79
	Ohia	171
3	Nephrolepis	63 ± 5
	Ohia	169
4	Nephrolepis	73
	Ohia	175
5	Pluchea	168 ± 6
	Nephrolepis	77
	Ohia	168 ± 8
6	Nephrolepis	81
	Ohia	188
7	Pluchea	181
8	Pluchea	181
	Nephrolepis	78
	Ohia	173
	Guava	103

PLANT ANALYSIS V: HGP-A AREA

Aggregate Mean Mercury Content of Vegetation for Comparative Study

Sample Area	Species Represented	Mercury ($\mu g \cdot kg^{-1}$, fr.wt.)
1. HGP-A, May-September, 1975	Dicranopteris, Nephrolepis, Lycopodium, Cyperus, Guave, Ohia, Eucalyptus, Koa Haloe	353 ± 63
2. Wellsite Within HGP-A Survey Area, February 1981		
Site 1	Dicranopteris, Guava, Ohia	110 ± 17
Site 2	Pluchea, Nephrolepis, Ohia	122 ± 43
Site 3	Pluchea, Nephrolepis, Ohia	136 ± 46
Site 4	Pluchea, Nephrolepis, Guava, Ohia	135 ± 47
3. Manoa Valley (Oahu)		
1972-75	Nephrolepis, Cyperus, Guava, Koa Haloe, Eucalyptus, Albizzia	58 ± 26
1978-79	Nephrolepis, Cyperus, Guava, Koa Haole, Eucalyptus	63 ± 33

PLANT ANALYSIS VI: General Review

Records of Environmental Eruptions and Eruptions 1969-74 and 1975-81 Campared

Period	Eruptions			Mercury at HGP-A		
	Site	Number	Volume $10^6 m^3$	Date	Soil	Plants
2/69 - 12/74	Kilauea			5/75	212 ± 66	353 ± 63
	Rift	4	36			
	Summit	4	39			
	Mauna Ulu	4	343			
11/75 - 2/81	Kilauea	2	40	2/81	63 ± 2	126 ± 10
	Rift	1	0.2			
	Summit	0	-			

PLANT ANALYSIS VII: AREA 1

Permanent Plant Sample Stations

Area No.	Location	Composition
1	Downwind	Metrosideros, Nephrolepis
	(S.W. of rig)	Stereocaulon in 6 m^2 quadrat.
		Metrosideros
		8 plants 1-2 m.
		4 plants ≤1 m.
		Nephrolepis
		220-260 plants
		Soil pH 619-7.1
2	Rise N.W. of	Metrosideros, Nephrolepis
	rig ca 60 M.	in $3m^2$ quadrant
		Metrosideros
		2 plants >2 m.
		2 plants 1-2 m.
		2 plants ≤ m.
		Nephrolepis
		280-320 plants
3	10 M E. of Tank	Pluchea, Psidium
	at Crater edge	
4	Transect Line on	Metrosideros, Psidium,
	rise W. of Pond	Nephrolepis, Dicranopteris
		Soil pH 6.2-6.4

PLANT ANALYSIS VIII: AREA 1

Leaf Tissue Mercury

Plant Are No.	Species	Mercury ug/kg
1	Metrosideros	97
	Nephrolepis	147
	Stereocaulon	103
	Soil	312
2	Metrosideros	167
	Nephrolepis	106
	Stereocaulon	82
3	Psidium	198
	Pluchea	232
4	Metrosideros	129
	Psidium	89
	Nephrolepis	280
	Dicranopteris	46
	Soil	164

PLANT ANALYSIS IX: AREA 2

Leaf Tissue Mercury

Station	Species	Mercury Content	Plant/Soil
A	Pluchea	181	3.02
	Metrosideros	128	2.13
	Dicranopteris	76	1.27
	Psidium	101	1.68
	Rubus	92	1.53
	Cyperus	58	0.97
B	Pluchea	171	2.13
	Metrosideros	109	1.67
	Dicranopteris	62	0.95
	Cyperus	49	0.75
	Lycopodium	58	0.89
A	Soil	60	
B	Soil	65	

PLANT ANALYSIS X: AREA 3

Leaf Tissue Mercury

Site	Species	Hg Content* ppb
1	a Metrosideros (ohia)	200
	b Psidium (guava)	89
	c Pluchea	206
	d Dicranopteris	88
2	a Ohia	170
	b Pluchea	168
	c Dicranopteris	81
	d Nephrolepis	80
3U	a Ohia	139
	b Guava	170
	c Pluchea	160
	d Rubus	100
	e Nephrolepis	80
3	a Guava	106
	b Rubus	91
	c Pluchea	151
	d Nephrolepis	72
3D	a Pluchea	155
	b Dicranopteris	71
	c Nephrolepis	80
4	a Guava	96
	b Pluchea	169
	c Dicranopteris	117
	d Nephrolepis	76
5	a Ohia	130
	b Guava	106
	c Pluchea	186
	d Dicranopteris	76
6	a Ohia	136
	b Guava	112
	c Pluchea	196
	d Dicranopteris	84

*Based on 8-12g leaf samples

Botanical Survey

BOTANICAL SURVEY I: AREA O

Endangered Species of the
Puna District (Maximum List)

Family	Species	Kapoho area sightings
Apocynaceae	*Rauvolfia remotiflora* Deg. and Sherff	negative
Campanulaceae	*Clermontia hawaiiensis* (Hbd.) Rock var. Hawaii	negative
Goodeniaceae	*Scaevola kilaueae* Deg. var. kilaueae	negative
Pittosporaceae	*Pittosporium hosmeri* Rock var. hosmeri	negative
Rubiaceae	*Bobea timonioides* (Hock) Hbd.	negative

BOTANICAL SURVEY II: AREA O

Selected Indicator Species

Ferns

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1. Dicranopteris linearis (Burm.) Underw.
   false staghorn, uluhe
   Common in forest and open as ground cover on aa

2. Nephrolepis exaltata (L.) Schott.
   Sword fern
   Common on forest floor, or in open when shaded
   by secondary scrub vegetation

Angiosperms

---

1. Pluchea odorata (L.) cass. (Compositae)
   Sour bush
   Rapidly colonizes disturbed areas, open scrub,
   roadsides. Common simi-woody plant

2. Metrosideros collina (J. R. & G. Forst.) Gray. subsp.
   polymorpha (Gaud.) Rock. (Myrtaceae) 'ōhi'a-lehua
   This indigenous tree is dominant canopy in this area
   and a great deal of Hawaii.

3. Psidium guajava L. (Myrtaceae)
   guava
   A common shrub of low tree in scrub areas, often
   makai of vigorous forest.

Vegetation of the Geothermal
AREAS 0,1,2,3

AREAS 1 Vegetation

The main types of vegetation are the native pioneer scrub community and the exotic ruderal herb community.

1) The native pioneer community is generally an open canopy low stature scrub on recent lava substrata. This vegetation is found on what appears to be lava from a relatively recent vent immediately mauka of the 1955 lava flow, on the 1955 lava flow proper, and at a vent to the east. Toward Puu Kaliu the vegetation of the 1955 flow is sparest and most uniform. It consists of scattered (10-20% cover) 'ōhi'a (Metrosideros collina) 1-5 m tall, with a fair number of smaller stature 'ōhi'a, some sword fern (Nephrolepis exaltata) and about 5% cover of the conspicuous exotic broomsedge (Andropogon virginicus). The common gray lichen often found on recent lava flows, Stereocaulon vulcani, is abundant,covering 90%$^+$ of the available rock area.

The vegetation,on what appears as recent lava in the immediate vicinity of the vent which has not been highly disturbed by construction, consists of low canopy (1-8 m) 'ōhi'a with an open canopy (40-60% cover). Ground ferns, especially the sword fern,are conspicuous,forming up to 80-90% cover with some broomsedge and exotic shrubs (Arundina, Melastoma & Psidium cattleianum).

Some of the native species in this area which make up minor components of the vegetation include sedges; 'uki (Machaerina mariscoides and M. angustifolia); the 'ama'uma'u fern (Sadleria cyatheoides); and a vine, huehue (Cocculus ferrandianus). As on the 1955 flow proper, Stereocaulon is quite common. The vegetation at the vent to the east is similar to that on recent substratam with the addition of club moss (Lycopodium cernuum).

2) The tall canopy 'ōhi'a forest is located upslope and to the north and northeast. Two substrata have had effect in the structure of the forests in the vicinity just upslope and along either side of the road leading to the area;the forest is situated on a'a. That on the slopes of Puu Kaliu is on ash or cinder. The forests on the a'a substratum are closed canopy ($80^{+\%}$ cover) 'ōhi'a 10-14 m tall with dbh (diameter at ca 1.5 m) averaging 25 cm and ranging from 10-40 cm. Scattered sparingly through the forest are 'ohe (Tetraplasandra hawaiensis) as tall as the 'ōhi'a canopy. They are the tall trees with large pinnate leaves. Below the dense 'ōhi'a canopy are subcanopy trees at 8-10 m tall including kopiko (Psychotria hawaiiensis), lama (Diospyros ferrea), and less commonly, kolea (Myrsine lessertiana). These trees usually do not exceed 10 cm dbh. Ie'ie (Freycinetia arborea), a climbing liana,grows high into the 'ōhi'a - sometimes to 10^{+} m. Two other lianas, maile (Alyxia olivaeformis) and huehue (Cocculus ferrandianus),are also present but not as abundant. Tree ferns (Cibotium sp.) are conspicuous components of the subcanopy vegetation at $2-6^{+}$ m tall. Two exotic shrubs are common in the forest - the Malabar melastome (Melastoma malabathricum) and the strawberry guava (Psidium cattleianum). Little light penetrates the dense forest, but some ground ferns are present such as the sword fern (Nephrolepis

exaltata), laua'e (Microsorium scolopendria), palapala'i (Microlepia setosa) and ho'io'-kula (Cyclosorus sandwicensis). At least the sword fern sometimes occurs in fairly dense patches. A few herbs and low shrubs are present including the ground orchid (Spathoglottis plicata), thimbleberry (Rubus rosaefolius), kamanamana (Adenostemma laevenia) and 'ala'ala-wai'nui (Peperomia spp.), but these do not form a dense cover. Mosses and liverworts cover most of the exposed rocks and soil, and many epiphytes (mostly ferns) are found on the branches and trunks of 'ōhi'a and other tree species in the forest.

Patches of uluhe (Dicranopteris linearis) are found in the forest where the canopy is slightly more open. It is not known whether these patches in the forest on a'a are associated with a different substratum. Subcanopy species are not so common where the uluhe is found.

The forest on the slopes of Puu Kaliu is associated with a different substratum - either cinder or ash - rather than the rocky a'a substratum in the forest just upslope. The forest on the slopes is taller (14-16, or rarely 20 m) and again dominated by 'ōhi'a with occasional 'ohe. The cover in this forest is not as great, and while the average dbh is again about 25 cm, some are much larger. One tree was seen at approximately 60 cm dbh. In this forest the native subcanopy tree species, including tree ferns, are lacking and uluhe forms a dense mass producing about 90% cover at 1-4 m in height. A few patches of the same exotic shrubs are present, and in places ti plants (Cordyline terminalis) are emergent from the uluhe.

On the Island of Hawaii many 'ōhi'a forests have recently been affected by "'ōhi'a dieback." The nature of this problem is currently being investigated, and though clumps of trees seem to be synchronously affected, no disease agent has been identified. This suggests that the dieback may be a natural phenomenon associated with environmental conditions. At any rate, as of February 1980 the 'ōhi'a forests in AREA 1 site were vigorous and healthy with the exception of two very small patches of dead trees: one, at the base of Puu Kaliu, and the other along the access road.

3) The secondary scrub vegetation occurs southeast south and makai on land that at some time in the past has been cleared of forest and subsequently recolonized by predominantly exotic low canopy (less than 5 m) shrubby species. Characteristic species include the common yellow guava (Psidium guajava), the strawberry guava (Psidium cattleianum), Malabar melastome (Melastoma malabathricum), lantana (Lantana camara), Melochia (Melochia umbellatum), Asiatic butterfly bush (Buddleja asiatica), sour bush (Pluchea odorata) and the native mamaki (Pipturus sp.). Some of these (the fastest growing and least woody) are typically found in recently disturbed areas such as immediately makai of the rig which is dominated by much Buddleja and Pluchea. Patches of grasses and herbs such as Andropogon virginicus, Cyperus sp., Desmodium uncinatum, and numerous other weedy species are found in openings of the exotic scrub vegetation. Whether distribution of the scrub vs. lower stature vegetation was determined by substratum differences or by disturbance history is not known.

Within the area of scrub vegetation, several ethnobotanical plants (most of Polynesian introduction) are found including a yam (Dioscorea pentaphylla), kukui (Aleurites mollucana), Kāmanamana (Adenostemma laevenia), 'awapuhi (Zingiber zerumbet), ti (Cordyline terminalis), papaya (Carica papaya), and certain weedy species often associated with historic and prehistoric agricultural activities such as kāmole (Ludwigia octovalris), ageratum (Ageratum conyaoides), honohono grass (Commeline diffusa), jau'u-laidi (Paspalum orbiculare) and honohono kukui (Oplismenus hirtellus). Several of these species were also found as minor components of the forest vegetation and most are able to persist for quite a while following the abandonment of a site.

4) The exotic ruderal herb community is that found along the roadside and in the immediate sites of interest. Most of the components of this vegetation are annual herbs which are able to rapidly colonize and maintain their populations in disturbed areas by virtue of their short life cycle. There are few native plants in this community.

AREA 2 Vegetation

A survey at Laepoo was conducted on 26 July 1980. For the purpose of preparing this report notes were taken of species diversity and vegetation parameters during a walk-through survey along the eastern easement, portions of the northern boundary, and along the bulldozed trail bisecting the triangular parcel of land.

Three main types of vegetation can be recognized within the surveyed area : the native forest vegetation, Polynesian vegetation and exotic secondary vegetation. Most of the parcel is vegetated with native vegetation consisting of successionally young 'ōhi'a (Metrosideros) dominated forests which have not been disturbed in the past and have few exotic (non-native) species present. There appear to be two or three different aged flows in the area as indicated by structural differences in the vegetation. In the eastern (makai) portion of the parcel the 'ōhi'a forms an open canopy of 20-40% cover at 6-8$^+$ m tall of trees 5-15 (to 20$^+$) cm diameter. The understory consists of dense, virtually 90% cover of uluhe (Dicranopteris) at 1-2 m. In the mauka section of the land parcel the forest appears older and consists of an open canopy forest with 40-60% cover of 'ōhi'a at 10-12 (to 15 m) ranging in diameter form 8-30 cm. This older forest also has a dense uluhe understory with some lama (Diospyros) at 5-8 m. Near the center of the parcel there is some even older forest consisting of closed canopy (60-80%) 'ōhi'a at 12-15 m tall with some Diospyros; however because of the more closed aspect of the upper canopy in this area the uluhe understory is not as dense - being replaced by certain species indicative of previous Polynesian land use. The low species diversity within the native forest vegetation occurring within the area can be accounted for by the relatively recent volcanic activity in the area. Nowhere within the surveyed area were found species characteristic of relatively older flows in Puna such as kopiko (Psychotria), ie'ie (Freyeinetia) and ohe (Tetraplasandra).

The second vegetation unit, Polynesian vegetation, is found along the eastern easement of the triangular land, as well as in a small area near the center of the property. It is characterized by a complement of important Hawaiian ethnobotanical plants including noni (Morinda citrifolia), hala (Pandanus tectorius), pi'ia (Dioscorea pentaphylla), uhi (D. alata), 'awapuhi (Zingiber zerumber) and ti (Cordyline terminalis). All these species persist for some time following abandonment. In addition to these, a small patch of bananas (Musa) and another of kukui (Aleurites moluccana) were found near the edge of the property, and a single patch of 'ape (Alocasia macrorrhiza) was found just outside the parcel. In certain areas within this vegetation type, Pandanus forms densely shaded solid stands with little growing in the understory. Elsewhere Psidium guajava, the common yellow guava is the upper story species at 5^{+} m. Since the guava allows light to penetrate to the lower forest there are several species in the understory including often dense growth of 'awapuhi (Zingiber zerumbet) and much of the climbing pi'ia (Dioscorea pentaphylla). The presence of numerous ethnobotanical plants in any given area, combined by the absence of the normal 'ōhi'a forest which was likely cleared in the past and replaced successionally by the yellow guava, is a good indicator of previous agricultural activity.

The third vegetation unit is found along the bulldozed trail bisecting the property, along the road at the eastern boundary, and on a few fairly sizeable areas within the parcel that have been bulldozed in the past. This vegetation is characterized by exotic (non-native) grasses, herbs and shrubs generally 1-5 m in height, which are capable of rapid colonization and which become established following disturbance to native forest cover. It is this sort of vegetation that would become established following future disturbance to native forest vegetation. Though mostly exotic there are a few native components of this vegetation including mamaki (Pipturus), which occurs at the interface of the secondary vegetation and the native forest, and Scleria, a sharp-edged native sedge which occurs along the bulldozed path. While Scleria has been included in the Fosberg and Herbst (1975) list of Rare and Endangered Species, it was thought at that time that insufficient information was available to decide whether it should be considered endangered or not. Though of limited distribution statewide the species is relatively common in exotic secondary vegetation of Puna.

Of the three vegetation units recognized for the area surveyed none is unique, though one, the successionally young native forest vegetation which includes few exotic species and is presently widely distributed in Puna, may become restricted in distribution in the future with increased industrial and agricultural activity. For this reason attempts should be made during construction to minimize damage to this vegetation type simply by restricting bulldozer activity to only those areas where actual construction is planned.

Exploratory sites at AREA 3 (includes AREA 0) near the HGP-A generator in Puna were visited on January 13, 1981, focusing on the structure and species composition of the plant cover. Structural aspects included height and closure of the tree canopy, range of tree trunk diameters, vegetation layers present, plant lifeforms present (ie., shrubs, ferns, vines, etc.) and relative age of the vegetation. Aspects of species composition included relative species diversity on the site and species type by origin, i.e., native, Polynesian or exotic species. Native species are those which are thought to have reached the Hawaiian Islands without the aid of man.

Polynesian species are those carried to the Islands by Polynesian (Hawaiian) immigrants. Exotic species are those introduced to the Islands by man since the arrival of Captain Cook in 1778. No rare native plant species were encountered during this survey.

