HAWAII GEOTHERMAL PROJECT

ENGINEERING PROGRAM

WARM WATER WELLS ON THE ISLAND OF HAWAII

TECHNICAL MEMORANDUM #1

JANUARY 1, 1974

Prepared Under

NATIONAL SCIENCE FOUNDATION

RESEARCH GRANT NO. GI-38319

By

Susan Shito

College of Engineering
University of Hawaii
Honolulu, Hawaii 96822

A literature search on the location and other characteristics of wells producing 79°F (26°C) water or hotter on the island of Hawaii turned up one pertinent publication, THE INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII.[1]

According to this publication, five drilled wells meeting this requirement are located in the Puna and South Kohala districts. They produce water with temperatures ranging from 79°F to 129°F (26°C to 54°C) with chloride contents of 254 ppm to 6200 ppm from elevations of 274 feet to 982.4 feet and static water levels of .56 to 5.24 feet. The diameters of these wells range from 10 inches to 15 inches.

Tables and maps follow. Included are a drilled well index, well location maps, and water quality tables.

---

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R 34 (Honolulu, Hawaii: State of Hawaii, 1970).

TABLE I

TABLE OF DRILLED WELLS EQUAL TO OR GREATER THAN 79°F[1]

USGS[2] NO.	WELL	OWNER	DISTRICT	LAT./LONG.	ELEV. (ft.)	YEAR DRILLED	DEPTH (ft.)	DIAM. (in.)	STATIC WATER LEVEL (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)	USE	DATA LOCATION
9-6	KAPOHO	County Hawaii BWS[3]	Puna	19 30 30 154 52 23	286.75	1960	337.15	12	3.15	338	93		DOWALD[4]
9-9	MALAMA-KI	Hawaii State DOWALD	Puna	19 27 30 154 53 00	274	1962	316	13	.56	6200	129	Not	DOWALD
14	KAWAIHAE WELL 1	Hawaii State DOWALD	S. Kohala	20 01 50 155 48 05	580	1961	620	15	3.3	302	81	Domes-tic	DOWALD
15	KAWAIHAE WELL 2	"	"	20 10 00 155 48 33	392.19	"	429.5	15	5.12	504	79	"	"
16	KAWAIHAE	"	"	20 01 47 155 47 13	982.4	1963	1046	10	5.24	254	97	Not	"

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R34 (Honolulu, HI: State of Hawaii, 1970), pp. 145-146.

[2] United States Geological Survey

[3] Board of Water Supply

[4] Department of Water and Land Development

TABLE II

WELL PUMPING TEST RECORDS[1]

Well No. 9-8 — KAPOHO

GENERAL INFORMATION

Contractor:	Ocean View Drilling Co.
Drilling equipment:	Percussion (cable tool) Walker Neer WS 31; Keystone 5D.
Drilling date:	September 18, 1960-December 22, 1960.
Ground elevation:	256.75 ft.
Total depth of well:	337.15 ft.
Size of hole:	11-3/4 in.
Elevation bottom of well:	-50.40 ft.

PUMPING TEST DATA

Date of pumping test:	January 27-30, 1961
Duration of pumping test:	76 hrs.
Depth to water level:	283.60 ft.
Length of airline:	303.02 ft.
Elevation centerline air-gage:	290.46 ft.
Elevation bottom airline	-12.56 ft.
Static water level above msl:	3.15 ft.
Maximum drawdown:	1.02 ft. at 317 gpm.
Rate of recovery:	Immediate.
Salinity (chlorides):	331-345 ppm.
Water temperature:	92-94°F

Well No. 9-9 — MALAMA-KI

GENERAL INFORMATION

Contractor:	Ocean View Drilling Co., Ltd.
Drilling equipment:	Bucyrus-Erie 22-W percussion rig.
Drilling date:	August 30, 1962 (completion).
Ground elevation:	274 ft. above msl.
Total depth of well:	318 ft.
Size of hole:	13 in.
Casing:	Outer diameter, 6-5/8 in.; length, 318 ft. (bottom 48 ft. perforated).

