POTENTIAL WATER DEVELOPMENT
OF THE KAHUA AREA, KOHALA, HAWAII

by

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ABSTRACT

On the basis of hydrology, geology, soils, and water quality, potential ground-water development along the coastal area of the Kahua area in the North Kohala District appears unfavorable for large supplies of fresh water. Low rainfall and the presence of barrier dikes limit recharge by percolation and underflow. Wells occurring near the coast are brackish and have low heads. A well in the wet uplands is essentially dry. South of the nearby town of Kawaihae ground-water sources of brackish quality are used for irrigation of a golf course and pasturage. Multiple low-yield wells parallel to the coast will maximize yield without further impairing water quality. Surface geophysical exploration and a study of upgrading the water quality economically for domestic use are suggested.

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INTRODUCTION

Prior to the development of a water source in the Hawaiian Islands, it is necessary to locate a possible site, estimate its potential, and calculate crude economic estimates of the development costs. Since almost always there is some water available, the problem is one of degree: how much and what quality.

In the present situation, it was apparent from surficial flows at the higher elevations that some fresh water was infiltrating the water table. The area of interest is the Kahua area and adjacent lands. This land lies below the 1500-foot elevation and between Kaiopae Point and Waiakailio Bay. The location is shown in Figure 1, which is a portion of a USGS topographic map. Two field trips were made by members of the WRRC staff to obtain the background information presented in this report. The objective was to estimate the possibility of locating a fresh-water source of about 1 mgd in the area of interest.

Kahualiiilii and Kahuanui, which comprise the general area of interest, extend from the crest of Kohala dome down the leeward side to the coastline a few miles northwest of the town of Kawaihae. As shown in Figure 2, this is a relatively dry area. Rainfall is abundant only in areas above 2500 feet. Vegetation is sparse and consists primarily of keawe and grasses. There are about 360 days of sunshine per year.

General Geology

The Kohala Mountains constitute the oldest of the five volcanic domes comprising the island of Hawaii. The Kohala dome was built during two distinct periods of volcanic activity. The basalts of the Pololu series formed the initial mountain mass. After the cessation of the Pololu eruptions, erosion and weathering dominated. The Kahua or leeward side of the mountain was much less affected by erosion than the rainy windward side. A later series of lava flows of trachytic and andesitic composition overlies a red soil formed during the quiescent stage. Numerous cinder cones were formed along the rift zone and ash was deposited over extensive areas on the leeward side. Volcanic material of this stage is known as the Hawi series. Comparatively few Hawi flows