As used here, the terms "scattered," "open" and "closed" refer to degree of canopy closure of cover. In a "scattered" canopy the crowns of the trees cover 5-20 percent of the ground area; "open" canopy covers 20-60 percent; "closed" canopy covers 60-90 percent.

Site 1.

Location: 2800' from HGP-A well site at heading 190^{o}, or approximately 600' from the west end of Hinalo Street at heading 190^{o}.

Description: The forest in this area is successionally young and dominated by native species. 'Ohi'a (Metrosideros collina) trees from 4 to 10 m tall form an open canopy, with scattered taller 'ohi'a to 15 m height. These tress are from 2 to about 25 m in diameter, the average tree being about 8 cm in diameter. Below this layer is a scattered shrub layer of shorter 'ohi'a. The ground is entirely covered in uluhe fern (Dicranopteris linearis), a native species which forms dense mats from 1 to 3 m deep on the site. While species diversity is relatively low, the uluhe mat hosts scattered individuals of a native sedge (Machaerina angustifolia), an exotic grass (Andropogon virginicus), an exotic orchid (Arundina bambusaefolia) and an exotic shrub (Pluchea odorata). Large mango trees grow both to the north and to the east of the site. Otherwise, evidence of Polynesian or other cultivation is slight on site 1.

Site 2.

Location: 1840' from the HGP-A plant at heading 147^{o}, which places the site immediately west of the first bend in the first southerly dirt road east of Hinalo St.

Description: This site hosts a tall statured stand of relatively old, large trees. The canopy is closed in places, more open elsewhere, with a few emergent 'ohi'a at nearly 20 m. Generally, the canopy is 12 to 16 m tall and composed of 'ohi'a Persea americana, and a few other native and exotic tree species. A second tree layer reaches to about 8 m and is largely of the native Psychotria sp. and the exotics Persea americana and Eugenia jambos. The vegetation is quite diverse in form; in addition to the native and exotic trees, the site is shared by native and exotic vines, grasses, shrubs, ferns and native tree ferns. The understory is open under the tall trees. Guava thickets lie to the north and remnant sugarcane fields to the south of the site's center. Site 2 shows considerable evidence of Polynesian occupation, including a Polynesian-introduced yam (Dioscorea pentaphylla) and the culturally important natives Pipturus hawaiensis and Freycinetia arborea in abundance. The vegetation is generally of very mixed origin, indicative of frequent and widespread disturbance in the past.

Site 3.

Location: 2800' from the HGP-A well site at heading 122^{o}.

Description: Site 3 lies mostly on recently cleared land south of the Pohoiki Road. A strip of mixed native and exotic forest from 50 to 200' wide lies parallel to and south of the road and borders the site. This is a remnant of relatively old 'ohi'a forest generally taller than 10 m and of high species diversity. The vegetation of the site itself, where intact, is mostly scattered young 'ohi'a from 1 to 5 m tall, 3 cm average diameter, underlain by a sparse shrub layer. The young a'a upon which this vegetation stands is everywhere covered by lichens.

Site 4.

Location: 4000' from HGP-A well site at heading 105°.

Description: Two vegetation types occupy site 4. Much of the site hosts scattered 'ohi'a of small (about 6 cm) average diameter and 2 to 8 m height underlain by a solid mat of uluhe fern. Exotic shrubs are frequent in this fern mat. These include *Psidium guajava*, *Pluchea odorata* and *Tibouchina semidecandra*. Among exotic grasses and the bamboo scattered 'ohi'a/uluhe vegetation is an 'ohi'a stand of 6 to 14 m in height, about 10 cm average diameter, and with an open or occassionally closed canopy. A second, shorter layer of 'ohi'a reaches to 3 m. This stand is also underlain by a mat of uluhe fern with occassional exotic species.

Site 4 shows little or no sign of Polynesian cultivation. Species diversity is relatively low.

Site 5.

Location: 4800' from HGP-A well site at 86°, or about 1000' from the west end of Lauone St. at 86°.

Description: The vegetation on site 5 is a very mixed mosaic of native, Polynesian, and exotic types. The area has been altered to a high degree by man's activities. An "island" of tall trees on the site is composed of mature 'ohi'a (6 to 13 m tall, 25 cm average diameter), a few other native tree species and large Polynesian and exotic tree components. Shrubs and vines are scattered under this tree layer and are mostly exotic species. Exotic grasses cover much of the ground. This "island" is surrounded by a mosaic of remnant sugarcane field, guava thicket, uluhe fern mat and densely vegetated openings with Andropogon virginicus, Arundina bambusaefolia and Psidium guajava dominating. The site shows much evidence of Polynesain cultivation, including patches of Aleurites mollucana, Pandanus odoratissumus, Cordyline terminalis and Zingiber zerumbet. Species diversity is relatively high. Remnant native species are indicative of a relatively old and large-statured original forest.

Site 6.

Location: 4200' from HGP-A well site at heading 73°, or 500' from east end of Hinalo St, at heading 46°.

Description: This site overlaps an undisturbed 'ohi'a/uluhe forest and a highly disturbed power-line right-of-way. In the intact forest on either side of the cleared right-of-way the 'ohi'a is successionally young, of 8 cm average diameter, and forms an open canopy of 8 to 12 m in height. Uluhe fern forms a thick (.5 to 2 m) mat throughout the understory. Species diversity is low, exotic invasion slight, and there is little evidence of Polynesian cultivation. The cleared right-of-way includes much of the southern half of the site. The vegetation here is young with scattered 'ohi'a from .5 to 2 m height. Exotic shrubs, grasses and ferns dominate the clearing with a considerable native sedge and fern component as well.

Older native forest occurs nearer the end of Hinalo St. Species diversity is high, and evidence of Polynesian planting is abundant. This area may host several intersting native species not found within the actual boundaries of site 6.

BOTANICAL SURVEY III: MASTER SPECIES LIST

FOR KAPOHO RESERVOIR AREAS 0,1,2,3 PUNA

status*	habit**	
		LICHENS
I		<u>Stereocaulon</u> <u>vulcani</u> Common lichen on lava flows
		FERNS & FERN ALLIES
I	h	<u>Lycopodium</u> <u>cernuum</u> L. wawae-'iole, club moss occasional in vent areas
E	e	<u>Lycopodium</u> <u>phyllanthum</u> H. & A. epiphytic on 'ōhi'a in forest
I	e	<u>Psilotum</u> <u>complanatum</u> Sw. epiphytic on 'ōhi'a in forest
I	e,h	<u>Psilotum</u> <u>nudum</u> L. moa epiphytic & terrestrial in forest and along road
E	e	<u>Adenophorus</u> <u>tamariscinus</u> (Kaulf.) Hook & Grev. occasional in forest
E	e	<u>Adenophorus</u> <u>tripinnatifidus</u> Gaud. epiphytic on 'ōhi'a in forest
I	e	<u>Asplenium</u> <u>nidus</u> L. 'edaha, bird's nest fern common epiphytic in forest
X	f	<u>Athyrium</u> <u>japonicum</u> (Thunb.) Copel found sparingly in forest

*
E - endemic, native to Hawaii and occurring nowhere else in the world
I - indigenous, native to Hawaii and occurring elsewhere as well
P - Polynesian introduction, not native to Hawaii but brought by Polynesian settlers. Most of these plants were used by Hawaiians

**
e - epiphyte, a plant growing on another
f - ground fern, a fern rooted on the ground
g - grass, or grass-like plant
h - herb, generally a plant less than 50 cm and not very woody
l - liana or vine
s - shrub, generally a woody palnt 0.5 - 5 m tall
t - tree, generally a woody plant greater than 5 m tall with one main trunk

status*	habit**	
X	f	Blechnum occidentale L. occasional at vent sites and along roads
E	t,f	Cibotium chamissoi Kaulf. hapu'u-'i'i, tree fern in 'ōhi'a forest, this tree fern has abundant stiff scales at the base of the fronds. It is often taller than C. glaucum
E	t,f	Cibotium glaucum Hook. & Arn. hapu'u, tree fern in 'ōhi'a forest, common
X	f	Cyclosorus dentatus (Forsk.) Ching wood-fern a colonizer of disturbed sites
E	f	Cyclosorus sandwicensis H. & A. ho'i'o-kula occasional in forest
I	l,f	Dicranopteris linearis (Burm.) Underw. uluhe, false staghorn fern common in parts of the forest
E	e	Elaphoglosum alatum Gaud. occasional in forest
E	e	Elaphoglossum crassifolium (Gaud.) And. & Crosby common in forest
E	e	Grammitis tenella Kaulf. kolokolo common on tress
E	f,e	Microlepia setosa (Sm.) Alston palapalali occasional in forest
P		Microsorium scolopendria (Burn.) Copel. laua'e, Maile scented fern found throughout the area
I	f	Nephrolepis exaltata (L.) Schozt. Sword fern common on forest floor and in the shade of secondary scrub vegetation

status*	habit**	
I	e	Nephrolepis sp. sword fern the epiphytic sword fern is different from the common terrestrial one
I	e	Ophioglossum pendulum L. laukahi occasional in forest on 'ōhi'a
X	f	Pityrogramma calomelanos (L.) Link silver fern occasional along road and in disturbed places
E	e	Pleopeltis thunbergiana Kaulf. pakahakaha grows on rocks and branches in the forest
E	f	Sadleria cyatheoides Kaulf. 'ama'uma'u occasional in forest and in vent area
E	e	Sphaerocionium lanceolatum (h. & A.) Copel. filmy fern occasionally on trees
E	f	Vandenboschia davallioides (Gaud.) Copel. filmy fern occasional on rocks in forest
I	e	Vittaria elongata Sw. ohe'ohe occasional on 'ōhi'a
		MONOCOTYLEDONS
X	h	ARACEAE (Anthurium Family) Anthurium andraeanum Lind. anthurium abandoned, cultivated ornamental
		COMMELINACEAE (Commelina Family)
X	h	Commelina diffusa Burm. f. honohono occasional in disturbed areas
		CYPERACEAE (Sedge Family)
X	g	Cyperus brevifolius (Rottb.) Hassk. Kili'o'opu occasional in open areas of scrub vegetation

status*	habit**	
X	g	Cyperus haspan L. occasional along road and in scrub vegetation
I	g	Cyperus polystachyos Rottb. occasional along road
X	g	Cyperus sp. occasional along road and in scrub area
I	g	Machaerina angustifolia (Gaud.) Koyama 'uki occasional in forest and near vents
I	g	Macharina mariscoides (Gaud.) Kern 'aha-nui, 'uki occasional near vents
		GRAMINEAE (Grass Family)
X	g	Andropogon glomeratus (Walt.) BSP. bush beardgrass occasional along road, and in disturbed areas
X	g	Andropogon virginicus L. broom sedge common along road, near vent areas, and on new lava flows
X	g	Axonopus compressus (Sw.) Beauv. carpetgrass occasional along road
X	g	Melinus minutiflora Beauv. molassesgrass occasional in disturbed areas
X	g	Oplismenus hirtellus (L.) Beauv. basketgrass, honohono-kukui occasional in forest
X	g	Paspalum conjugatum Berg. Hilo grass occasional in forest and disturbed areas
X	g	Paspalum orbiculare Forst. f. mau'u-laiki, rice grass occasional in disturbed places

status*	habit**	
X	g	Paspalum urvillei Steud. Vaseygrass occasional in disturbed places
X	g	Sacciolepis indica (L.) Chase glenwoodgrass occasional in disturbed places
P	g	Sacharrum officinarum L. sugar cane, kō small patch along road to rig
X	g	Setaria geniculata (Poir.) Beauv. perennial foxtail occasional in disturbed places
X	g	Sporobolus indicus (L.) R. Br. dropseed occasional in disturbed places
		DIOSCOREACEAE (Yam Family)
P	l	Dioscorea pentaphylla L. pi'ia, pi'a, five-leafed yam occasional in forest
		LILIACEAE (Lily Family)
P	s	Cordyline terminalis (L.) Kunth ti, ki occasional in forest
		MUSACEAE (Banana Family)
P	s	Musa x paradisiaca L. banana along trail to Puu Kaliu
		ORCHIDACEAE (Orchid Family)
X	s	Arundina bambusae folia (Roxb.) Lindl common in disturbed places
X	s	Spathoglottis plicata Bl. ground orchid occasional in forest
		PANDANACEAE (Screw Pine Family)
I	l	Freycinetia arborea Gaud. ie'ie common in forest

status*	habit**	
I	t	<u>Pandanus</u> <u>odoratissimus</u> L. hala, pandanus
		ZINGIBERACEAE (Ginger Family)
P	h	<u>Zingiber</u> <u>zerumbet</u> (L.) Roscoe 'awapuhi kua hiwi, shampoo ginger occasional in forest
		DICOTYLEDONS
		APOCYNACEAE (Periwinkly Family)
E	l	<u>Alyxia</u> <u>olivaeformis</u> Gaud. maile occasional in forest
		AQUIFOLIACEAE (Holly Family)
E	t	<u>Ilex</u> <u>anomala</u> H. & A. kāwa'u this is a sub-canopy forest tree species, widely distributed on Hawaii but relatively uncommon at the site
		ARAILIACEAE (Panax Family)
E	t	<u>Tetraplasandra</u> <u>hawaiensis</u> Gray 'ohe occasional in forest
		BEGONIACEAE (Begonia Family)
X	h	<u>Begonia</u> sp. begonia uncommon in forest
		CARICACEAE (Papaya Family)
X	t	<u>Carica</u> <u>papaya</u> L. papaya occasional in exotic scrub vegetation
		COMPOSITAE (Daisy Family)
P	h	<u>Adenostemma</u> <u>lavenia</u> (L.) Ktze. kāmanamana This species may be indicative of Polynesian activity and not indigenous. It was seen in a few places on the aa substratum, but was not widespread in the area.
X	h	<u>Ageratum</u> <u>conyzoides</u> L. ageratum common in disturbed places

status*	habit**	
X	h	*Chicoridae* sp. occasional in forest
X	h	*Emilia javanica* (Burm. f.) C. B. Robins pua-lele occasional in disturbed places
X	h,s	*Erigeron bonariensis* L. hairy horseweed found in disturbed places
X	h,s	*Erechtites valerianaefolia* (Wolf) DC. found in disturbed places
X	h	*Eupatorium riparium* Regel Hamakua pamakani, spreading mist flower occasional in disturbed places
X	s	*Pluchea odorata* (L.) Cass. shrubby fleabane, sour bush Rapidly colonizes disturbed areas, also seen along the roadway
		EBANACEAE (Ebony Family)
E	t	*Diospyros ferrea* (Willd.) Bakh. ssp. *sandwicensis* (A. DC.) Fosb. lama common in forest
		EUPHORBIACEAE (Spurge Family)
P	t	*Aleurites moluccana* (L.) Willd. kukui, candlenut
X	h	*Euphorbia geniculafa* Ortega wild spurge occasional along road
X	h	*Euphorbia hirta* L. garden spurge common in disturbed places
X	t	*Manihot glaziovii* Muell-Arg. Ceara rubber trees along road, but not an important component in the predominately native forests

status*	habit**	
		LABIATAE (Mint Family)
X	h,s	Coleus blumei Benth. coleus Occasionally in the forest on the west side of roads
X	s,h	Hyptis pectinata (L.) Poit. comb hyptis occasional in disturbed places
		LEGUMINOSAE (Pea Family)
X	t	Albizia lebbeck (L.) Benth. siris tree trees in forest - but only fear foad and not an important component in the predominately native forests
X	h	Cassia leschenaultiana DC. laukī, partridge pea common along road
X	h,s	Crotalaria incana L. fuzzy rattle-pod along road
X	h	Desmodium uncinatum (Jacq.) DC. Spanish clover occasional in disturbed places
X	h	Mimosa pudica L. sensitive plant, sleeping grass, hilahila Along roads
		LOGANIACEAE (Strychnine Family)
X	s	Buddleja asiatica asiatic butterfly bush, huelo-'tlio common in disturbed areas
		LYTHRACEAE (Loosestrife Family)
X	h	Cuphea carthagenensis (Jacq.) Macbride tarweed, puakamdi occasional in wet spots
		MELASTOMATACEAE (Melastoma Family)
X	s	Melastoma malabathricum L. Malabar melastome common in secondary forest

status*	habit**	
X	h	Melastoma sp. a few plants along roads
		MENISPERMACEAE (Moonseed Family)
E	l	Cocculus ferrandianus Gaud. huehue occasional in forest and elsewhere
		MORACEAE
X	s,h	Cannabis sativa L. pakalolo, marijuana a few abandoned patches seen
		MYRSINACEAE (Myrsine Family)
E	t	Myrsine lessertiana A. DC. kōlea common sub-canopy tree species in the forest on the aa substratum
E	e	Myrsine sandwicensis A. DC. kōlea-lau-li'i occasional sub-canopy shrub in forest on aa substratum
		MYRTACEAE (Myrtle Family)
E	t	Metrosideros collina (J. R. & G. Forst.) Gray ssp. polymorpha 'ōhi'a-lehua the dominant canopy tree species throughout the area
X	s,t	Psidium cattleianum Sabine red strawberry guava in forest and along road
X	s,t	Psidium cattleianum Sabine f. lucidum Deg. yellow strawberry guava occasional in forest and along road
X	s,t	Psidium guajava L. guave common shrub in low scrub makai of good forest
		ONAGRACEAE (Evening Primrose Family)
X	h	Ludwigia octovalvis (Jacq.) Raven primrose willow, kāmole occasional weed in wet spot

status*	habit**	
		PASSIFLORACEAE (Passion Flower Family)
X	l	Passiflora foerida L. scarlet fruited passionfruit, love-in-a-mist occasional in scrub and along road
X	l	Passiflora sp. passion fruit uncommon in scrub
		PIPERACEAE (Pepper Family)
E	e,h	Peperomia spp. 'ala 'ala-wai-nui occasional in forest
P	s	Piper methysticum Forst. f. 'awa cultivated by Hawaiians in past, and probably even in recent times.
		ROSACEAE (Rose Family)
X	h	Rubus rosae folius Sm. thimbleberry, ola'a occasional in forest
		RUBIACEAE (Coffee Family)
X	h	Borreria sp. common herb in disturbed places
E	t	Psychotria hawaiiensis (Gray) Fosb. kopiko common sub-canopy tree species in forest
		SCROPHULARIACEAE (Snapdragon Family)
X	h	Castilleja arvensis Schlect. & Cham. Indian paint brush occasional in distrubed places
		STERCULIACEAE (Chocolate Family)
X	t,s	Melochia umbellata (Houtt.) Stapf. melochia common secondary forest species
		UMBELLIFERAE (Carrot Family)
X	h	Centella asiatica (L.) Urban Asiatic pennywort occasional in disturbed places

status*	habit**	
		URTICACEAE (Nettle Family)
E	s	Pipturus sp. mamaki common shrub in pioneer and disturbed habitats
		VERBENACEAE (Verbena Family)
X	s	Lantana camara L. lantana occasional in scrub
X	h	Verbena literalis HBK. ha'uōwī, weed verbena occasional in disturbed places

WIND RESOURCE

AREA 4

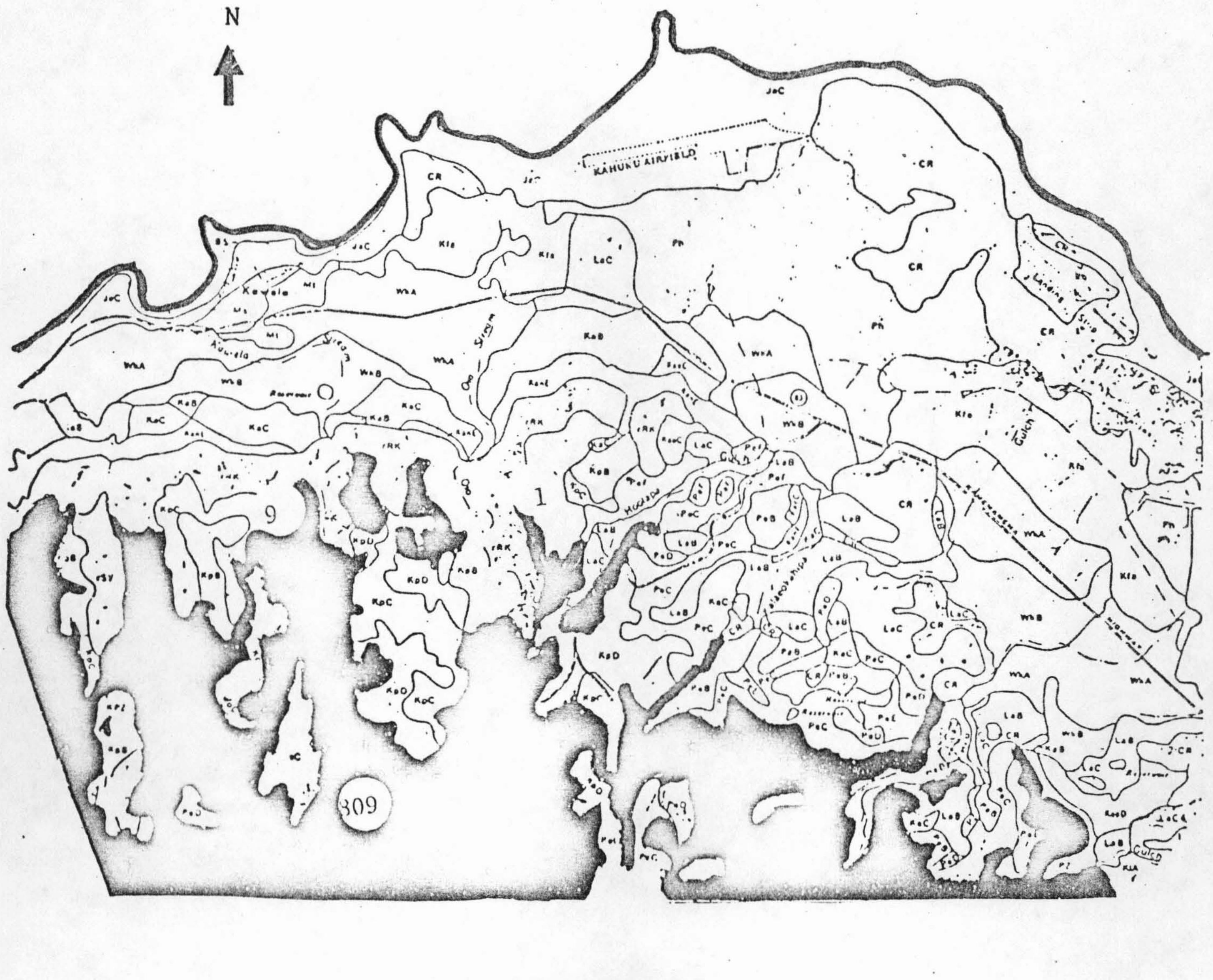
The Kahuku Area

The Kahuku wind energy prospect area lies at the northern end of the Koolau rift zone and Schofield Plateau on remnants of Tertiary flows. Potassium-Argon dating indicates an age of 2.2-2.6 million years for Koolau rocks. The low hills have in some cases weathered away to reveal part of the extensive dike complex characteristic of the Koolau range. Almost all of the rocks of the Koolau Volcanic Series are tholeiitic and olivine basalts with small amounts of oceanite and orthorhombic pyroxene. Alkalic lavas are virtually unknown. The low, dissected hills at the site are "fronted" to the north by an extensive Quaternary (Pleistocene) alluvium and calcareous reef and dune formations of the same epoch.

Soils consist generally of silty clays of the Kemoo and Paumalu series. Most of the windsites are surrounded by rugged badlands. The Kahuku prospect soil series together total about 8500 acres and comprise about 2% of Oahu's soil.

KAHUKU BADLANDS

Shown is a schematic modification of the standard soil map for northern Oahu. Hill 809 is a convenient reference point. The area in black is characterized as a "badlands complex" according to the United States Department of Agriculture Soil Conservation Service's Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai and Lanai published in 1972. Both of the soils series represented at the Kahuku prospect, Kemo'o and Paumalu, are included in these Badlands; these areas are typically silty clay, sometimes gravelly, with slope angles of 20% or more. Only 30% of the hilltop windsites are at all free of badlands.



KAHUKU BADLANDS: AREA 4 (Wind)

Soil Analysis

Soil Series

Kemoo

This series consists of well-drained soils on uplands on the island of Oahu. These soils developed in material weathered from basic igneous rock. They are gently sloping to very steep. Elevations range from 300 to 1,200 feet. The annual rainfall amounts to 35 to 60 inches, most of which occurs between November and April. The mean annual soil temperature is 71° F. Kemoo soils occur mainly on the windward slopes of the Waianae Range and from Waimea Bay to Kahuku on the Koolau Range. They are geographically associated with Halawa, Mahana, and Paumalu soils.

These soils are used mainly for pasture. Small areas are used for sugarcane. The natural vegetation consists of guava, koa haole, Christmas berry, lantana, and Bermuda grass.

Kemoo silty clay, 12 to 20 percent slopes (KpD). - This soil occurs on uplands. Included in mapping were small areas of silty clay loam or silt loam. These areas are at the higher elevations. The soils in these included areas have a concentration of heavy minerals in the surface layer. Also included were small, eroded spots and stony areas.

In a representative profile the surface layer is very dusky red to dark reddish-brown, subangular blocky silty clay about 12 inches thick. The subsoil, about 55 inches thick, is dark reddish-brown to dusky-red silty clay that has subangular blocky structure. The substratum is soft, weathered rock. The soil is slightly acid in the surface layer and slightly acid to neutral in the subsoil.

Permeability is moderate to moderately rapid. Runoff is medium, and the erosion hazard is moderate. The available water capacity is 1.4 inches per foot of soil. Workability is slightly difficult because of the slope. In places roots penetrate to a depth of 5 feet or more.

Representative profile: Island of Oahu, lat. 21°33'00" N. and long. 158°07'23" W.

This soil is used mainly for pasture. Small areas at lower elevations are used for sugarcane. (Capability classification IVe, nonirrigated; sugarcane group 1; pineapple group 6; pasture group 5; woodland group 5.)

Kemoo silty clay, 2 to 6 percent slopes (KpB). - On this soil, runoff is low to medium and the erosion hazard is slight. Workability is easy.

This soil is used for sugarcane and pasture. (Capability classification IIe, nonirrigated; sugarcane group 1; pineapple group 5; pasture group 5; woodland group 5.)

Kemoo silty clay, 6 to 12 percent slopes (KpC). - On this soil, runoff is medium and the erosion hazard is slight to moderate. Workability is slightly difficult because of the slope. Included in mapping were small, eroded areas.

This soil is used for sugarcane and pasture. (Capability classification IIIe, nonirrigated; sugarcane group 1; pineapple group 6; pasture group 5; woodland group 5.)

Kemoo silty clay, 20 to 35 percent slopes (KpE). - On this soil, runoff is medium to rapid and the erosion hazard is moderate to severe. Workability is difficult because of the slope. Included in mapping were small, eroded spots and areas of Stony land and of Rock outcrop.

This soil is used for pasture. (Capability classification VIe, nonirrigated; pasture group 5; woodland group 5.)

Kemoo silty clay, 35 to 70 percent slopes (KpF). - This soil occurs on side slopes along drainageways. Runoff is rapid, and the erosion hazard is severe. Included in mapping were small, eroded spots, stony areas and outcrop.

This soil is used for pasture. (Capability classification VIIe, nonirrigated; pasture group 5; woodland group 15.)

Kemoo-Badland complex (KPZ). - Kemoo silty clay makes up 40 to 80 percent of this complex. The slope ranges from 10 to 70 percent. Runoff is medium to rapid and the erosion hazard is moderate to severe. Badland consists of nearly barren areas that have remained after removal of the Kemoo soil by erosion. On this soil, runoff is rapid and the erosion hazard is very severe. About 80 percent of Badland is oriented in the direction of the trade winds.

Included in mapping were small areas of Rock outcrop, Stony land, Stony steep land and Rock land.

This complex is used for pasture. (Kemoo part is capability classification VIIe, nonirrigated; pasture group 5; woodland group 5. Badland part is in capability classification VIIIe.)

Paumalu

This series consists of well-drained silty clay soils on uplands in the northern part of Oahu. These soils developed in old alluvium and colluvium derived from basic igneous rock. They are gently sloping to very steep. Elevations range from 700 to 1,000 feet. The annual rainfall amounts to 50 to 70 inches and is well distributed throughout the year. The mean annual soil temperature is 71° F. Paumalu soils are geographically associated with Kemoo soils, near Kahuku.

These soils are used for pasture and sugarcane. The natural vegetation consists of guava, kaiwe, Christmas berry, ricegrass, and carpetgrass.

Paumalu silty clay, 15 to 25 percent slopes (PeD). - This soil occurs as small, irregularly shaped areas. Included in mapping were small, eroded areas.

In a representative profile the surface layer and the subsoil are dark reddish-brown silty clay that has subangular and angular blocky structure. The surface layer is about 9 inches thick, and the subsoil is 30 to more than 60 inches thick. The substratum is highly weathered gravel. The soil is very strongly acid in the surface layer and strongly acid to medium acid in the subsoil.

Permeability is moderately rapid. Runoff is medium, and the erosion hazard is moderate. The available water capacity is about 1.3 inches per foot of soil. In places roots penetrate to a depth of 5 feet or more. Workability is difficult because of the slope.

Representative profile: Island of Oahu, lat. 21°40'18" N. and Long. 158°01'02" W.

This soil is used for pasture and sugarcane. (Capability classification IVe, irrigated or nonirrigated; pasture group 8; woodland group 7.)

Paunalu silty clay, 3 to 8 percent sloped (PeB). - On this soil, runoff is slow and the erosion hazard is slight. Workability is easy.

This soil is used for sugarcane and pasture. (Capability classification IIe, irrigated or nonirrigated; pasture group 8; woodland group 7.)

Paumalu silty clay, 8 to 15 percent slopes (PeC). - On this soil, runoff is slow to medium and the erosion hazard is slight to moderate. Workability is slightly difficult.

This soil is used for sugarcane and pasture. (Capability classification IIIe, irrigated or nonirrigated; pasture group 8: woodland group 7.)

Paumalu silty clay, 25 to 40 percent slopes (PeE). - On this soil, runoff is medium to rapid and the erosion hazard is moderate to severe.

This soil is used for pasture and sugarcane. (Capability classification VIe, irrigated or nonirrigated; pasture group 8; woodland group 7.)

Paumalu silty clay, 40 to 70 percent slopes (PeF). - On this soil, runoff is rapid and the erosion hazard is severe.

This soil is used for pasture. (Capability classification VIIe, nonirrigated; pasture group 8: woodland group 14.)

Paumalu-Badland complex (PZ). - In this complex,Paumalu soils make up to 40 to 80 percent of the acreage. The slope is 10 to 70 percent. The Paumalu soils are similar to Paumalu silty clay, 15 to 25 percent slopes, except for the slope. Runoff is medium to rapid, and the erosion hazard is moderate to severe.

Badland consists of nearly barren land that has remained after the Paumalu soils were removed by wind and water erosion. Runoff is rapid, and the erosion hazard is very severe. About 80 percent of the Badland part occurs in the direction of the trade winds. Rock outcrop, Stony land, Stony steep land, and Rock land were included in mapping, and they make up as much as 25 percent of the area.

This complex is used for pasture and military purposes. (Paumalu part is in capability classification VIIe, nonirrigated; pasture group 8; woodland group 7. Badland part is in capability classification VIIIe, nonirrigated.)

Soil pH Patterns

Topsoil (A1) pH values have been determined for each site, and our findings have been tabulated here.

Mean soil pH for the windsites lies between 5.3 and 5.9. This is deceptive, however. The overall average low and high values for all sites give a range of 4.02 to 7.94. This seems to be exceptionally wide for a relatively limited area. Even the presence of two distinguishable soil series, Kemoo and Paumalu, does not in itself account for the range, nor do the conditions of weathering per se that created the badlands complex.

As the grouped data show, slope angle and compass location ("exposure") of samples do not interact at all.

On the other hand, the soil type (series) and exposure parameters do show signs of interactions. Kemoo and Paumalu soils are in themselves quite similar save for a coarser texture in the "gravelly" Paumalu subseries.

When they are compared at north-facing vs other compass locations, it becomes quite evident that weathering on more exposed north edges and faces of windsite hills causes the two soils to differentiate.

Neither Able nor Baker sites was representative of both soils in adequate numbers, although they are included in our tabulation. Paumalu series soils build up moving east and southward, hence are better represented along access Gate Charlie. As the mean values show, Kemoo on north exposure is more than 1.0 pH unit higher than similarly sited Paumalu. Although some suggestion of this difference may exist for centrally located samples with a Δ pH of ca 0.71, it is not found for more protected sample sites.

Presumably, the other similar Kemoo and Paumalu soils undergo chemical differentiation under the more severe conditions of weathering. This may well have led to leaching or eroding away of buffering or neutralizing constituents.

Within the averages, individual sample locations at some windsites show localized, possibly anomalously high pH values. The (tentative) conclusion that this situation is in fact localized is supported by the absence of any clear-cut east-west trend or north-south (slope angle) relationship.

Further insight may be gained when chemical analyses of the same samples applied to pH measurements, for nitrogen, phosphorus, potassium, iron, zinc and copper.

SOIL ANALYSIS I

Soil pH-Slope Angle-Compass Location Relationships

Compass Location	Slope Angle (n = 14-21) <20%	>20%
North	5.47 ± 0.61	5.51 ± 0.51
Central	5.31 ± 0.89	5.26 ± 0.56
South	5.66 ± 0.70	5.87 ± 0.56
East	5.62 ± 0.53	5.58 ± 0.50
West	5.82 ± 0.35	5.74 ± 0.51

SOIL ANALYSIS II

Soil pH-Soil Series-Compass Location Relationships

Compass Location	Soil Series at Site: Kemoo (K)	Soil Series at Site: Paumalu (P) or K/P Interface
	a. Able Gate Access (n = 1-8)	
North	5.69 ± 0.54	5.65 ± 0.015 (2)
Central	5.08 ± 0.57	6.8 (1)
South	5.61 ± 0.56	6.35 ± 0.05 (2)
East	5.42 ± 0.52	5.85 ± 0.05 (2)
West	5.94 ± 0.18	6.10 ± 0.10
	b. Baker Gate Access (n = 1-7)	
North	5.62 ± 0.45	4.6 ± 0.10 (2)
Central	5.45 ± 0.45	6.5 (1)
South	5.55 ± 0.62	5.95 ± 0.15 (2)
East	5.46 ± 0.57	6.45 ± 0.15 (2)
West	5.73 ± 0.49	5.9 (1)
	c. Charlie Gate Access (n = 7-10)	
North	6.04 ± 0.53	4.84 ± 0.30
Central	5.03 ± 0.57	4.32 ± 0.72
South	6.04 ± 0.78	5.59 ± 0.44
East	5.58 ± 0.89	5.51 ± 0.53
West	5.91 ± 0.68	5.34 ± 0.73

SOIL ANALYSIS IIIa

Windsite Number 1 Soil pH

15 February - 15 April, 1981

Location of Samples (in feet from Center)	Description of Samples	pH Determination		
		a	b	mean
Center	Brown, medium fine	4.85	5.33	5.09
North				
25	Brown, medium fine	6.50	6.37	6.43
50	Brown, medium fine	5.84	6.00	5.92
South				
25	Brown, medium fine	5.95	6.09	6.02
50	Brown, medium fine	5.42	4.88	5.15
East				
25	Brown, medium fine	4.75	5.01	4.88
50	Brown, medium fine	5.80	5.89	5.84
West				
25	Brown, medium fine	5.51	5.43	5.47
50	Brown, medium fine	5.14	5.09	5.11

SOIL ANALYSIS IIIb

Windsite Number 2 Soil pH

15 February - 15 March, 1981

Location of Samples (in feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Light brown, coarse	4.40	4.80	4.60
North				
25	Brown, fine	4.32	5.00	4.66
50	Brown, fine	4.80	5.34	5.07
South				
25	Light brown, coarse	4.61	4.83	4.72
50	Light brown, coarse	4.41	4.79	4.60
East				
25	Brown, coarse	4.23	4.44	4.33
50	Brown, coarse	4.35	4.34	4.35
West				
25	Brown, coarse	6.67	6.60	6.63
50	Brown, coarse	6.55	7.01	6.78

SOIL ANALYSIS IIIc

Windsite Number 3 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, very fine	6.45	6.33	6.39
North				
25	Brown, fine	6.64	5.90	6.27
50	Brown, fine	6.40	6.01	6.20
South				
25	Brown, very fine	7.17	7.10	7.14
50	Brown, very fine	6.96	7.29	7.12
East				
25	Brown, coarse	6.66	5.97	6.32
50	Brown, coarse	6.83	6.58	6.90
West				
25	Brown, very fine	6.76	6.40	6.59
50	Brown, very fine	5.00	5.03	5.02