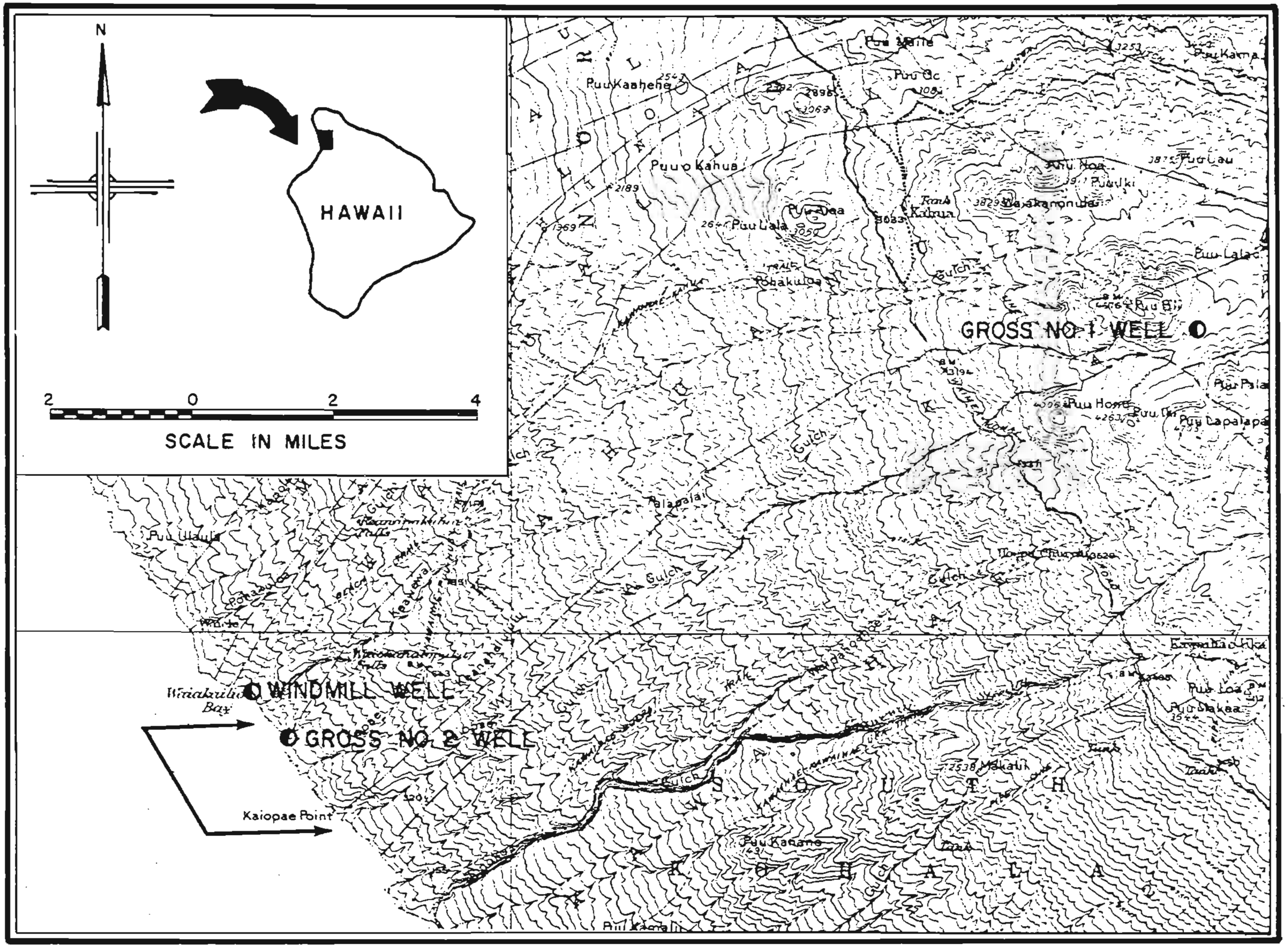

FIGURE 1. TOPOGRAPHIC MAP SHOWING WELL LOCATIONS AND GENERAL AREA OF INTEREST.