SOIL ANALYSIS IIId

Windsite Number 4 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Red-brown, coarse	4.24	4.17	4.20
North				
40	Brown, coarse	7.12	7.41	7.27
South				
30	Brown, coarse	7.58	7.29	7.44
East				
20	Red-brown, coarse	5.85	5.61	5.73
West				
25	Brown, coarse	5.45	5.49	5.47
Road	Red-brown, coarse	6.05	6.15	6.10

SOIL ANALYSIS IIIe

Windsite Number 5 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Red-brown, coarse	5.26	5.42	5.34
North				
50	Brown, coarse	7.14	6.83	6.94
South				
25	Brown, medium fine	6.50	6.41	6.45
50	Red-brown, coarse	5.84	5.68	5.76
East				
25	Dark brown, coarse	6.40	6.57	6.48
West				
25	Brown, medium fine	6.17	6.17	6.17
Road	Brown, coarse	7.93	7.94	7.93

SOIL ANALYSIS IIIf

Windsite Number 6 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Red-brown, coarse	4.31	4.30	4.31
North				
25	Brown, very fine	4.86	4.90	4.88
50	Brown, very fine (replanted)	5.10	5.00	5.05
South				
25	Brown, very fine	5.73	5.56	5.64
50	Brown, very fine	5.80	5.64	5.72
East				
25	Brown, coarse	4.91	5.37	5.14
50	Brown, coarse	5.10	4.95	5.03
West				
25	Brown, very fine	4.60	4.93	4.76
50	Brown, very fine	4.98	5.01	5.00
North Replant	Light brown, coarse	4.04	4.02	4.03
Road	Brown, coarse	5.72	5.88	5.80

SOIL ANALYSIS IIIg

Windsite Number 7 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, very fine	4.20	4.24	4.22
North				
25	Brown, very fine	4.88	5.09	4.99
50	Brown, very fine	4.89	5.22	5.05
South				
25	Brown, fine	5.40	5.13	5.27
50	Brown, fine	5.96	6.20	6.08
East				
25	Brown, fine	6.00	6.31	6.15
50	Brown, fine	6.20	6.01	6.11
West				
25	Brown, very fine	4.90	5.00	4.98
50	Brown, very fine	6.41	6.23	6.31

SOIL ANALYSIS IIIh

Windsite Number 8 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination a	b	ave.
Center	Dark brown, very fine	4.84	5.22	5.03
North				
25 (edge)	Brown, fine	5.68	5.43	5.55
South				
25 (edge)	Brown, fine	5.91	6.29	6.10
East				
25	Brown, fine	6.26	6.01	6.13
50	Brown, fine	6.21	5.73	5.97
West				
50	Brown, very fine	4.31	4.63	4.47
100	Brown, very fine	4.50	4.59	4.55

SOIL ANALYSIS IIIi

Windsite Number 9 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Dark brown, coarse	4.79	4.69	4.74
North				
25	Dark brown, coarse	4.42	4.49	4.46
South				
25	Dark brown, coarse	4.68	4.61	4.65
50	Dark brown, coarse	4.49	4.53	4.51
East				
25	Dark brown, coarse	4.34	4.32	4.33
50	Dark brown, coarse	4.67	4.58	4.62
West				
25	Dark brown, coarse	6.02	5.97	5.99
50	Dark brown, coarse	6.29	6.37	6.33

SOIL ANALYSIS IIIj

Windsite Number 10 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Dark brown, coarse	6.40	6.22	6.31
North				
25	Dark brown, coarse	6.06	5.93	6.00
50	Dark brown, coarse	5.86	5.84	5.85
South				
25	Dark brown, coarse	6.08	5.98	6.03
East				
25	Dark brown, coarse	5.76	6.03	5.90
50	Dark brown, coarse	6.02	6.09	6.06
West				
25	Dark brown, coarse	6.27	6.21	6.24
50	Dark brown, coarse	5.82	5.71	5.76

SOIL ANALYSIS IIIk

Windsite Number 11 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Red, coarse	5.38	5.19	5.28
North				
25	Light brown, fine	5.37	5.42	5.39
South				
50	Red, coarse	5.56	5.59	5.57
East				
25	Red, coarse	5.90	5.21	5.56
West				
50	Red, coarse	5.15	5.09	5.12

SOIL ANALYSIS III1

Windsite Number 12 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Dark brown, fine	5.42	5.51	5.46
North				
25	Dark brown, fine	5.89	6.03	5.96
50	Dark brown, fine	6.00	5.87	5.93
South				
25	Dark brown, fine	5.94	6.16	6.05
50	Dark brown, fine	6.47	6.31	6.39
East				
25	Dark brown, fine	6.04	6.04	6.04
50	Dark brown, fine	5.79	5.77	5.78
West				
25	Dark brown, fine	5.90	6.19	6.05
50	Dark brown, fine	6.03	5.99	6.01

SOIL ANALYSIS IIIm

Windsite Number 13 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, coarse	6.71	6.24	6.48
North				
25	Brown, coarse	4.73	4.30	4.50
50	Brown, coarse	4.74	4.70	4.72
South				
25	Brown, coarse	5.53	6.00	5.76
50	Brown, coarse	6.20	5.97	6.09
East				
25	Brown, coarse	6.55	6.55	6.55
50	Brown, coarse	6.14	6.42	6.28
West				
25	Brown, coarse	6.03	5.79	5.91

SOIL ANALYSIS IIIn

Windsite Number 14 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Red-brown, fine	6.53	6.33	6.43
North				
30	Red, very fine	4.53	4.53	4.53
South				
30	Red-brown, coarse	6.10	5.86	5.98
East				
30	Red, coarse	4.74	4.72	4.71
50	Brown, coarse	5.33	5.07	5.20
West				
30	Brown, coarse	6.05	6.16	6.11
50	Brown, coarse	6.59	6.36	6.48

SOIL ANALYSIS IIIo

Windsite Number 15 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Dark brown, coarse	4.75	4.73	4.74
North				
25	Dark brown, coarse	4.93	5.00	4.97
50	Dark brown, coarse	5.48	5.47	5.47
South				
25	Dark brown, coarse	4.44	4.59	4.51
50	Dark brown, coarse	5.01	4.79	4.90
East				
25	Dark brown, coarse	4.34	4.68	4.51
West				
25	Dark brown, coarse	5.89	5.81	5.85

SOIL ANALYSIS IIIp

Windsite Number 16 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, coarse	4.36	4.32	4.34
North				
25	Brown, coarse	6.03	5.71	5.82
50	Brown, coarse	6.24	6.03	6.13
South				
25	Brown, coarse	6.92	6.84	6.88
50	Brown, coarse	6.47	6.31	6.39
East				
25	Brown, coarse	5.59	5.46	5.52
50	Brown, coarse	5.93	5.79	5.86
West				
25	Brown, coarse	5.50	5.39	5.44
50	Brown, coarse	5.97	5.58	5.78

SOIL ANALYSIS IIIq

Windsite Number 17 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination a	b	ave.
Center	Brown, coarse	5.46	5.39	5.43
North				
25	Brown, coarse	6.39	6.49	6.44
50	Brown, coarse	6.73	6.52	6.63
South				
25	Brown, rocky	5.69	5.61	5.65
50	Brown, rocky	5.11	5.29	5.20
East				
25	Brown, coarse	6.06	6.31	6.19
West				
25	Brown, coarse	6.00	5.93	5.97

SOIL ANALYSIS IIIr

Windsite Number 18 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, coarse	5.88	6.02	5.95
North				
25	Brown, coarse	5.16	4.87	5.02
50	Brown, coarse	5.27	5.01	5.14
South				
25	Brown, coarse	5.73	5.86	5.79
50	Brown, coarse	5.61	5.60	5.60
East				
25	Brown, coarse	4.62	4.97	4.77
50	Brown, coarse	5.37	5.77	5.57
West				
25	Brown, coarse	6.63	6.54	6.59

SOIL ANALYSIS IIIs

Windsite Number 19 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, coarse	6.80	6.77	6.78
North				
25	Brown, coarse	5.73	5.37	5.54
50	Brown, coarse	5.74	5.76	5.75
South				
25	Brown, coarse	6.66	6.09	6.37
50	Brown, coarse	6.26	6.52	6.39
East				
25	Brown, coarse	5.97	5.66	5.81
50	Brown, coarse	6.00	5.88	5.94
West				
25	Brown, coarse	6.39	5.97	6.18
50	Brown, coarse	6.00	5.92	5.96

SOIL ANALYSIS IIIt

Windsite Number 20 Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination		
		a	b	ave.
Center	Brown, coarse	4.38	4.73	4.55
North				
30	Brown, coarse	5.60	5.07	5.63
South				
30	Brown, coarse	6.08	6.06	6.07
East				
30	Brown, coarse	6.40	6.51	6.45
West				
30	Brown, coarse	4.98	4.88	4.93
Road	Brown, coarse	7.25	7.34	7.29

SOIL ANALYSIS IIIu

Windsite Number 20a Soil pH

February - March 1981

Location of Samples (In feet from Center)	Description of Samples	pH Determination a	b	ave.
Center	Yellow-brown, coarse	4.55	4.61	4.58
North				
30	Brown, coarse	4.30	4.56	4.43
South				
30	Brown, coarse	4.73	4.82	4.77
East				
30	Brown, coarse	4.58	4.40	4.49
West				
30	Brown, coarse	4.41	4.58	4.49
Road	Brown, coarse	7.25	7.34	7.29
Roadside Talus	Dark brown, coarse, heterogeneous	4.49	4.52	4.51

SOIL ANALYSIS IIIv

Hill 809 and DOE/NASA Windmill

January 1981

Location of Samples	Description of Samples	pH Determination a	b	ave.
H809				
Summit				
North side	Brown, fine	6.32	6.40	6.36
South side	Brown, fine	5.60	5.91	5.76
East side	Brown, coarse	5.12	5.21	6.16
West side	Brown, coarse	5.59	5.22	5.40
Approach Road	Light brown, fine	4.91	5.14	5.03
DOE/NASA Windmill				
North side	Brown, coarse	6.16	6.39	6.28
South side	Red brown, fine	6.07	6.66	6.36
East side	Brown, fine	6.01	5.87	6.04
West side	Light brown, fine	6.60	6.44	6.52

Toxic Metals: Soil Mercury and Arsenic

Mercury. On the Kilauea plateau, Island of Hawaii, along the East rift, sites such as the Puhimau "hot spot" may contain as much as 56,000 ppb of soil Hg. Even in the Kapoho area, some 20 miles to the East along the rift (the area of geothermal exploration in Puna) soil values of 100-500 ppb are common.

On much older Oahu, soil Hg values rarely equal the USGS mean crustal abundance figure of 50 ppb. Exceptions are some south-west sediments which may contain 150-200 ppb.

Along the extremely weathered north shore of Oahu, especially in the dissected badlands and near-badlands Kahuku area, the soil Hg level at the windsite locations sampled did not exceed 16 ppb.

The range noted, 3-16 ppb, appears to be correlated inversely with soil acidity:

pH	Mean Hg
4 - 5	5.4
5 - 6	6.9
6 - 7	10.4
7 - 8	14.0

The most probable basis for this relationship is leaching of acid-soluble forms of mercury.

Arsenic. Unlike the effluents of Rotorua Wairiki (New Zealand), Larderelle (Italy), and other hydrogeothermal systems, Hawaiian midplate vulcanism is not associated with high yields of arsenic.

Some soils in the Puna area of the Island of Hawaii near the East rift contain up to 1 - 2 ppm of arsenic as As(V).

Like mercury, arsenic occurs in Kahuku soils at extremely low levels, meeting our detection limit of 0.05 ppm in only 10 cases of 63.

Again, a correlation seems to exist between soil pH and arsenic content:

pH	As Detected	Samples
4 - 5	0	16
5 - 6	1	27
6 - 7	6	17
7 - 8	3	3

SOIL ANALYSIS IV

Mercury (Hg) and Arsenic (As) In Selected
Windsite Samples

Gate Access	Site	North	Sample Center	South
Able	15 pH	5.47	4.74	4.90
	Hg*	8	7	5
	As	ND	ND	ND
	16 pH	6.13	4.34	6.39
	Hg	9	5	10
	As	ND	ND	+
	17 pH	6.63	5.43	5.20
	Hg	10	7	6
	As	+	ND	ND
	18 pH	5.14	5.95	5.60
	Hg	6	8	7
	As	ND	+	ND
	19 pH	5.75	6.78	6.39
	Hg	8	12	10
	As	ND	+	ND
Baker	9 pH	4.46	4.74	4.51
	Hg	6	7	6
	As	ND	ND	ND
	10 pH	5.85	6.31	6.03
	Hg	8	11	10
	As	ND	+	+
	11 pH	5.39	5.28	5.57
	Hg	8	8	9
	As	ND	ND	ND
	12 pH	5.93	5.46	6.39
	Hg	8	6	12
	As	ND	ND	+
	13 pH	4.72	6.48	6.09
	Hg	7	12	11
	As	ND	+	+
Charlie	1 pH	5.92	5.09	5.15
	Hg	9	6	7
	As	ND	ND	ND

*Hg in parts per billion (ppb) or ug/kg
As + $\geq$ 0.05 ppm; ND <0.05 ppm

Mercury (Hg) and Arsenic (As) In Selected
Windsite Samples (Cont'd)

Gate Access	Site	Sample North	Sample Center	Sample South
Charlie (cont'd)	2 pH	5.07	4.60	4.60
	Hg	7	5	6
	As	ND	ND	ND
	3 pH	6.20	6.39	7.12
	Hg	9	10	13
	As	ND	+	+
	4 pH	7.27	4.20	7.44
	Hg	16	4	13
	As	+	ND	+
	5 pH	6.94	5.34	5.76
	Hg	13	7	8
	As	+	ND	ND
	6 pH	5.05	4.31	5.72
	Hg	6	4	7
	As	ND	ND	ND
	7 pH	5.05	4.22	6.08
	Hg	6	3	10
	As	ND	ND	ND
	8 pH	5.55	5.08	6.10
	Hg	7	6	11
	As	ND	ND	ND
	14 pH	4.53	6.43	5.98
	Hg	5	9	8
	As	ND	ND	ND
	20 pH	5.03	4.55	6.07
	Hg	5	6	8
	As	ND	ND	ND
	20a pH	4.43	4.58	4.77
	Hg	5	6	6
	As	ND	ND	ND

Toxic Metals: Soil Copper, Lead and Zinc

Copper is required in trace amounts by virtually all organisms. Like other metals that serve as co-factors in a catalytic capacity, its concentration in living organisms is carefully regulated because excesses are highly toxic. Using the copper content of standard clay loam potting soil as a reference point, 4.12 ppm, our data show virtually every test site to be seriously in excess (pp. 140-44). Only 6 of nearly 70 locations sampled fell within or near a two-fold excess of the standard. We would generally conclude that all other locations contain toxic levels in their A1 soil horizon. This does not preclude the presence of resistant forms of plant and microbial life, but the majority of desirable endemics would not thrive here.

Regression analysis shows no significant relationship between copper content and soil pH:

$$\text{Cu, in ppm} = 28.6 - 1.10 \text{ pH}$$

but $r = -0.06$ r = correlation coefficient

and for $N = 69$, the probability (p) that the relationship is significant is less than 80%.

Like copper, zinc is recognized as an essential trace metal with wide and diverse functions in the living cell. It, too, can be harmful to life if present in excess, although it is better tolerated by most organisms under such circumstances than is copper. Our reference standard soil zinc content of 8.62 ppm is exceeded at 40 sites in the survey area, but in a number of cases, namely 13, there is a possible deficiency condition.

Acute deficiency is not indicated. Unlike copper a pronounced correlation does exist between zinc content of the top soil and its pH. Upon regression analysis we found

$$Zn, \text{ in ppm} = 35.9 - 3.39 \text{ pH}.$$

In this case r (correlation coefficient) = - 0.24 (N = 69) and the probability (p) is in excess of 90%. As was the case both for mercury and arsenic, the metal content is pH sensitive but the relationship is inverse. The problem of pollution in the windsite areas from military activities, namely spent cartridges, has been referred to elsewhere in this report. Our concern that the high cover density in some areas of these metals might in concert with exposure to relatively high concentrations of salt lead to rapid corrosion and entry into the soil has been realized. If these casings are indeed copper alloy (brass) then a relationship between soil copper and zinc concentrations might be anticipated, as the cartridges would constitute a single source. Regression analysis confirms this supposition:

$$Zn, \text{ in ppm} = 1.69 + 0.70 \text{ Cu, in ppm}.$$

For the sample population (N = 69) an r value of 0.528 establishes the probability in excess of 99.9%. It is thus clear that a substantial history of detritus accumulation from small arms use has contributed to an exceptionally severe pollution problem.

That the above relationship between copper and zinc is not a fortuitous one is shown by several items of evidence:

1. copper and zinc are correlated even though each one behaves independently in respect to pH;

2. copper and zinc are correlated but inversely related to mercury and arsenic;

3. copper and lead, another pollutant in the area, are not significantly correlated. Regression analysis yields r = -0.02, which even with our substantial population falls below the 80% level.

In itself, lead constitutes a problem of concern. Our standard soil contains less than 4 parts per million (ppm), and most sites also fall into this safe category. However, some sites have unquestionable high and dangerous levels of lead, namely windsites#3, 4, 6, 9, 16, 17 and 18 and all locations sampled at each site. In addition parts of windsites #11, 13, 20, 20A also contain harmful excesses. Unlike copper and zinc, lead has no known supportive biological function, but on the contrary, interfers selectively with the formation of chlorophyll in plants and hemoglobin in animals.

The relationship between lead content of the soil and pH was found to be

$$\text{Pb, in ppm} = 13.82 - 1.07 \text{ pH},$$

but an r = - 0.12 fails to reach the 80% confidence level; hence the relationship has no significance. We assume that the most probable source of this lead is automotive.

Nutrients

Our soil reference standard contains:

1912 ppm	total iron
300 ppm	potassium
60.5 ppm	nitrate representing the total nitrogen of the sample.

Iron is an essential metal for practically all life. However it is normally required at higher concentrations than the so-called "trace" elements, such as those already discussed. Most of the iron, in the soils sampled at Kahuku as in our standard, is not in direct or soluble form. Indeed it is not clear from the analytic results in the field, a content of 0.6 to 1%, as to the available iron content of the soil. Regression analysis suggests an inverse relation between iron content and pH; however, the r value determined at -0.045 is completely non-significant. This suggests that most of the iron analyzed was present as the oxide or in the silicate matrix of igneous fines and residues. The high concentrations noted in field samples are a result of differential leaching of other minerals and the generally low humic, or organic carbon, content of these soil types.

It is a common experience in the iron rich clayey, heavily leached reddish and reddish brown Hawaiian soils, that in addition to having little soluble iron they prove to be deficient in phosphorus. This is a reflection primarily of phosphate availability rather than absence because the element in its usual forms is tightly bound to the iron.

From the standpoint of soil fertility, the problems of most concern relate to potassium and nitrogen as well as phosphorus. It is immediately evident on inspection of our analytic data that moderate to acute potassium deficiency is probable in virtually every sample. Many sites contain less than one-fifth of the standard concentration. Furthermore potassium content is pH sensitive; thus our regression analysis yields

K in ppm = 3.70 + 6.57 pH.

For the sample population of N= 69, a value of r = 0.187 establishes a better than 80% probability for signficant relationship. It should be pointed out that potassium has probably been leached by precipitation from these soils, the rain fall characteristic of such exposed locations is likely to be relatively rich in sea salt condensation nuclei. Thus, this soil would be expected to be as sodium enriched as it is potassium depleted. This is not a desirable soil condition for the vegetation types that would be best suited to surface improvement and site stabilization.

The soil nitrogen supply at the windsites is generally inadequate although not quite to the degree or severity found for potassium. Among the windsites, nitrogen can only be judged adequate at Windsites #1, 8, and 18. At sites #2, 3 and 15 it is perhaps marginal, but the remaining thirteen are clearly and markedly deficient. No correlation between nitrogen content and soil pH was observed.

SOIL ANALYSIS V

ELEMENTAL ANALYSIS OF SOIL FROM WINDSITES

(PPM)

Site	Cu	Fe	K	Pb	Zn	nitrate
1-0	41.62	6575	15.3	<4	27.62	28.0
1-N	25.88	7188	128.8	<4	10.37	70.5
1-S	25.50	9325	62.4	<4	79.62	47.0
2-0	17.75	10325	20.0	<4	12.25	41.5
2-N	15.62	8238	20.0	8.87	14.75	24.5
2-S	11.25	7762	13.3	<4	5.88	34.0
3-0	44.88	3075	37.3	13.40	41.62	23.5
3-N	29.25	3288	55.7	7.92	7.75	34.0
3-S	30.50	6638	18.0	8.16	9.12	22.0
4-0	17.75	8688	11.0	<4	5.62	20.
4-N	31.75	8775	62.3	<4	19.25	20
4-S	26.88	6412	51.1	8.70	16.12	25.5
4-road	6.12	3950	2.7	<4	2.09	20

Site	Cu	Fe	K	Pb	Zn	nitrate
5-0	6.5	3788	9.2	4	5.7	22.0
5-N	11.62	3150	71.0	4	17.88	25.5
5-S	13.75	3938	23.0	4	2.12	20
5-road	15.00	4625	58.0	10.52	45.25	23.7
6-0	14.88	1588	44.5	12.34	0.88	21.0
6-N	27.75	2850	65.4	51.72	37.12	24.5
6-S	10.12	1338	12.3	4	2.62	22.5
6-road	10.12	3938	115.0	8.02	22.25	20
6-replanted	9.25	1700	10.2	12.12	1.00	20
6-grey dust			30.2	4		46.0
6-A			23.0	4		29.0
7-N	12.25	2888	18.0	4	2.09	31.0
7-S	8.75	3925	18.0	4	7.80	24.5
8-O	7.0	4138	2.0	4	11.00	20
8-N	9.38	6112	7.2	4	19.00	60
8-S	17.00	4538	72.6	4	15.75	97.5

Site	Cu	Fe	K	Pb	Zn	nitrate
9-0	56.5	4525	91.0	14.85	38.75	20
9-N	23.50	5225	48.6	4	63.38	20
9-S	36.62	2400	72.6	11.89	57.38	20
10-0	13.62	8812	72.6	4	11.38	39.0
10-N	17.38	10150	72.6	4	9.75	20
10-S	8.50	6325	32.7	4	3.75	20
11-N	19.00	13025	26.1	10.29	12.62	39.0
11-S	45.88	15962	25.6	4	13.50	22.5
12-0	11.38	4725	15.8	4	3.50	21.0
12-N	12.25	7725	15.8	4	3.38	20
12-S	21.38	5000	55.7	4	9.62	20
13-0	19.75	3075	61.3	7.34	20.38	48
13-N	24.38	6612	97.6	4	11.12	23.5
13-S	10.25	6788	12.3	4	2.25	22.5
14-0	20.50	8488	51.1	4	32.88	21.0
14-N	16.25	4250	30.2	4	4.25	21.0
14-S	23.12	8462	30.2	4	9.50	34.0

Site	Cu	Fe	K	Pb	Zn	nitrate
15-0	20.62	10650	58.3	4	15.75	59.0
15-N	9.38	8138	45.5	4	8.12	20
15-S	25.38	8012	51.1	4	16.12	33.5
16-0	26.00	5362	23.0	11.21	20.30	58.0
16-N	21.12	2225	96.6	8.47	19.75	66.0
16-S	19.75	2588	72.6	7.79	16.50	22.5
17-0	30.25	6350	37.3	21.68	50.38	23.5
17-N	40.00	8475	93.5	13.71	50.88	30.5
17-S	22.25	10725	23.0	4	20.75	20
18-0	55.12	9600	44.5	31.01	38.12	47.0
18-N	44.50	7412	26.6	25.77	33.00	53.0
18-S	22.75	3138	72.6	21.22	15.12	58.0
19-0	11.88	2912	30.2	4	4.25	21.0
19-N	22.00	14325	23.0	4	8.50	24.5
19-S	22.0	4575	28.6	4	4.75	22.5

Site	Cu	Fe	K	Pb	Zn	nitrate
20-0	37.50	5475	5.0	4	11.30	20
20-N	29.75	4838	31.1	14.82	32.88	22.0
20-S	34.62	6325	22.0	6.01	13.75	21.0
20A-0	49.62	8800	18.0	6.01	10.50	20
20A-N	19.50	5588	9.2	4	6.50	20
20A-S	50.38	8238	44.5	16.02	35.62	20
hill 809-0	10.25	2688	23.0	4	2.62	20
hill 809-N	11.88	2850	12.3	4	2.00	22.0
hill 809-S	18.38	2650	17.4	4	2.50	28.0
DOE/NASA windsite	14.25	8638	119.1	4	8.12	78.0
STANDARD SOIL	4.12	1912	300.0	4	8.62	60.5

Botanical Survey

VEGETATION

The site examined ranged from 27 to 38 in species count including 3-9 noxious weeds but only 3-5 endemics. Overall, 12% of species were endemics whereas 21% were identified as undesirable weeds. Admittedly the dividing line between troublesome weeds and foreign introductions (exotics) of no particular value is somewhat vague; hence the only plants of any significance in terms of site management are the Santalum noted above and the small group of endemics. The latter 12%, although "expendable" appear to be ecologically stable. In the event of their demise, the prospects for improvement of the area would diminish.

The low frequency of endemic species is underscored when site-to-site comparisons are made because species diversity is quite low, including only 9 endemics in hilltop, i.e., upland locations. These species also fall into 9 different genera and families of Angiosperms:

Family	Genus	Name	Habit	Site Presence
Cyperaceae	Carex	---	Herb	4, 20a
Epacridaceae	Styphelia	Pukiawe	Shrub	3,4,7,8,14,20
Goodeniaceae	Scaevola	Naupaka	Shrub	20, 20a
Liliaceae	Pleomele	Hala-pepe	Tree	20a
Menispermaceae	Cocculus	Huehue	Vine	1,2,4,5,20
Myrtaceae	Metrosideros	Ohia lehua	Tree	14
Rosaceae	Osteomeles	'Ulei	Shrub	1-20
Rubiaceae	Canthium	Alahe'e	Herb	20a
Thymelaeaceae	Wikstroemia	'Akia	Shrub	1-20a

Among the exotics and indigenes are common species of legumes -- Acacia, Cassia, Crotalaria, Desmodium, Mimosa; grasses --Chrysopogon, Digitaria, Paspalum, Setaria, Sporobolus; and less frequent composites -- Bidens, Emilia, Pluchea, Wedelia. Occasional escapees from cultivation in this group include sugarcane, pine, hibiscus, ti and mango.

Guava, lantana, prickly pear cactus, many grasses, Leucaena and Christmas berry are among the more persistent weeds, undesirable because they contain harmful or toxic factors or aggressively crowd out desirable species.

Windsite Number 1

This site is a very exposed, moderately eroded ridgetop. The pad site itself hosts exotic grasses and herbs with scattered individuals of the native shrub Osteomeles. Casuarina equisetifolia trees from 4- to 13-meters in height are scattered in the southern part of the site. Leucaena leucocephala, Schinus terebinthifolius and remnant sugarcane form a dense shrub layer on leeward slopes. These same exotics are more scattered on the windward slopes, with large patches of the native Osteomeles and Wikstroemia shrubs to windward as well. Old sugarcane fields lie to the north and east of this site.

Windsite Number 2

Most of the site lies within fifteen vertical feet of the ridgetop. This area is heavily eroded, dominated by Casuarina equisetifolia in the tree layer and bare ground below with scattered clumps of Paspalum orbiculare, Setaria verticulata and Waltheria americana. The leeward slope is covered entirely by Casuarina and Passiflora suberosa, with few other species and little or no understory. The windward slope below and north of the pad site hosts considerable patches of the native shrubs Osteomeles and Wikstroemia with a number of exotic shrubs, herbs and grasses mixed in.

Windsite Number 3

The central part of site 3 is covered in the exotic grasses _Setaria geniculata_ and an unidentified grass planted by the military, with exotic herbs, vines and a few _Osteomeles anthyllidifolia_ individuals scattered throughout. Surrounding this is a shrubland composed largely of _Leucaena leucocephala_ and _Schinus terebinthifolius_, with _Psidium guajava_ and _Passiflora suberosa_ also common. There is no tree layer. The southeastern quarter of the site hosts a sizeable, healthy population of _Santalum ellipticum_, the only individuals of this native species encountered in our fairly extensive fieldwork in the area. Much of the population lies outside the flagged site boundaries but precautions should be taken to protect the entire population.

Windsite Number 4

Site 4 lies on an open grassy ridgetop dominated by the exotic grasses _Andropogon virginicus_ and the unidentified grass planted by the Army. The ridge hosts very widely scattered _Casuarina equisetifolia_ trees. The leeward (west-facing) slope is covered with a dense exotic shrub layer of _Leucaena leucocephala_ and _Schinus terebinthifolius_. The windward (east-facing) slopes host grassland with large patches of the native shrub _Osteomeles anthyllidifolia_ and _Wikstroemia sp_.

Windsite Number 5

Exotic grasses and herbs form a nearly complete mat on the ridgetop portion of this site. The surrounding slopes host a _Schinus/Leucaena_ scrub with a few scattered individuals of the native shrubs _Wikstroemia_ and _Osteomeles_. There is no tree layer except for a small plantation of exotic _Pinus tabulaeformis_ on the west-facing slope.

Windsite Number 6

Site 6 is extremely eroded, with the majority of the site either barren or in the unidentified grass planted by the Army. There is no tree layer except for a clump of several species to the northwest around what may have been an old habitation. Schinus/Leucaena scrubs surround the site on gradual sites.

Windsite Number 7

The south end of this site is very much like site 8, with a scattered tree layer of 5- to 13-meter Casuarina equisetifolia and shrub and herb layers composed mostly of exotic species. While the ridgetop upon which site 7 centers is heavily eroded, the north and east adjacent slopes are covered with a dense mat of the natives Osteomeles anthyllidifolia and Wikstroemia sp. to 1 meter. The north end of the site is very open and 30-40% of the site is barren, reddish subsoil.

Windsite Number 1 Species List

February-March 1981

a. Endemic

Cocculus fernandianus
Osteomeles anthyllidifolia
Wikstroemia sp.

b. Exotics and Indigenous

Acacia farnesiana
Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Chrysopogon aciculatus
Desmodium triflorum
Emilia sonchifolia
Heteropogon contortus
Morinda citrifolia
Passiflora foetida
Passiflora suberosa
Paspalum orbiculare
Phyllanthus debilis
Rhynchelytrum repens
Saccharum officinarum
Setaria geniculata
Sporobolus poiretii
Stachytarpheta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Brachiaria mutica
Lantana camara
Leucaena leucocephala
Melinis minutiflora
Opuntia megacantha
Panicum maximum
Psidium guajava
Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 2 Species List

February-March 1981

a. Endemic

Cocculus fernandianus
Osteomeles anthyllidifolia
Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Chrysopogon aciculatus
Desmodium triflorum
Emilia sonchifolia
Erigeron canadensis
Heteropogon contortus
Nephrolepis hirsutula
Paspalum orbiculare
Passiflora edulis
Passiflora foetida
Passiflora suberosa
Phyllanthus debilis
Rhynchelytrum repens
Setaria geniculata
Setaria verticillata
Sporobolus africanus
Stachytarpheta jamaicensis
Vernonia cinerea
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Clidemia hirta
Lantana camara
Leucaena leucocephala
Melinis minutiflora
Panicum maximum
Psidium guajava
Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 3 Species List

February-March 1981

---

a. Endemic

Osteomeles anthyllidifolia

Santalum ellipticum

Styphelia tameiameiae

Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor

Cassia leschenaultiana

Casuarina equisitifolia

Chrysopogon aciculatus

Desmodium triflorum

Grevillia robusta

Microsorium scolopendria

Nephrolepis hirsutula

Passiflora foetida

Passiflora suberosa

Plantago lanceolata

Rhynchelytrum repens

Setaria geniculata

Spathoglottis plicata

Sphenomeris chinensis

Stachytarpheta jamaicensis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

Lantana camara

Leucaena leucocephala

Melinis minutiflora

Psidium guajava

Schinus terebenthifolius

d. Rare, Threatened and Endangered

Santalum ellipticum

Windsite Number 4 Species List

February-March 1981

a. Endemic

Carex wahuensis
Cocculus fernandianus
Osteomeles anthyllidifolia
Styphelia tameiameiae
Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor
Cassia leschenaultiana
Chrysopogon aciculatus
Crotolaria mucronata
Desmodium sp.
Desmodium triflorum
Digitaria adscendens
Emilia sonchifolia
Erigeron canadensis
Microsorium scolopendria
Paspalum orbiculare
Passiflora suberosa
Plantago lanceolata
Rhyncheletrum repens
Setaria geniculata
Setaria verticillata
Spathoglottis plicata
Sphenomeris chinensis
Stachytarpheta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Leucaena leucocephala
Psidium guajava
Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 5 Species List

February-March 1981

a. Endemic

Cocculus fernandianus

Osteomeles anthyllidifolia

Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor

Cassia leschenaultiana

Chrysopogon aciculatus

Cordyline terminalis

Crotolaria incana

Desmodium sp.

Desmodium triflorum

Emilia sonchifolia

Erigeron canadensis

Microsorium scolopendria

Mimosa pudica

Nephrolepis hirsutula

Paspalum orbiculare

Passiflora foetida

Passiflora suberosa

Phyllanthus niruri

Pinus tabulaeformis

Plantago lanceolata

Rhyncheletrum repens

Setaria geniculata

Setaria verticillata

Spathoglottis plicata

Sporobolus poiretii

Stachytarpheta jamaicensis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

Lantana camara

Leucaena leucocephala

Melinis minutiflora

Psidium guajava

Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 6 Species List

February-March 1981

a. Endemic

Osteomeles anthyllidifolia

Wikstroemia sp.

b. Exotics and Indigenous

Agave sisalana

Bidens pilosa var. minor

Cassia leschenaultiana

Casuarina equisetifolia

Catimbium speciosa

Chrysopogon aciculatus

Desmodium triflorum

Emilia sonchifolia

Ficus sp.

Hibiscus rosa-sinensis

Hibiscus tiliaceus

Nephrolepis hirsutula

Passiflora suberosa

Pennisetum setosum

Persea americana

Spathoglottis plicata

Sphenomeris chinensis

Stachytarpheta jamaicensis

Waltheria americana

c. Noxious Weeds

Clidemia hirta

Lantana camara

Leucaena leucocephala

Melinis minutiflora

Psidium guajava

Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 7 Species List

February-March 1981

a. Endemic

Osteomeles anthyllidifolia

Styphelia tameiameiae

Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor

Cassia leschenaultiana

Casuarina equisetifolia

Centella asiatica

Chrysopogon aciculatus

Cordyline terminalis

Desmodium triflorum

Emilia sonchifolia

Erigeron canadensis

Microsorium scolopendria

Mimosa pudica

Nephrolepis hirsutula

Passiflora foetida

Passiflora suberosa

Phyllanthus niruri

Pittyrogramma calomelanos

Setaria geniculata

Spathoglottis plicata

Sphenomeris chinensis

Stachytarpheta jamaicensis

Trichachne insularis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

Brachiaria mutica

Lantana camara

Leucaena leucocephala

Melinus minutiflora

Pluchia odorata

Psidium guajava

Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 8 Species List

February-March 1981

---

a. Endemic

Osteomeles anthyllidifolia

Styphelia tameiameiae

Wikstroemia sp.

b. Exotics and Indigenous

Albizia falcataria

Bidens pilosa var. minor

Cassia leschenaultiana

Casuarina equisetifolia

Centella asiatica

Chrysopogon aciculatus

Cordyline terminalis

Crotolaria mucronata

Desmodium sp.

Desmodium triflorum

Erigeron canadensis

Eucalyptus sp.

Microsorium scolopendria

Mimosa pudica

Nephrolepis hirsutula

Oxalis sp.