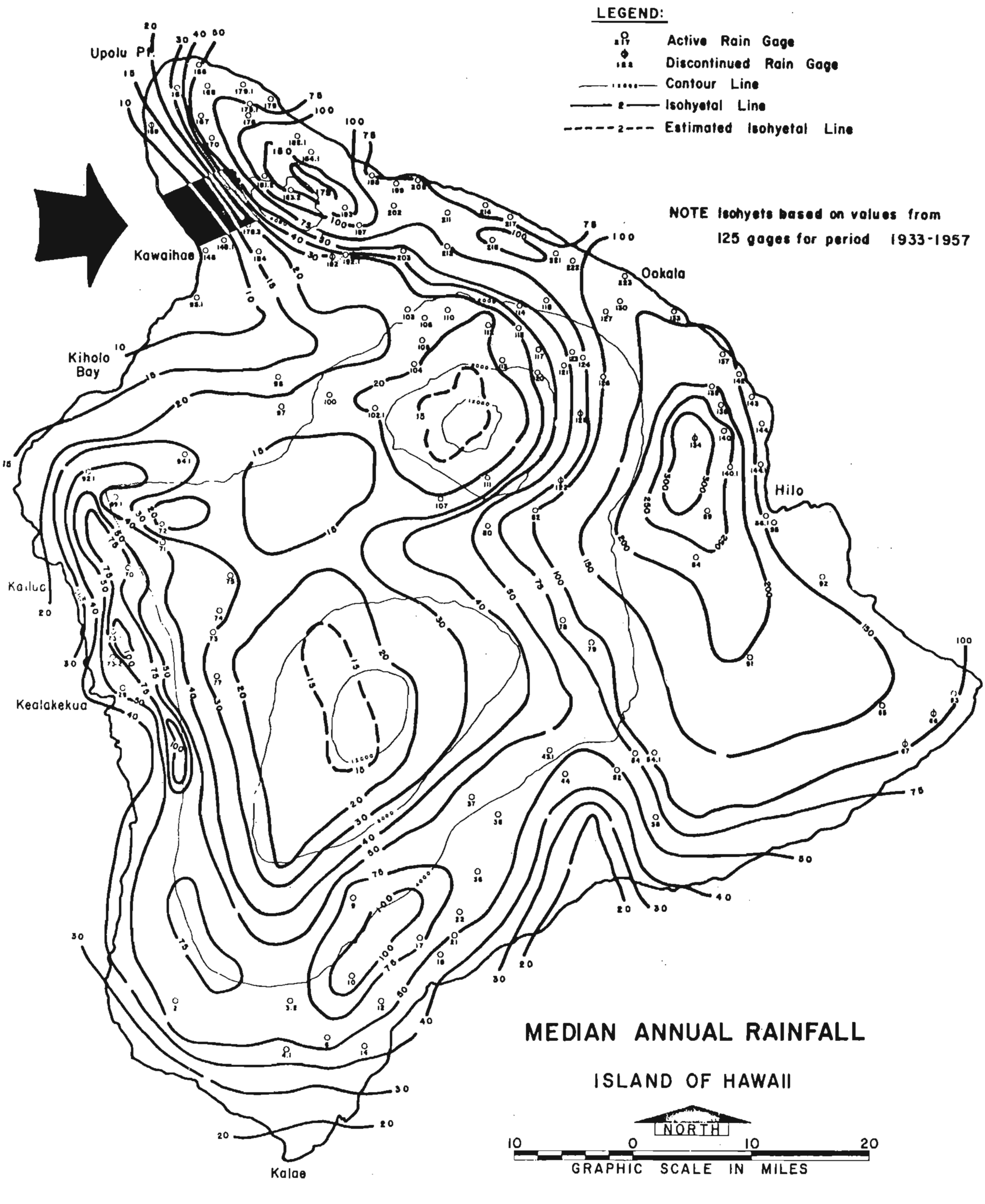

FIGURE 2. ISOHYTEL MAP OF THE ISLAND OF HAWAII.
(After *Rainfall of the Hawaiian Islands*, Hawaii Water Authority, State of Hawaii, p. 5, September 1959.)

reached the leeward coast in the Kahua area. (The general geologic map from Stearns is shown as Figure 3.)

INVESTIGATION OF OFFSHORE SPRINGS

A reconnaissance of the coastal area to study the general hydrogeology of the shore and nearshore areas was made in 1967 specifically to verify basal-water springs identified in Figure 4. Three members of the research team, with face masks and snorkles, swam along the shoreline in the anomalous areas. Water samples were taken at points in the ocean where definite temperature contrasts were felt by the swimmers. Perceptible temperature contrasts were estimated to be a few degrees farenheit. Refraction effects due to mixing of fluids of different densities were not observed.

Specific conductances of the ocean samples, listed in Table 1, indicate only ocean water. On the basis of the field observations and water analyses, basal springs could not be identified in this area. (The USGS photos were made in the wet months, February and March; hence, runoff may have been observed.)

TABLE 1. SPECIFIC CONDUCTANCES OF OCEAN SAMPLES

LOCATION	SPECIFIC CONDUCTANCE/micromhos
KAIOPAE BAY (#141 ON USGS INFRARED MAP #22)	45,000 micromhos
KAIOPAE POINT (#140 ON USGS MAP #22)	44,500 micromhos
WAIAKAIKIO BAY (#142 ON USGS MAP #22)	44,000 micromhos

WELLS ON KAHUA RANCH

There are three wells of concern, as shown in Figure 1. A water sample was taken at the shallow windmill well which is less than 100 feet from shore. The well was silted up and contained only about 6 inches of water. Mr. A. Richards[1] reported that a considerable amount

[1]See Acknowledgements; p. 15.