Passiflora foetida

Passiflora suberosa

Phyllanthus niruri

Pittyrogramma calomelanos

Pluchia odorata

Setaria geniculata

Spathoglottis plicata

Sphenomeris chinensis

Stachytarpheta jamaicensis

Trichachne insularis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

Brachiaria mutica

Lantana camara

Leucaena leucocephala

Melinus minutiflora

Panicum maximum

Psidium guajava

Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 9 Species List

February-March 1981

a. Endemic

Osteomeles anthyllidifolia

Styphelia tameiameiae

Wikstroemia sp.

b. Exotics and Indigenous

Andropogon pertusus

Bidens pilosa var. minor

Casuarina equisetifolia

Chrysopogon aciculatus

Desmodium triflorum

Leucaena leucocephala

Paspalum orbiculare

Passiflora suberosa

Pennisetum setosum

Phyllanthus niruri

Psidium guajava

Psilotum nudum

Schinus terebinthifolius

Setaria geniculata

Spathoglottis plicata

Stachytarpheta jamaicensis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

Lantana camara

d. Rare, Threatened and Endangered

none

Windsite Number 10 Species List

February-March 1981

---

a. Endemic

Osteomeles anthyllidifolia

Wikstroemia sp.

b. Exotics and Indigenous

Acacia farnesiana

Andropogon pertusus

Bidens pilosa var. minor

Cassia leschenaultiana

Chrysopogon aciculatus

Desmodium triflorum

Digitaria sanguinalis

Eucalyptus sp.

Leucaena leucocephala

Microsorium scolopendria

Passiflora suberosa

Psidium guajava

Schinus terebinthifolius

Spathoglottis plicata

Sphenomeris chinensis

Waltheria americana

c. Noxious Weeds

none

d. Rare, Threatened and Endangered

none

Windsite Number 11 Species List

February-March 1981

a. Endemic

Osteomeles anthyllidifolia
Styphelia tameiameiae
Wikstroemia sp.

b. Exotics and Indigenous

Acacia farnesiana
Andropogon pertusus
Bidens pilosa var. minor
Casuarina equisethifolia
Chrysopogon aciculatus
Desmodium triflorum
Digitaria sanguinalis
Eucalyptus sp.
Leucaena leucocephala
Nephrolepis exaltata
Paspalum orbiculare
Passiflora suberosa
Plantago lanceolata
Psidium guajava
Schinus terebinthifolius
Setaria geniculata
Spathoglottis plicata
Sphenomeris chinensis
Stachytarpehta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Lantana camara
Psidium cattleianum

d. Rare, Threatened and Endangered

none

Windsite Number 12 Species List

February-March 1981

---

a. Endemic

Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Centella asiatica
Chrysopogon aciculatus
Crotolaria mucronata
Desmodium triflorum
Eucalyptus sp.
Leucaena leucocephala
Pennisetum clandestinum
Pennisetum setosum
Setaria geniculata
Spathoglottis plicata
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Lantana camara
Psidium cattleianum

d. Rare, Threatened and Endangered

none

Windsite Number 13 Species List
February-March 1981

a. Endemic

Osteomeles anthyllidifolia
Styphelia tameiameiae
Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Centella asiatica
Chrysopogon aciculatus
Desmodium zriflorum
Emilia sonchifolia
Eucalyptus sp.
Leucaena leucocephala
Nephrolepis hirsutula
Paspalum orbiculare
Passiflora foetida
Passiflora suberosa
Phyllathus niruri
Psidium guajava
Pteridium aquilinum
Rhynchelytrum repens
Schinus terebinthifolius
Setaria geniculata
Spathoglottis plicata
Sporobolus poirettii
Stachytarpheta jamaicensis

c. Noxious Weeds

Andropogon virginicus
Lantana camara

d. Rare, Threatened and Endangered

none

Windsite Number 14 Species List

February-March 1981

a. Endemic

Metrosideros collina

Osteomeles anthylliofolia

Styphelia tameiameiae

Wikstroemia sp.

b. Exotics and Indigenous

Acacia confusa

Bidens pilosa var. minor

Cassia leschenaultiana

Centella asiatica

Chrysopogon aciculatus

Cordyline terminalis

Desmodium triflorum

Eleusine indica

Erigeron canadensis

Grevillea robusta

Nephrolepis hirsutula

Passiflora foetida

Pennisetum setosum

Psidium cattleianum

Saccharum officinarum

Scavela gaudischaudiana

Spathoglottis plicata

Sphenomeris chinensis

Sporobolus poiretii

Stachytarpheta jamaicensis

Wedelia trilobata

c. Noxious Weeds

Andropogon virginicus

Brachiaria mutica

Psidium guajava

d. Rare, Threatened and Endangered

none

Windsite Number 15 Species List

February-March 1981

a. Endemic

Carex wahevensis

Osteomeles anthyllidifolia

Wikstroemia sp.

b. Exotics and Indigenous

Acacia farnesiana

Andropogon pertusus

Bidens pilosa var. minor

Cassia leschenaultiana

Casuarina equisetifolia

Chrysopogon aciculatus

Desmodium triflorum

Ficus sp.

Heteropogon contortus

Leucaena leucocephala

Microsorium scolopendria

Mimosa pudica

Opuntia megacantha

Paspalum orbiculare

Passiflora edulis

Passiflora foetida

Passiflora suberosa

Pennisetum clandestinum

Phoenix dactylifera

Plantago lanceolata

Psidium guajava

Psilotum nudum

Rhynchelytrum repens

Schinus terebinthifolius

Setaria geniculata

Spathoglottis plicata

Stachytarpheta jamaicensis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

d. Rare, Threatened and Endangered

none

Windsite Number 16 Species List

February-March 1981

a. Endemic

none

b. Exotics and Indigenous

Bidens pilosa var. minor
Chrysopogon aciculatus
Desmodium triflorum
Panicum maximum
Plantago lanceolata
Psidium guajava
Schinus terebinthifolius
Setaria geniculata
Sporobolus africanus
Stachytarpheta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Lantana camara

d. Rare, Threatened and Endangered

none

Windsite Number 17 Species List

February-March 1981

a. Endemic

Osteomeles anzhyllidifolia

Styphelia tameiameiae

Wikstroemia sp.

b. Exotics and Indigenous

Acanthospermum australe

Bidens pilosa var. minor

Casuarina equisetifolia

Cynodon daczylon

Chrysopogon aciculazus

Desmodium triflorum

Digizaria sanguinalis

Paspalum conjugatum

Paspalum orbiculare

Pennisetum clandestinum

Pennisetum setosum

Plantago lanceolaza

Psidium guajava

Schinus terebinthifolius

Setaria geniculata

Sporobolus africanus

Stachytarpheta jamaicensis

Waltheria americana

c. Noxious Weeds

Andropogon virginicus

Lantana camara

d. Rare, Threatened and Endangered

none

Windsite Number 18 Species List
February-March 1981

a. Endemic

Osteomeles anthyllidifolia

b. Exotics and Indigenous

Acanthospermum australe
Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Desmodium triflorum
Leucaena leucocephala
Pennisetum clandestinum
Plantago lanceolata
Psidium guajava
Setaria geniculata
Sporobolus africanus
Stachytarpheta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus

d. Rare, Threatened and Endangered

none

Windsite Number 19 Species List
February-March 1981

---

a. Endemic

Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Centella asiatica
Desmodium triflorum
Eucalyptus sp.
Grevillea robusta
Nephrolepis hirsutula
Oxalis corniculata
Panicum maximum
Passiflora edulis
Passiflora suberosa
Psidium guajava
Schinus terebinthifolius
Setaria geniculata
Sphenomeris chinensis
Sporobolus africanus
Stachytarpheta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Lantana camara

d. Rare, Threatened and Endangered

none

Windsite Number 20 Species List

February-March 1981

a. Endemic

Cocculus fernandianus
Osteomeles anthyllidifolia
Schaevola gaudischaudiana
Styphelia tameiameiae
Wikstroemia sp.

b. Exotics and Indigenous

Acanthospermum australe
Andropogon sp.
Bidens pilosa var. minor
Cassia leschenaultiana
Casuarina equisetifolia
Centella asiatica
Chrysopogon acicularis
Desmodium triflorum
Erigeron canadensis
Grevillea robusta
Nephrolepis exaltata
Paspalum orbiculare
Passiflora suberosa
Phyllanthus niruri
Pinus tabulaeformis
Psilotum nudum
Setaria geniculata
Spathoglottis plicata
Sphenoneris chinensis
Stachytarpheta jamaicensis
Waltheria americana

c. Noxious Weeds

Andropogon virginicus
Brachiaria mutica
Lantana camara
Leucaena leucocephala
Melinis minutiflora
Pluchea odorata
Psidium cattleianum
Psidium guajava
Schinus terebenthifolius

d. Rare, Threatened and Endangered

none

Windsite Number 20a Species List

February-March 1981

a. Endemic

Canthium odoratum

Carex sp.

Pleomele aurea

Scaevola gaudischaudiana

Wikstroemia sp.

b. Exotics and Indigenous

Bidens pilosa var. minor

Casuarina equisetifolia

Cordyline terminalis

Cyclosorus dentata

Desmodium triflorum

Eucalyptus sp.

Ficus benjamina

Grevillea robusta

Mangifera indica

Oplismenus hirtellus

Passiflora edulis

Passiflora suberosa

Pteridium aquilinum

Richardia brasiliensis

Setaria geniculata

Spathoglottis plicata

Sphenomeris chinensis

Stachytarpheta jamaicensis

c. Noxious Weeds

Andropogon virginicus

Buddleja asiatica

Clidemia hirta

Melinis minutiflora

Psidium cattleianum

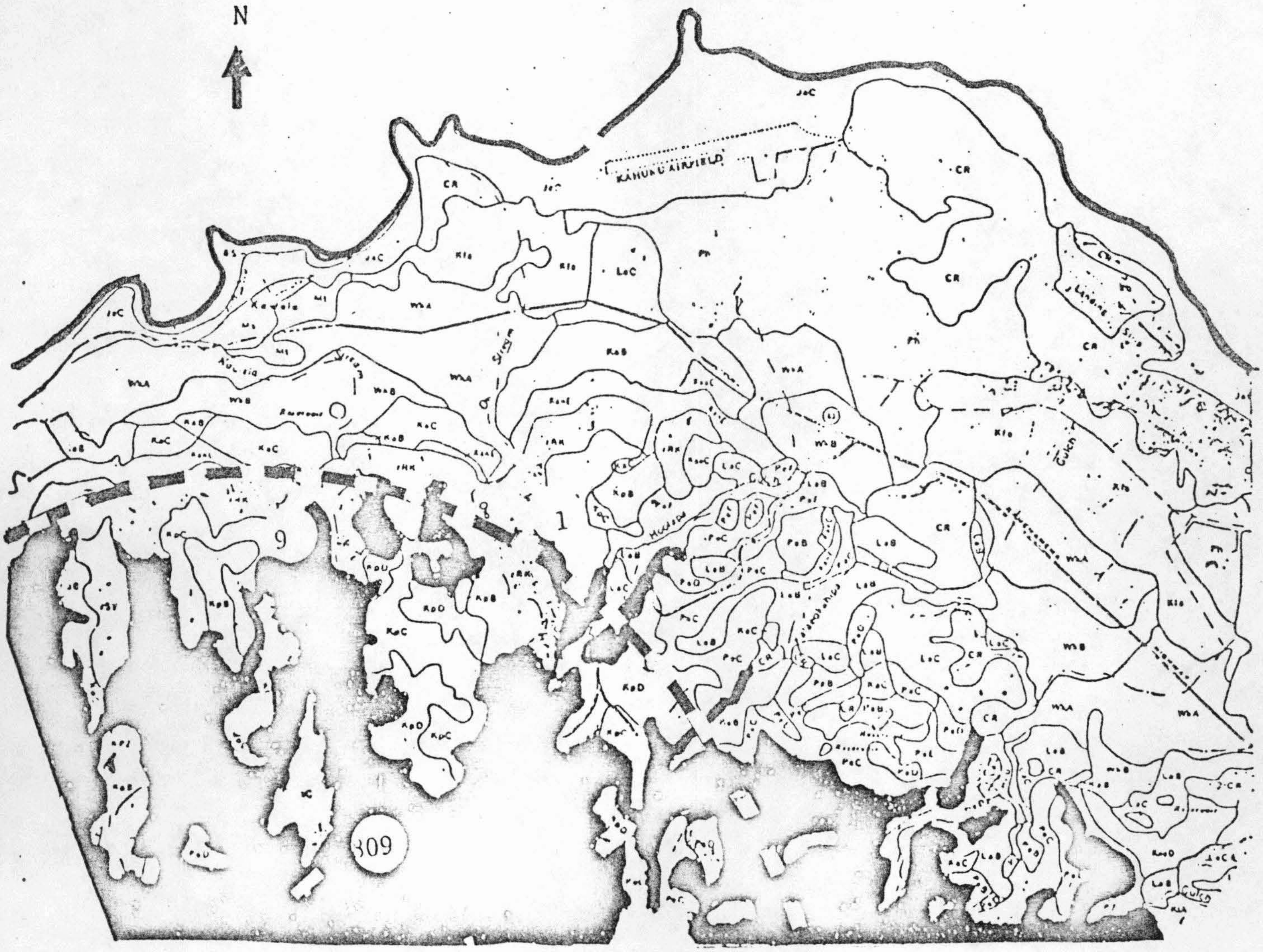
Psidium guajava

d. Rare, Threatened and Endangered

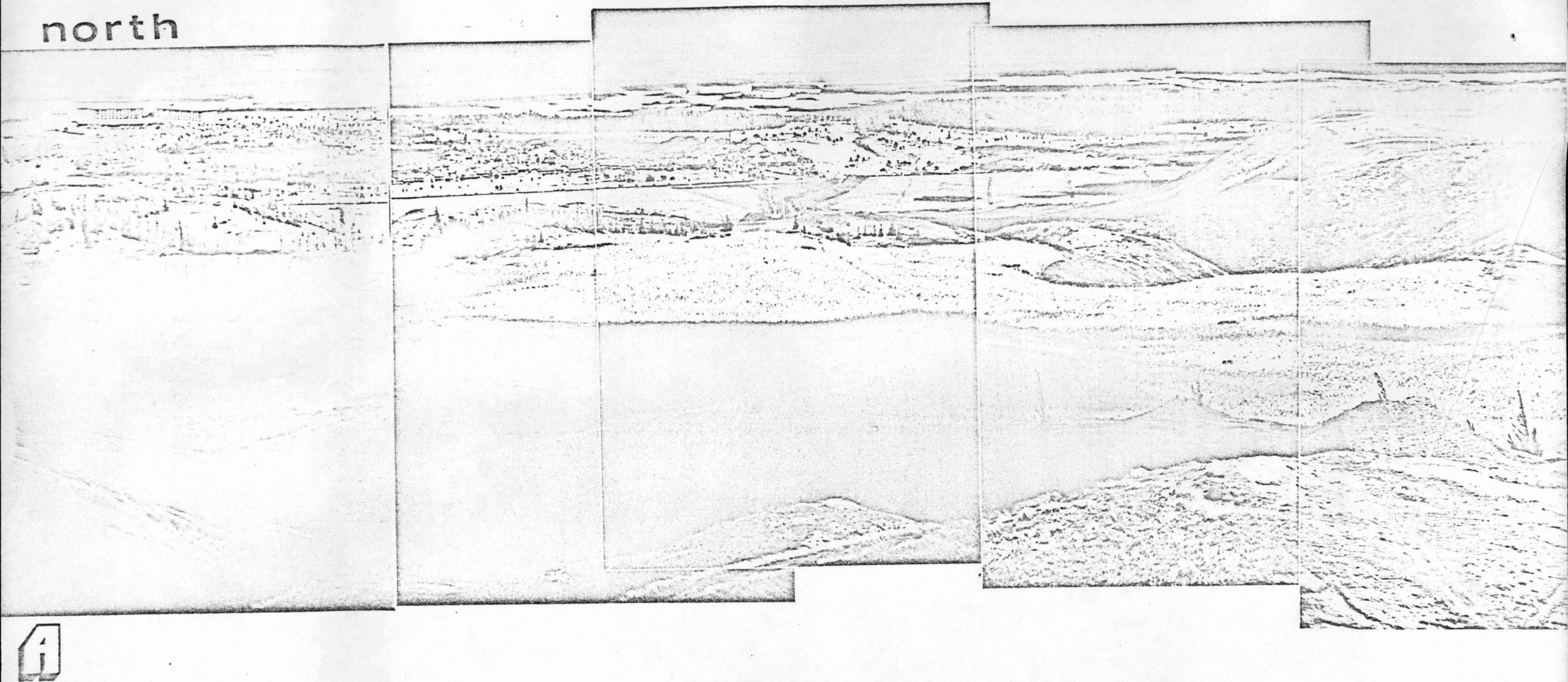
none

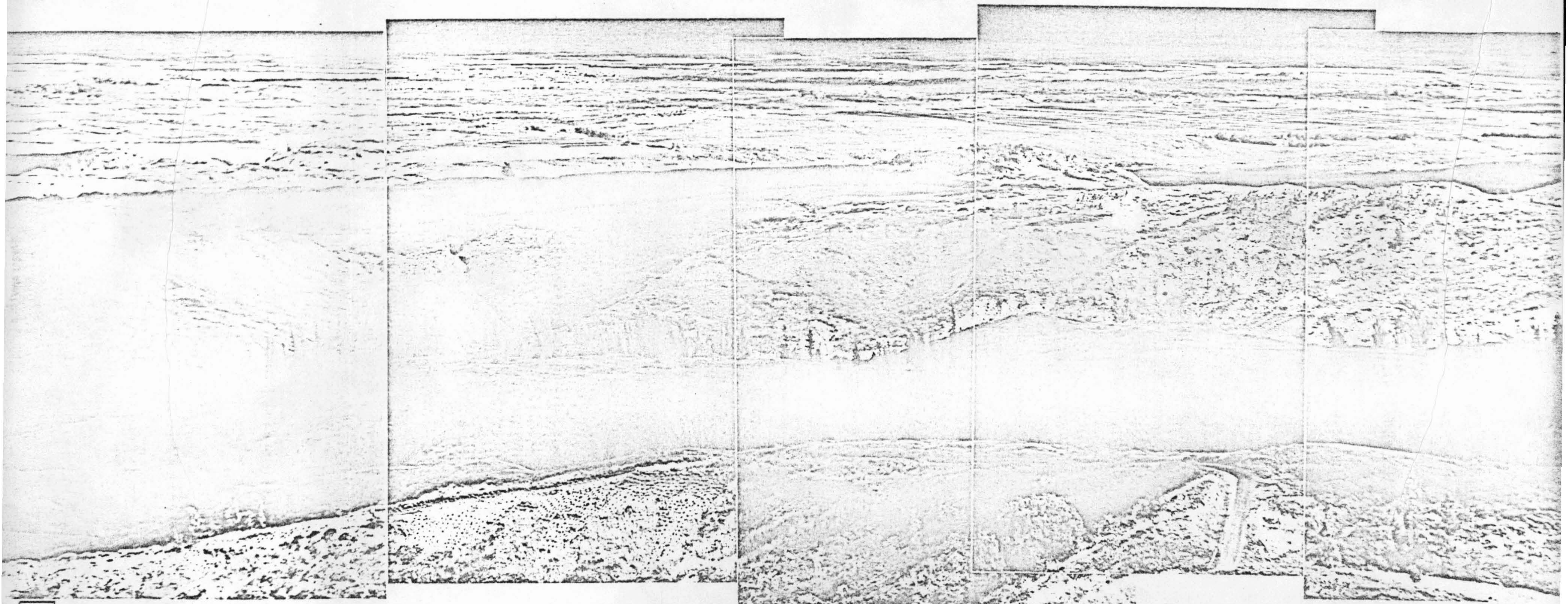
A 360° Photomosaic of the Kahuku area
as seen from Hill 809
(see Kahuku Badlands Map above)

Most Proposed Windsites are Enclosed
Within Dashed Arc on Line with or
N. of Hill 809 on Schematic Map



KAHUKU BADLANDS: AREA 4 (Wind)


north
A



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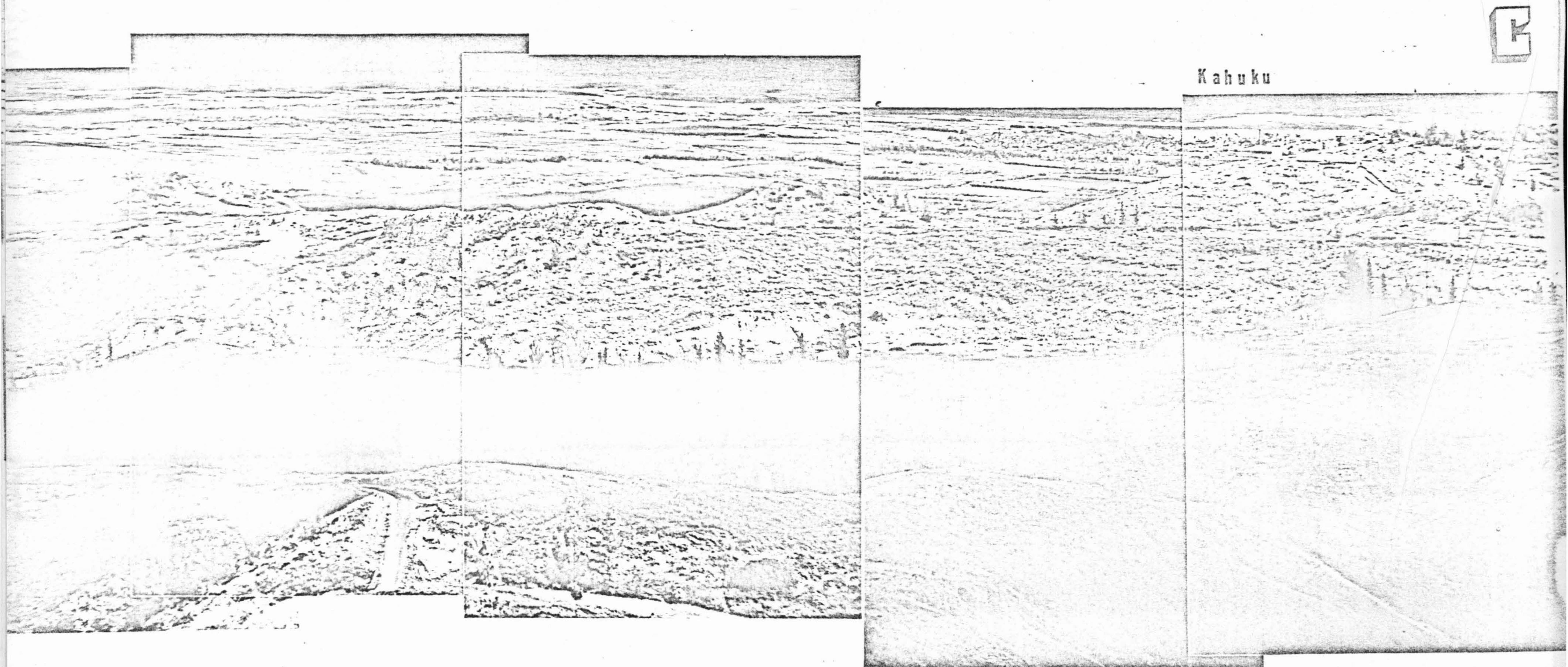
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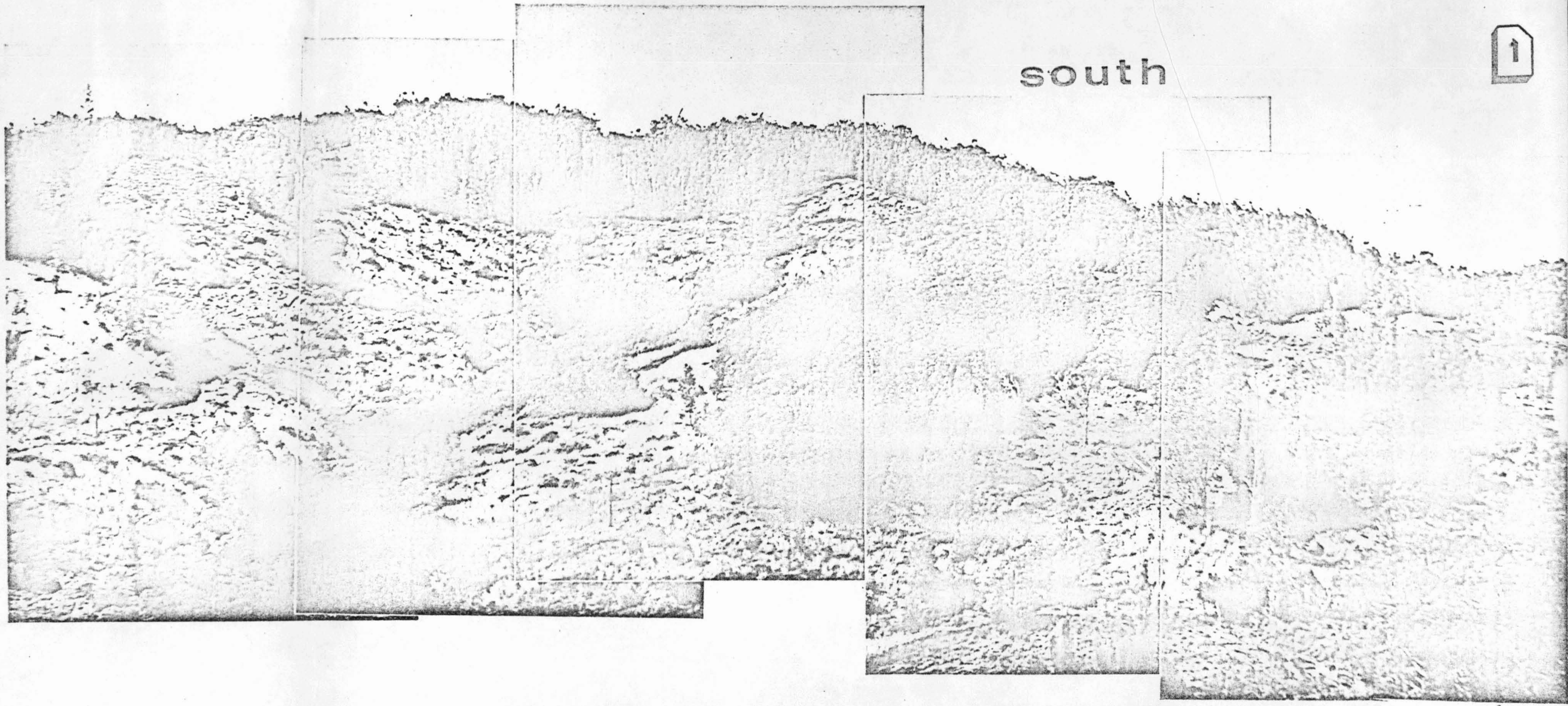
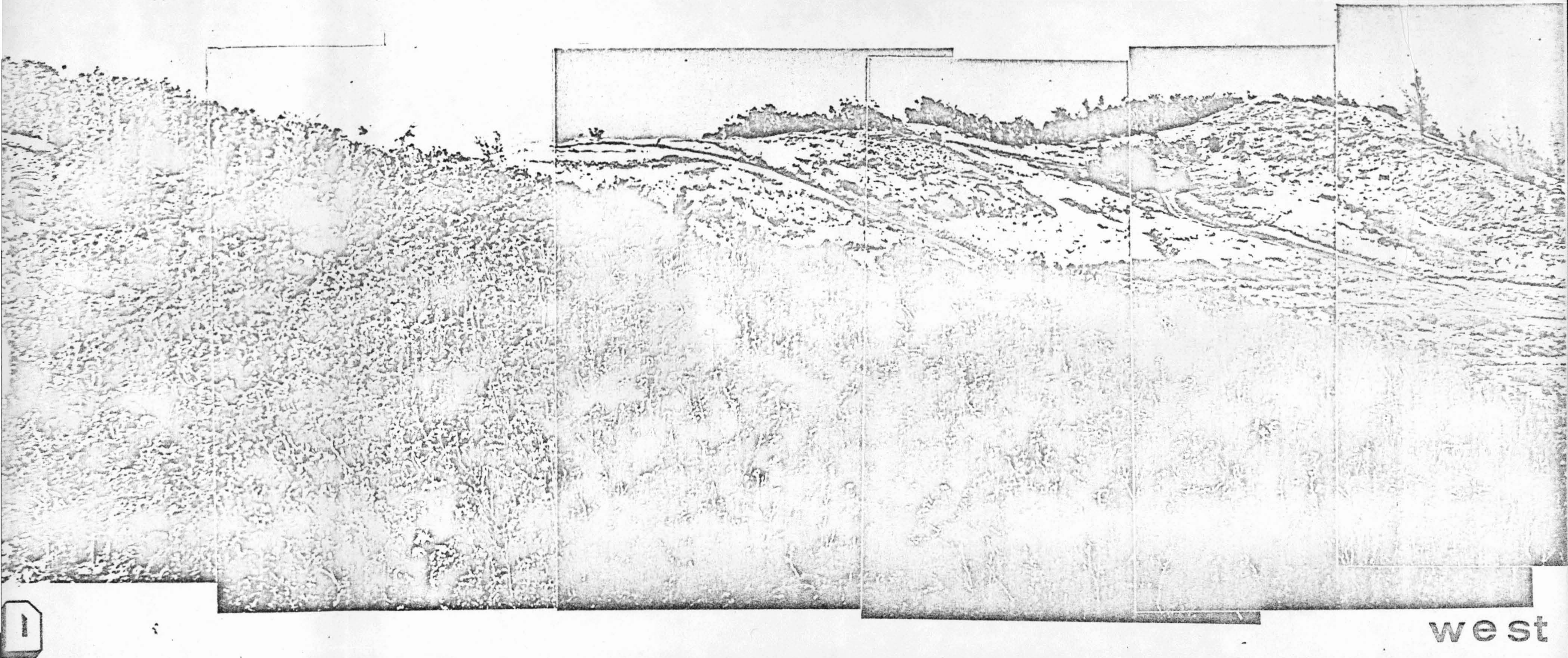
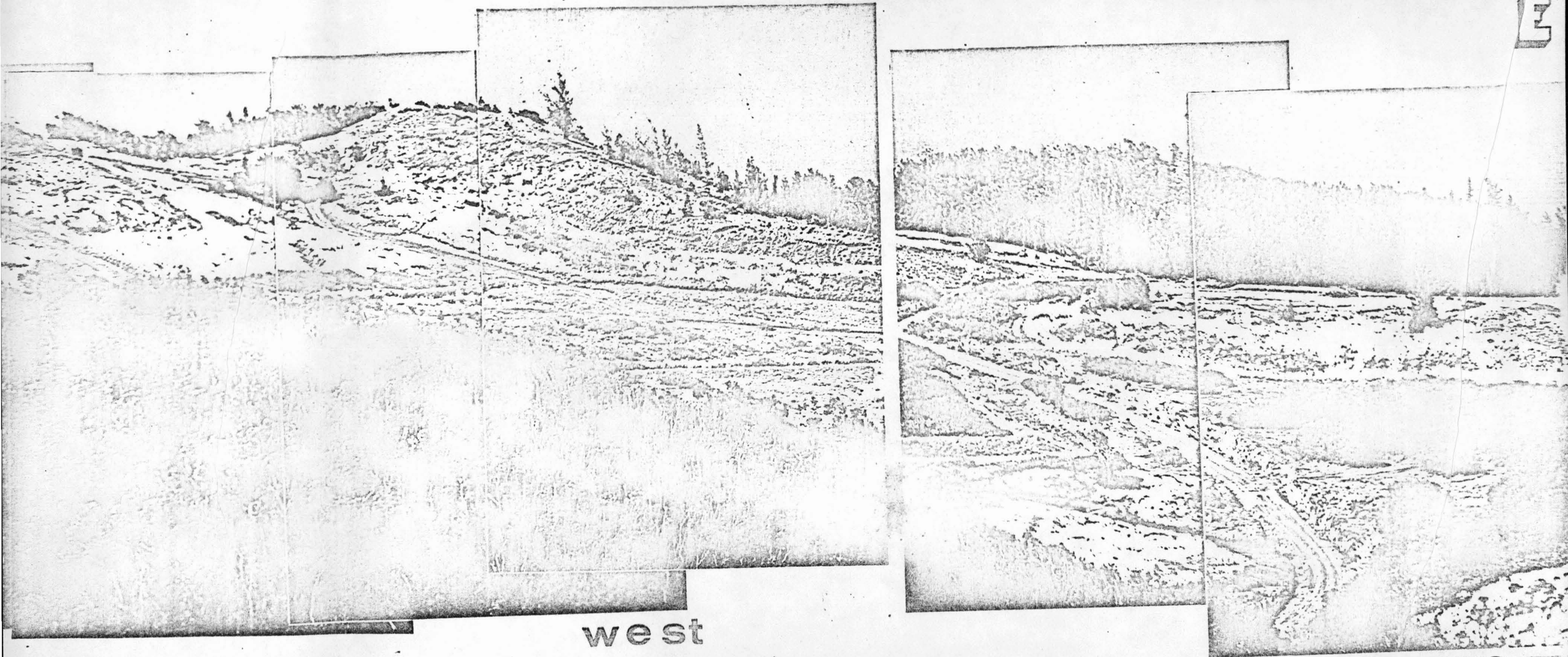

south
1

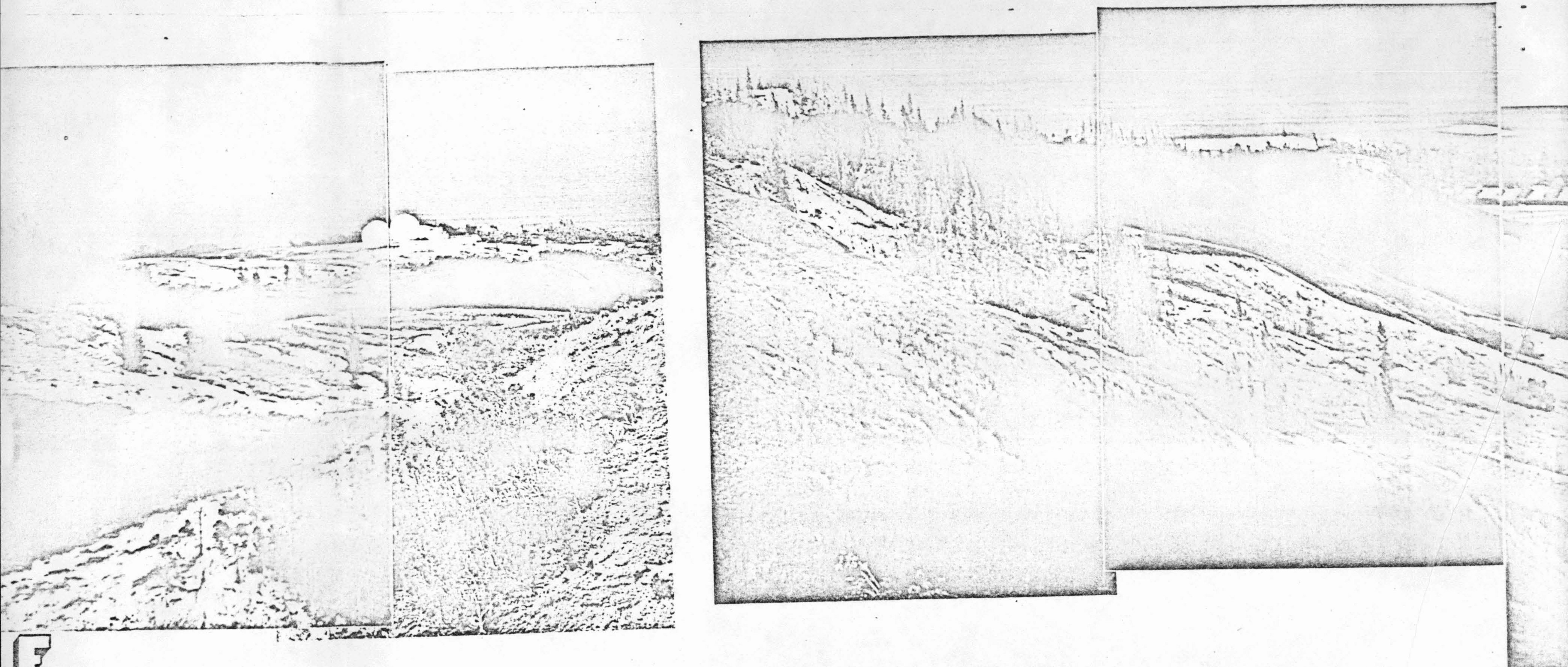


west

E

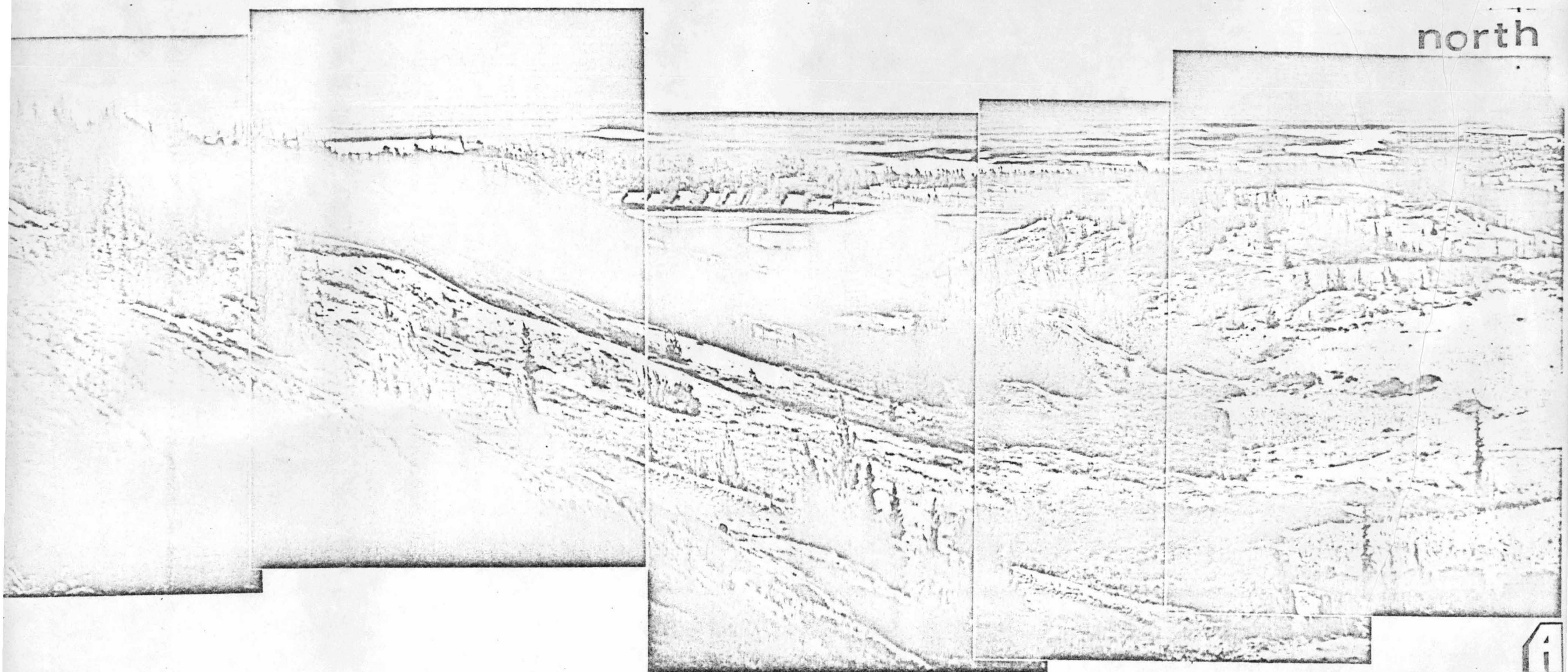


west



E

north



A

HOME WIND RESOURCE (AREA 4A)