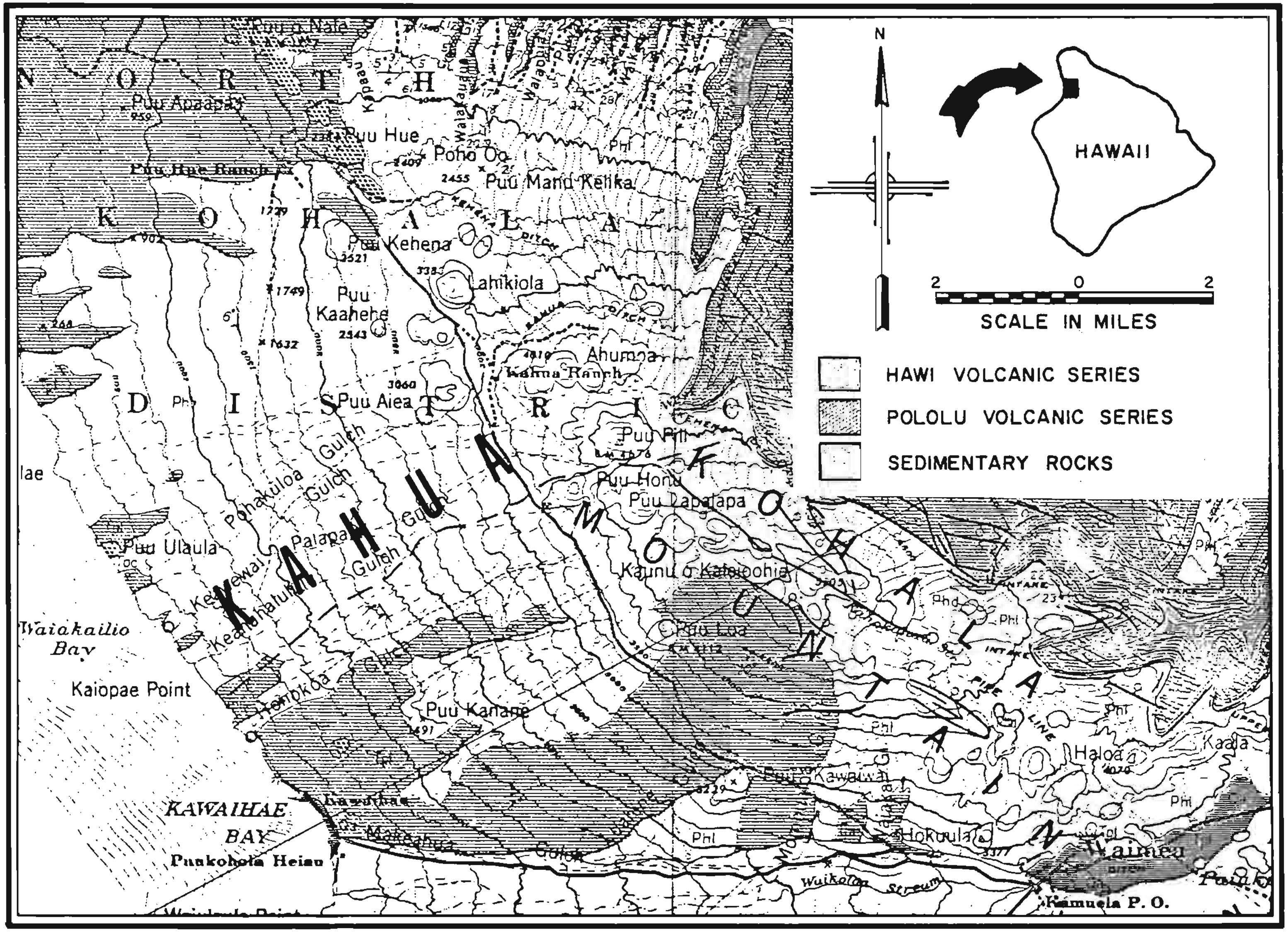

FIGURE 3. GENERAL GEOLOGIC MAP OF THE KAHUA AREA.
(FROM STEARNS AND MACDONALD, 1946)

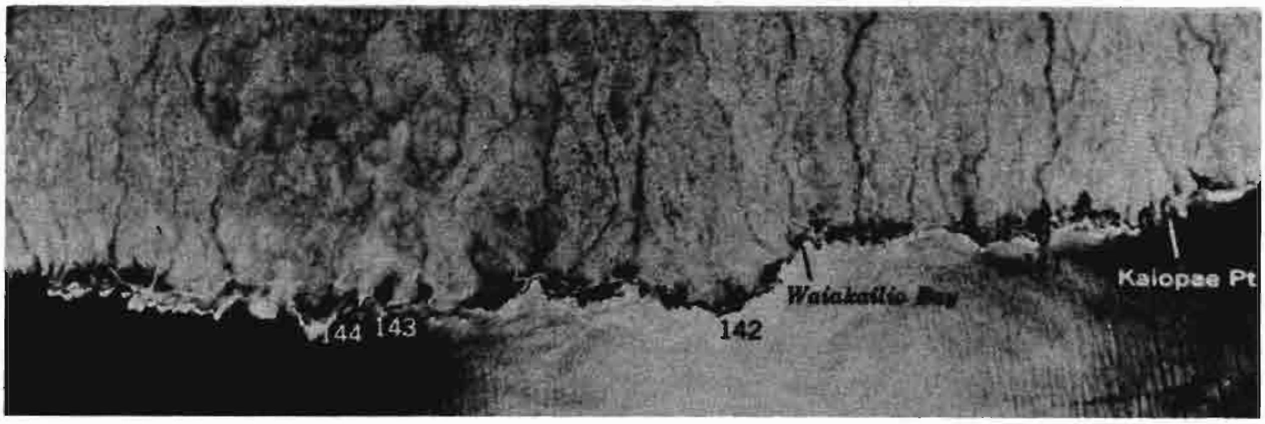

FIGURE 4. SPRINGS IDENTIFIED BY USGS INFRARED METHOD. (FROM FISCHER, *et al.*, 1966.)

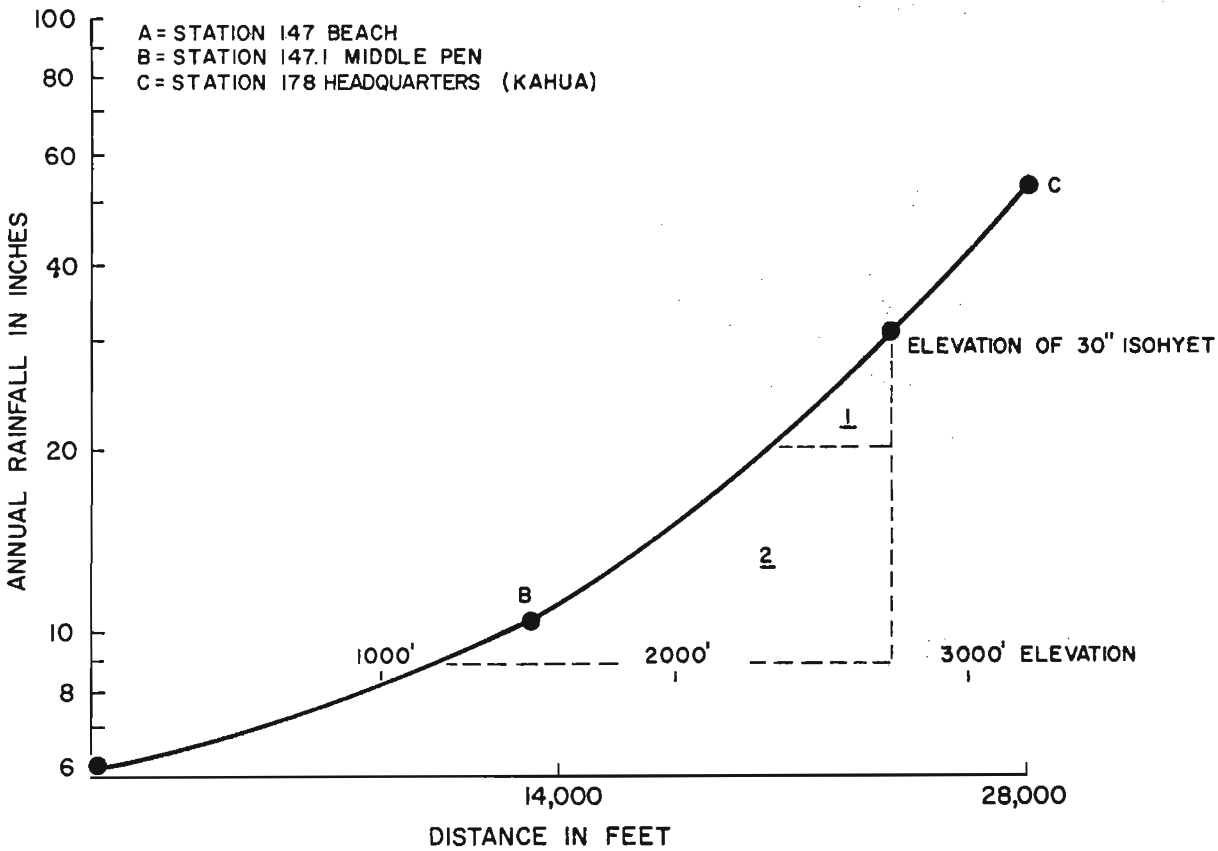

FIGURE 5. PLOT OF RAINFALL *vs* ELEVATION.

of water was pumped from this windmill well for compaction of the fill and keeping down dust during one phase of the construction of the new highway to Kohala, but no samples were taken nor any records kept of pumpage. Our sample showed a field specific conductance of 3920 micromhos and a chloride content of 950 ppm as determined by mercuric nitrate titration.

A second well, Gross No. 2, was drilled in October 1962. Its approximate location is shown on Figure 1. The well was located about 100 feet above the jeep road and a section of 6" casing projected from the ground. The log of this well, as obtained from A. Richards, is shown below:

Gross No. 2 well. Ground elevation 45.3", cased to 42' water level 43.8' below ground (elev. 1.4')

Hard lava	0 - 39 feet
Very hard blue rock	39 - 49 feet
Porous lava	49 - 55 feet

A pump test (probably a bailer test, as the saturated portion of the well was a NX hole) was run on the well by the driller. At a reported 15 gpm the drawdown was negligible and the salinity reported as 224 grains per gallon. The results of sounding the well and taking a thief sample by WRRC were:

Depth of well	49.8	feet
Depth to water	43.6	feet
Elevation of water surface	1.4	feet
Specific conductance (field determination without temperature correction)	7000	micromhos
Chloride content ($HgNO_3$ method)	1900	ppm

A third well drilled downslope from the above well was buried by debris and soil probably brought in by a flash flood. This well is located between the jeep trail and the ocean. A driller's log was not available.

HYDROGEOLOGY OF THE COASTAL AREA

A red bed consisting of old baked soil showing columnar structure generally marks the unconformable contact between the older flows and the newer flows. The red bed is usually above sea level and frequently pinches out. Little or no water was observed perched on this bed. The Hawi flows are generally exposed in the cliffs only above sea level. The Pololu flows (as mapped here by Stearns) which constitute the basal water aquifers are very tight and tough, and occasionally showing vertical and synclinal structure suggesting lateral coalescence of many lava flow fronts. This was in striking contrast to the normal, flat-bedded flows of the overlying Hawi series. Clinker beds are thin, discontinuous, and sparse. No lava tubes were seen anywhere along the coastline of the ranch, although burial caves are said to occur within a few miles.

Local Views on Water

The numerous ruins indicate that a large number of Hawaiians once lived here. The location name, Waiakailio Bay, means "water of the dog," suggesting that the water was fit for dogs to drink.

When the U. S. Navy took over the island of Kahoolawe as a target range, the Kahoolawe cattle were brought to this area and released. These cattle reportedly drank water from the bay. Present day cowboys report being "overturned" while skindiving in this area, but this seems more likely to be the result of wave action than fresh-water outflow.