MIXED MUNICIPAL

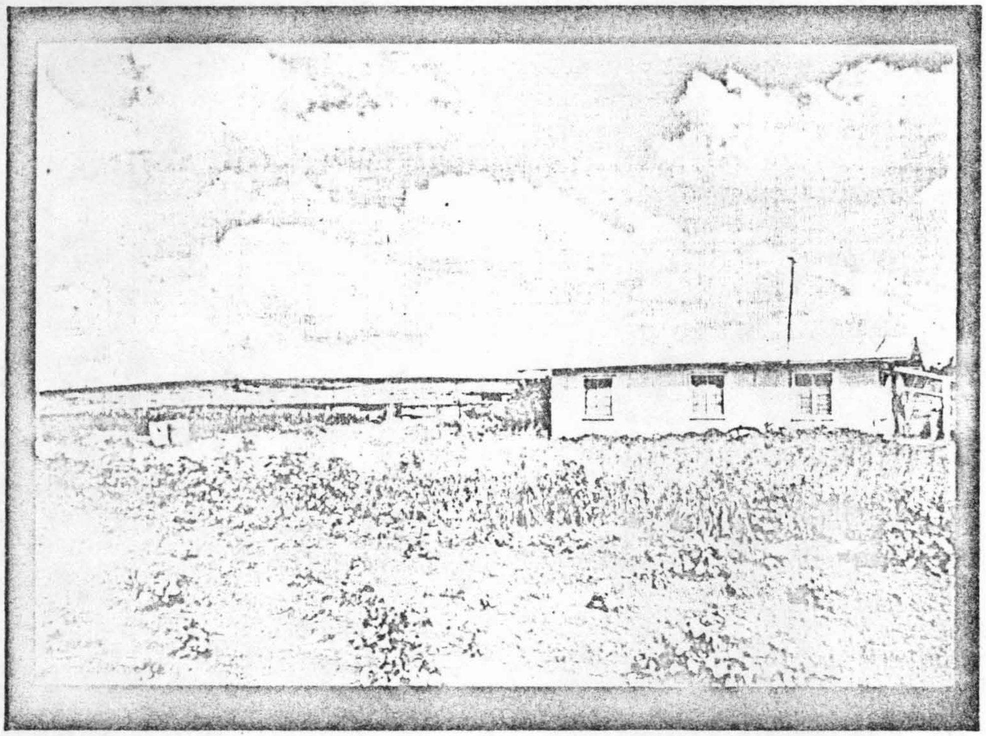
POWER STATION (AREA 5)

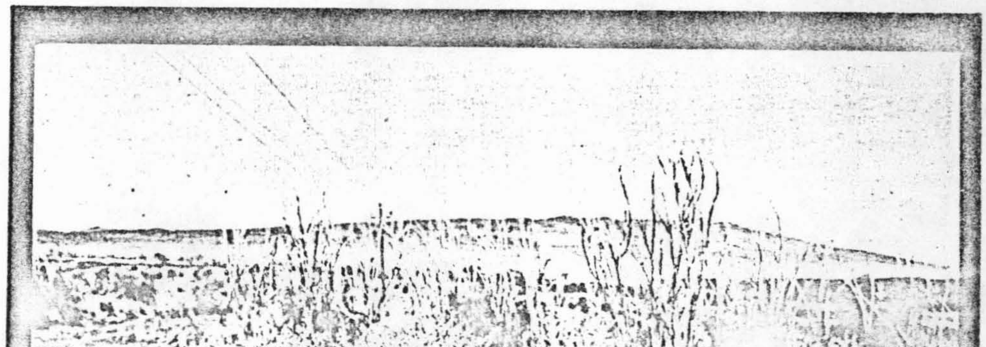
Special Molokai Study

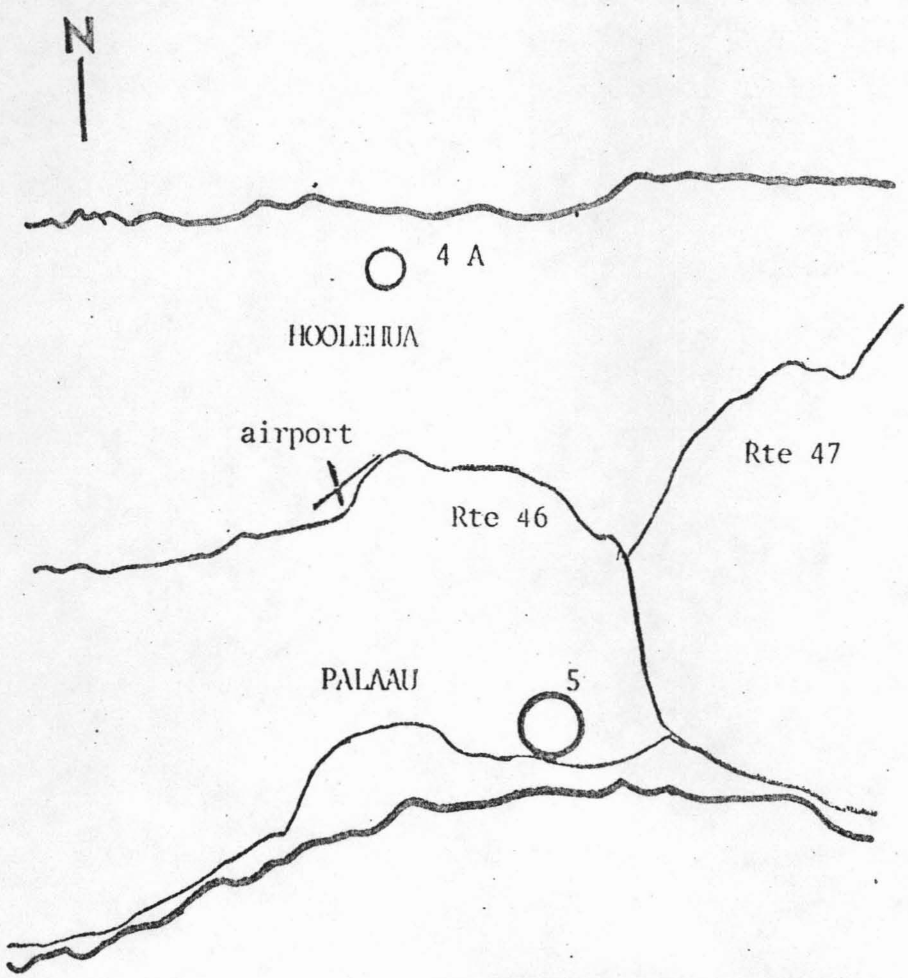
Molokai Study

Photographs

UPPER LEFT:	B. Davis house in Hoolehua looking toward the southeast
LOWER RIGHT:	Near new Molokai Electric site in Palaau looking northward







MOLOKAI: AREA 4 A (Wind), AREA 5
(Solar thermal, biomass, diesel).

AREAS 4A, 5

An examination of the countryside surrounding both energy sites quickly shows evidence of extensive human disturbance. This is reflected especially in dissected terrain, moderately eroded; in rocky outcrops; in poor quality upper soil layers; lack of healthy continuous ground cover and a preponderance of noxious and undesirable weeds.

The chemical composition of the air at both sites indicates that hydrogen sulfide, sulfur dioxide, carbon monoxide, nitrogen oxide, and mercury are probably in the normal range for unpolluted baselines.

Soil analyses support a similar conclusion. In fact soil figures for mercury and arsenic are unusually low, even for unpolluted volcanic sites. A long history of weathering and concomitant leaching of the soil is certainly indicated.

In this sort of situation - an unpolluted but severely degraded environment - it is tempting to feel relaxed about further environmental impacts. However acceptable this attitude may be when a small household wind generator is involved, it is a dangerous posture when considering a large electrical generating site.

If the usual effluents from fossil fuel fired generating stations of similar capacity were to be released without abatement, all stabalizing effects of the remaining vegetation would be lost. Head erosion and gullying would soon follow. Even if the station operates with a sizable percentage of "non-polluting" energy sources, monitoring is at least necessary for some time after startup.

Molokai Energy- Related Environmental Baseline Study				
Environment Chemistry- February, 1980				
Location	Samples	Analytical Results		
Molokai Electric New Palaau Facility	Air	H_2S < 30	ppb	(4 sites)
		SO_2 < 0.1	ppm	(4 sites)
		CO < 0.2	ppm	(2 sites)
		NOx < 0.2	ppm	(2 sites)
		Hg < 0.1	$\mu g.m^{-3}$	(2 sites)
	Soil	As < 0.05	ppm	(2 sites)
		Hg < 20	ppb	(4 sites)
Davis House	Air	H_2S < 30	ppb	
		SO_2 < 0.1	ppm	
		CO < 0.2	ppm	
		NOx < 0.2	ppm	
		Hg < 0.1	$\mu g.m^{-3}$	

Palaau Molokai Electric Site

4.9.80 Sample Areas

Family	Species	Common Name
Amaranthaceae	Amaranthus spinosus L.	Pakai Kuku
Chenopodiaceae	Chenopodium album L.	Lambs Quarter
Compositae	Emilia sonchifolia (L.) DC	Red Pualele
	Pluchea indica (L.) Less.	Indian Fleabane
	Sonchus oleraceus L.	Pualele
Convolvulaceae	Merremia aegyptia (L.) Urban	Hairy Morning Glory
Gramineae	Chloris barbata Swartz	Swollen Finger Grass
	Chloris radiata (L.) Swartz	Radiate Finger Grass
	Digitaria sp.	Crabgrass
	Pennisetum setaceum (Forsk.) Chiov.	Fountain Grass
	Rhynchelytrum repens (Willd.) C.E. Hubb	Natal Redtop
	Setaria glauca (L.) Beauv.	Yellow Foxtail
Leguminosae	Crotalaria mucronata. Desv.	Smooth Rattle Pod
	Desmodium triflorum (L) DC	3-flowered Beggarweed
	Leucena leucocephalum (Lam.) deWit	Koa Haole
Malvaceae	Abutilon molle Sweet	Hairy Abutilon

Davis House- Wind Generator Site

4.9.80 Sample Areas

Family	Species	Common Name
	NE Direction	
Amaranthaceae	Amaranthus spinosus L.	Pakai kuku
Compositae	Ambrosia artemisiaefolia L.	Ragweed
	Bidens pilosa L.	Spanish Needle
	Erechtites hieracifolia (L.) Raf.	Fireweed
	Gaillardia pulchella Foug.	Gaillardia
Cucurbitaceae	Momordica charantia var. Pavel Crantz	Balsam Apple, Peria
Gramineae	Cenchrus echinatus L.	Sandbur
Leguminosae	Cassia leschenaultiana DC	Japanese tea
	Crotalaria mucronata (Desv.)	Smooth Rattle Pod
	Desmodium tortuosum (Sw.) DC	Florida Beggarweed
Malvaceae	Malva parviflora L.	Cheese Weed

Davis House- Wind Generator Site

4.9.80 Sample Areas

Family	Species	Common Name
	SW Direction	
Chenopodiaceae	Chenopodium album L.	Lambs Quarters
Compositae	Xanthium strumarium L.var	
	canadense (Mill.) Torr. and A. Gray	Cocklebur, kikania
Gramineae	Pennisetum setosum (Swartz) L.C. Rich	Feathery Pennisetum
Malvaceae	Malva parviflora L.	Cheeseweed
	W Direction	
Chenopodiaceae	Chenopodium album L.	Lambs Quarters
Compositae	Emilia sonchifolia	Red Pualele
	Sonchus oleraceus	Pualele
Cucurbitaceae	Momordica charantia var.	
	Pavel Crantz	Balsam Apple, Peria
Gramineae	Panicum repens L.	Wainaku Grass.

Davis House- Wind Generator Site
4.9.80 Sample Areas

Family	Species	Common Name
	SE Direction	
Chenopodiaceae	Chenopodium album L.	Lambs Quarters
Compositae	Emilia sonchifolia (L.) DC	Red Pualele
	Erechtites hieracifolia (L) Raf.	Fireweed
Gramineae	Panicum torridum Gaud	Kakonakoa
	Setaria glauca (L) Beauv.	Yellow foxtail
Malvaceae	Malva parviflora L.	Cheeseweed
	NNW Direction	
Amaranthaceae	Amaranthus spinosus L.	Pakai kuku
	Amaranthus sp. (possible dubius)	Spleen Amaranth
Chenopodiaceae	Chenopodium album L.	Lambs Quarters
Compositae	Gaillardia pulchella. Foug.	Gaillardia
Gramineae	Cynodon dactylon (L) Pers.	Manienie
	Stenotaphrum secundatum (walt.) kintze	Buffalo Grass
Leguminosae	Desmodium triflorum (L) DC	3-flowered Beggar Weed

Davis House- Wind Generator Site
4.9.80 Sample Areas

Family	Species	Common Name
	NW Direction	
Amaranthaceae	Amaranthus spinosus L.	Pakai kuku
Compositae	Chrysanthemum leucanthemum	
	var pinnatifidum. Lecuq and Laviotte	Ox Eye Daisy
Gramineae	Eleusine indica (L.) Guerth	Wiregrass
	Setaria glauca (L) Beauv.	Yellow Foxtail
Solanaceae	Datura stramonium L.	Jimson Weed

Conclusions and Recommendations

Although our experience with environmental measurements dates back to 1969, and with HGP-A to 1975, the majority of data and findings presented here are the results of research, analysis and field work carried out within the one-year grant period.

To acquire, assimilate and offer in finished form in a single year the proceeds of this relatively large data assemblage is not possible if the whole is to be well done.

It is clear that there are high points of consistency and suggestions of trends and patterns that are within natural variability and reliability, reproducible or predictable.

Examples of these are

* Sensitive relations between natural Kilauea East Rift Activity Periods and Puna District (HGP-A) air, soil and plant mercury levels ;
* Related to above high "normal" levels of mercury (and occasionally sulfur-gases) in the Puna District;
* Unlike other olcanic- eothermal areas, a low arsenic level;
* A pronounced tendency in plants to concentrate soil mercury;
* Scarcity of rare, threatened or endangered species in the geothermal prospect areas;
* Relatively ligh incidence of disturbed forest land in the geothermal area;
* Correlation between natural toxic metals and soil pH;
* Correlation beteen human uses in non-geothermal areas and toxicants such s lead, zinc and copper;
* Relation betw n soil pH and slope exposure;
* Definition adlands in terms of soil chemistry.

Although our experience with environmental measurements dates back to 1969, and with HGP-A to 1975, the majority of data and findings presented here are the results of research, analysis and field work carried out within the one-year grant period.

To acquire, assimilate and offer in finished form in a single year the proceeds of this relatively large data assemblage is not possible if the whole is to be well done.

It is clear that there are high points of consistency and suggestions of trends and patterns that are within natural variability and reliability, reproducible or predictable.

Examples of these are

* Sensitive relations between natural Kilauea East Rift Activity Periods and Puna District (HGP-A) air, soil and plant mercury levels ;
* Related to above high "normal" levels of mercury (and occasionally sulfur-gases) in the Puna District;
* Unlike other olcanic- eothermal areas, a low arsenic level;
* A pronounced tendency in plants to concentrate soil mercury;
* Scarcity of rare, threatened or endangered species in the geothermal prospect areas;
* Relatively high incidence of disturbed forest land in the geothermal area;
* Correlation between natural toxic metals and soil pH;
* Correlation between human uses in non-geothermal areas and toxicants such as lead, zinc and copper;
* Relation between soil pH and slope exposure;
* Definition of badlands in terms of soil chemistry.

These are a few indications of generalizations that could become part of regional guidelines, depending upon the resource and the locale for their particular direction and assemblage.

If this sort of baseline philosophy is to be implemented, then a great deal more is needed than the modest beginnings embodied in the report. And we do indeed recommend that the State of Hawaii make serious commitments to establishment of a comprehensive set of regional environmental baselines over the next 4-5 years.