RECONNAISSANCE OF THE UPLANDS

During the second field trip on 4 and 5 August 1967, the major recharge areas of water on the ranch were studied. The upper well, Gross No. 1, was investigated (see Figure 1). The well site, selected by Henry Gross (of water witch fame), lies in a swampy area between two cinder cones, Puu Pili and Puu Honu. The well was drilled to a depth of about 156 feet in February and March 1962 by the cable tool method. Although not specific, the log obtained from A. Richards indicates that drilling fluid was maintained in the hole most of the time. The most important features were the occurrence of water at 67 feet and the abrupt loss of water at 72 feet into red cinders. Before the loss, 10 feet of water was reported standing in the well. This behavior indicates a perched source. By August 1962, the well had caved back to 72.3 feet, and contained only 0.4 foot of water. Pebbles dropped into the well during the August 1967 visit indicated no water. The casing was not cemented in at the surface and the annulus was open to an undetermined depth.

A stagnant stream runs through the middle of the swamp. The relatively high rainfall, high frequency of cloud cover, and fog drip maintain the prevailing wet conditions.

A survey of the area indicated the presence of an ash bed, approximately one to three feet thick at many positions along a nearby stream bank and in the stream bottom. As an ash bed did not always underlie the water, which was generally standing in pools with very little movement, it was concluded that there were probably multiple ash beds from the nearby cones. The impermeability of the ash beds creates the swampy condition. Furthermore, the ash has weathered into a dark relatively impermeable soil due to the poor drainage. As a permeability test a rod was rammed into the sides of the stream to a depth below stream level a few inches from the stream. Frequently, even after several minutes, there was no invasion of water into the hole.

Additional evidence of the extreme shallowness of the water was the prevalence of fallen shallow-rooted trees. Despite the strong prevailing wind at this elevation, the distribution of the fallen trees did not favor the downwind direction. Cattle have been credited with felling the trees. The size of some of the trees was impressive.

The Kahua Ranch, which owns most of the land in this area, has experimented with catching fog-drip for water and was not successful because strong winds blew down the catchment framework.

There are several large open reservoirs, owned by the ranch, fed by pipeline from springs in this area and also some smaller ones lined and covered with plastic and is considering several cinder cones as potential sites for additional reservoirs. Keawewai Stream of upper Honokoa Gulch was visited. Where it is crossed by the Kawaihae-Hoepa Trail an estimate of stream flow was made. Waipahoehoe Gulch was dry at all points observed below the highway.

RECONNAISSANCE OF HONOKOA GULCH

In an effort to obtain a geologic profile, a hike of about 1½ miles was made along the coastal reach of Honokoa Gulch. The stream bed was dry but about 2½ miles up from the coast, the entire stream purportedly percolates into the ground, and all surficial flow disappears. This is in contrast to the flow of about 5 mgd observed in the stream approximately 4 miles from the coast. No gaging or flow data are available for this stream. Examination of the sides of the gulch for more than a mile showed some prominent red beds of soil. Frequent voids and caves were observed but moisture seepage was found at only one spot, low on the wall, about three feet above the bed of the stream. Even this minute seepage appeared to be intermittent, as there were plants within a few feet of the seep which had withered. The stream and lava flow gradients are essentially the same along this reach, thus little additional stratigraphic knowledge was gained. Waterfalls occurring further upstream were not examined.

WELLS IN ADJACENT AREAS

The first well drilled on Hawaii was one drilled at Mahukona by McCandless in 1881 (McCandless, 1936). It yielded only salty water, was abandoned, and cannot now be located (D. C. Cox, oral communication).

Two wells have been drilled east of Kawaihae by the State Division of Water and Land Development, starting in Mauna Kea lava flows but presumably penetrating to Kohala lava flows before reaching the water table. Well no. 14, drilled in 1961 at a point 1.5 miles from the shore at an altitude of 500 feet, indicated a head of about 3 feet and a chloride content of about 300 ppm (Anon., 1961a, Davis and Yamanaga, 1963). Well no. 16, drilled in 1963 at a point about 4 miles from the coast at an altitude of 982 feet, indicated a head of about 5 feet, a chloride content of about 250 ppm, and a temperature of 96° to 98°F (Anon., 1963).

A third well, no. 15, drilled by the Division of Water and Land Development in Mauna Kea lavas southeast of Kawaihae, about a mile from the coast at an altitude of 392 feet, indicated a head of about 3 feet and a chloride content of about 500 ppm (Anon., 1961b).

The heads indicated in these three wells near Kawaihae do not indicate any barrier between the Kohala aquifer and the Mauna Kea aquifer in the Kawaihae area. The high water temperature in well no. 16 indicates abnormal geothermal heating. A part of the head measured at this well, and probably at the other wells also, is very likely to be the result of the warmth, and hence low density of the salt water beneath the fresh water, and the thickness of the fresh water is not likely to be as great as would normally be suggested by the heads.

In 1961, Parker Ranch successfully obtained 2 mgd by sinking a pit and then driving a tunnel near Puako (S. P. Bowles, personal communication). The water is currently used for irrigation of pasture and corn. The U. S. Army reportedly improved a spring north of Hapuna Beach by walling it up. Other pits for water reportedly occur at Puako. In the fall of 1966, small ponds mauka of the road, fed by basal water discharge, were observed by C. Lao at Puako. No samples were taken but surrounding vegetation was thriving on the water. A former resident of Puako said the water was brackish. According to Bowles, the best water in the area of which he had knowledge contained 400 ppm chloride. The Puako-Hapuna water developments occur in Mauna Kea flows. Rainfall maps indicate recharge potential is much less than for the Kohala flows.

HYDROLOGIC APPRAISAL

Analysis of available data indicates that probably only a small quantity of rainfall is available for percolation into the ground-water body. A semi-log plot of rainfall versus elevation (Figure 5) shows that the 30-inch isohyet probably occurs at about the 2700-foot elevation. This elevation lies between Puu Uala and Puu Aiea cinder cones associated with Hawi volcanic activity on the rift zone. Hawi series dikes, and perhaps, Pololu series dikes also may constitute a barrier to the seaward discharge of ground water. Although leakage probably occurs through the dikes, an unknown quantity of a larger magnitude probably discharges parallel to the dike system. Therefore, recharge above the line of cinder cones may not be contributing substantially to the basal aquifer in the area in question.

As a rough guide, it has been considered that little infiltration occurs in areas of less than about 30-inches rainfall per year, evaporation and transpiration accounting for most of the rain. The average rate of evapotranspiration depends, of course, on cloud cover, winds, vegetation, fog drip, and especially the distribution of the rainfall in time. During periods of storms, the soil reservoir may be filled and deep percolation may occur, whereas, during periods of light orographic showers there may be no deep percolation. The meteorological data available suggest that about 50 percent of the rainfall in the Kahua area above 2000 feet, about 70 percent at 2000 feet, and about 85 percent at the coast, come during seasonal cyclonic storms. The remainder is orographic.

A close relation exists between soil type and amount of rainfall. A soil map of the U. S. Soil Conservation Service is presented as Figure 6. The Kawaihae series,[1] which occurs from the coast up to about 1200 feet is a member of the Red Desert Great Soil Group, typically showing calcium carbonate accumulation. This suggests that rainfall below the 1200-foot elevation is insufficient to leach minerals consistently down to the water table, and the formation of *caliche* may effectively reduce downward percolation of water. The Puu Pa series,[2] a member of the Reddish Brown Great Soil Group, occurs up to the 2800-foot elevation in the Kahua area. This soil forms under rainfalls of 20 to 35 inches. *Caliche* may form in these deeper soils near bedrock.

The meteorological and soils data suggest that there is not much infiltration directly to the basal ground-water aquifer, and hence not

[1] Kawaihae series is a member of an ashy, isohyperthermic family of Typic Vitrandepts. Typically, these soils are very stony and have a dark reddish brown A horizon. The B horizon is very friable and has a weak prismatic structure. (National Cooperative Soil Survey. Approved, 7-27-67.)

[2] The Puu Pa series is a member of an ashy over fragmental isothermic family of Ustollic Entrandepts. Typically, these soils have a very dark brown A horizon and a very friable C horizon with weak subangular blocky structure. *(Op. cit.)*

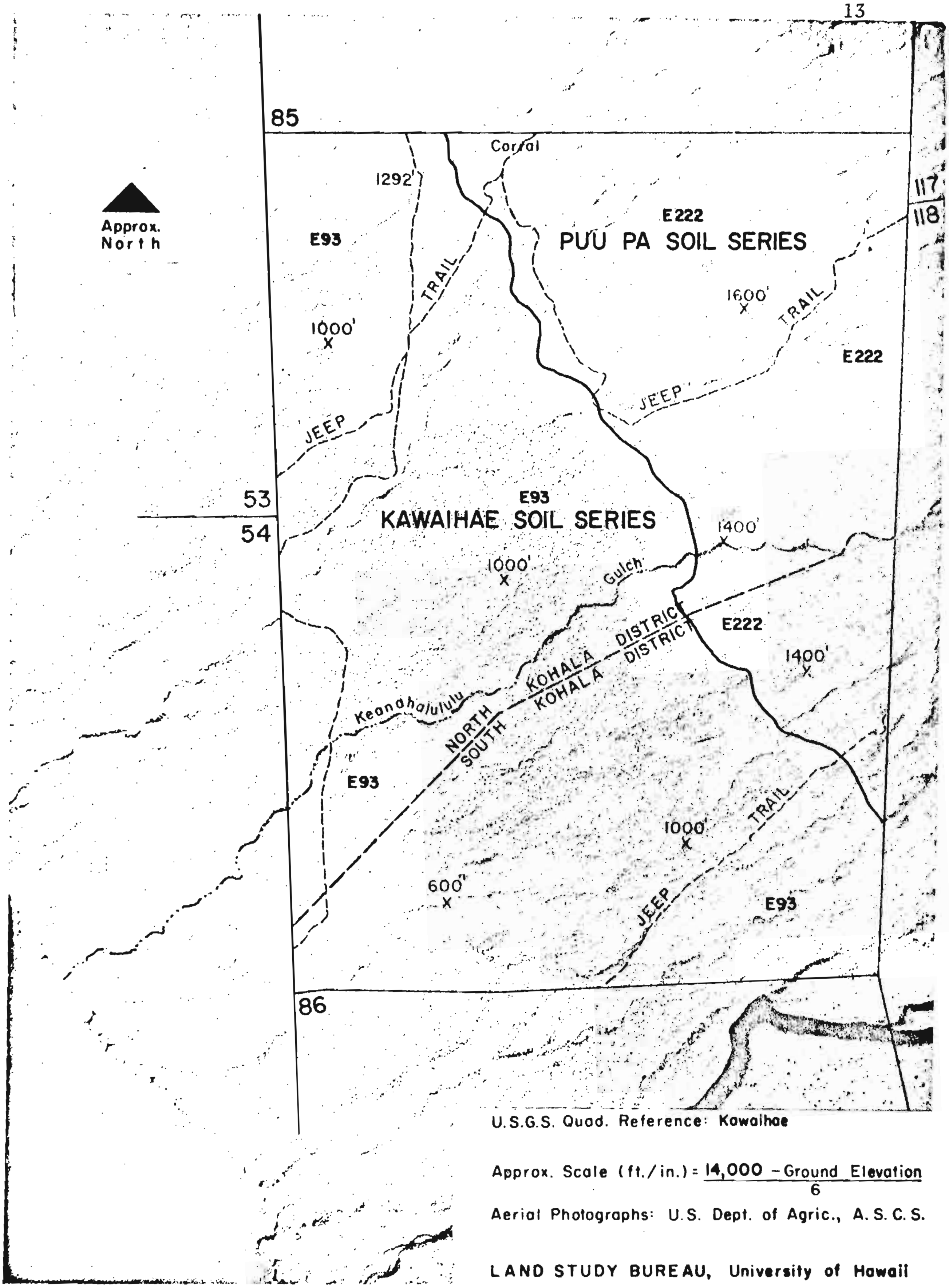

FIGURE 6. SOIL MAP OF THE KAHUA AREA.

much recharge unless water discharge from the dike system in the area is significant.

Nothing observed in the field or from drilling information seems to justify optimism regarding the possible development of fresh water in significant quantities, *e.g.*, a million gallons per day, from this region.

The wells in the area are brackish, have low heads, and can probably yield only small quantities without becoming more saline. The influx to the water table from the high rainfall region is controlled by dikes associated with the numerous cinder cones and the graben along the ridge (see Figure 3). The annual recharge below the dike zone must be small and estimated to be not much more than 15,000 gallons for a strip one foot wide based on recharge rainfall in excess of 20 inches up to the cinder cones.

A line of shallow wells parallel to the coast pumped at low rates to minimize drawdown and head reduction will certainly maximize the available supply without further degrading water quality. The low heads, which occur along this reach of coast, indicate the balance of the Herzberg lens to be rather sensitive as the cushion of fresh water is rather thin even at distances over a mile from the coast. The maximum thickness of the lens would be no more than 120 feet for a head of three feet above sea level, say 1½ miles back, and probably less since the abnormally high temperature of the ground water accounts for a portion of the head.

Selection of a suitable site can be guided by the knowledge that a mile from the shoreline, the head is likely to be about 3 feet. A surface geophysical survey by the resistivity-sounding method might confirm this estimate. It is estimated that an electrical resistivity or induction survey along the road under construction could be run to estimate the relative depth to the brackish interface at an approximate cost of $5000.

Both theory and the history of the wells near Kawaihae indicate that the head and thickness of the Herzberg lens should be greater inland than at the coast. The quality of the water available for development should also improve inland.

The locations of the Kahua and the Kawaihae areas relative to the principal recharge area of the Kohala Mountain range suggest that the hydraulic gradient should be greater in the former than in the latter. To determine the actual head and quality of basal ground water in the Pololu series at some distance from the coast in the Kahua Ranch area, an exploratory well should be drilled. Measurements during carefully controlled pumping tests in such a well would add to measurements of initial head and salinity to provide a basis for a more accurate estimate of the results of actual development. Electric logging of the well would indicate the porosity of the rock and the thickness of the various zones of water quality. From this data the optimum well construction for the particular site could be inferred.

It is apparent from the high chloride content in the wells drilled to date that processing of any water found in the area of interest would be necessary to make it acceptable for most uses. Many methods for such processing can be considered, *e.g.*, reverse osmosis, but the first method to be tested in a pilot plant might be solar stills because of the reliable solar radiation in this area. Demand and supply of prime quality water can be markedly reduced if sanitation and irrigation uses are met by brackish water. Dual supply systems are standard on ocean vessels and have also been successfully implemented in cities such as Coalinga, California. A dual supply should permit a larger development of the area than would a single system.

In order to make a comparison between the costs and risks of finding water locally with the costs and risks of bringing in water from higher elevation, the risk element should be clearly recognized.

ACKNOWLEDGEMENTS

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