PUMPING TEST DATA

Date of pumping test:	September 6-7, 1962.
Static water level above msl:	+0.54 to +0.84 ft.
Drawdown:	0.07 ft. at 100 gpm; 0.30 ft. at 300 gpm; 0.76 ft. at 480 gpm.
Salinity (chlorides):	6,400 -7,000 ppm.
Water temperature:	129°F.
Personnel:	Don Davis, U.S. Geological Survey; Stanley Shin, Sam Wong, State Division of Water and Land Dev.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP (°F)
September 6, 1962						
10:50 am	Start pump.					
10:52	—	—	—	0	7,240	127.50
10:57	130	—	—	0	—	—
	Decrease engine speed.					
11:03	106	—	—	0	5,690	128.25
11:15	54	—	—	0	5,530	129.00
	Adjust motor.					
11:23	98	—	—	0	5,690	129.50
11:45	106	—	—	0	5,690	129.75
12:00 N	128	—	—	0	5,900	129.50
12:30 pm	101	—	—	0	6,180	129.75
1:00	80	—	—	0	6,370	130.50
	Increase engine speed.					
1:10	114	—	—	—	—	—
1:30	128	—	—	0	5,690	129.50
2:00	127	—	—	0	5,610	129.50
2:30	120	—	—	0.05	5,760	130.00
3:00	80	—	—	0.05	5,610	130.00
	Increase engine speed.					
3:15	106	—	—	—	—	—
3:30	101	—	—	0.07	5,860	129.50
4:00	118	—	—	0.11	6,020	129.50
4:03	Increase engine speed.					
4:05	350	—	—	0.16	—	—
4:15	360	—	—	0.16	6,830	129.25
5:00	360	—	—	0.18	6,590	129.00
5:28	—	—	—	0.23	—	129.00
5:30	370	—	—	0.23	6,672	129.00
6:00	320	—	—	0.23	6,870	129.00
7:00	355	—	—	0.23	6,590	129.00
8:00	340	—	—	0.23	6,590	129.00
9:00	335	—	—	0.23	6,750	129.00
10:00	340	—	—	0.23	6,670	129.00
11:00	380	—	—	0.30	6,830	129.00
12:00 M	365	—	—	0.30	6,830	129.00
September 7, 1962						
1:00 am	400	—	—	0.43	6,910	128.50
2:00	430	—	—	0.53	7,000	128.75
3:00	450	—	—	0.60	6,910	128.75
4:00	480	—	—	0.65	6,910	128.75
5:00	480	—	—	0.74	6,910	128.50
6:00	430	—	—	0.69	6,830	128.50
7:00	420	—	—	0.65	6,750	128.50
8:00	450	—	—	0.60	6,670	128.50
9:00	480	—	—	0.67	6,590	127.50
10:00	480	—	—	0.30	6,670	127.25
10:08	Stop pump.					
	Recovery test.					
10:08:30	0	—	—	0.18	—	—
10:09:00	0	—	—	0.18	—	—
10:09:30	0	—	—	0.18	—	—
10:10:00	0	—	—	0.18	—	—
10:10:30	0	—	—	0.18	—	—
10:11:00	0	—	—	0.18	—	—
10:11:30	0	—	—	0.18	—	—
10:12:00	0	—	—	0.18	—	—
10:12:30	0	—	—	0.18	—	—
10:13:00	0	—	—	0.18	—	—

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R 34, (Honolulu, HI: State of Hawaii, 1970), pp. 149-150, 153-154.

TABLE II (con't)

Well No. 14 — KAWAIHAE WELL 1

GENERAL INFORMATION

Contractor:	Samson and Zerbe, Ltd.
Drilling equipment:	Bucyrus Erie 28-L drill rig.
Drilling date:	October 8, 1960-January 26, 1961.
Ground elevation:	579.37 ft., msl.
Total depth of well:	620 ft.
Size of drilled hole:	15 in.

PUMPING TEST DATA

Date of pumping test:	February 15-18, 1961.
Length of airline:	615.83 ft.
Elevation centerline air gage:	579.37 ft.
Static water level:	3.27 ft.
Salinity (chlorides):	296-308 p.p.m.
Drawdown:	0 ft. at 50 gpm; 0 ft. at 100 gpm; 0.04-0.05 ft. at 150 gpm; 0.04-0.11 ft. at 180 gpm.
Water temperature:	81°F.
Personnel:	Sam Wong, Hawaii Division of Hydrography.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
February 15, 1961						
7:45 am	0	—	—	(static)	—	—
7:55	0	—	—	(static)	—	—
8:00	Start pump.					
8:10	52	—	—	—	—	—
8:15	54	—	—	—	302	—
8:20	55	—	—	—	—	82
8:30	57	—	—	—	298	82
8:37	57	—	—	—	—	—
8:45	60	—	—	—	302	82
8:48	Increase engine speed.					
8:53	100	—	—	0	—	82
9:00	100	—	—	—	298	81.5
9:15	100	—	—	—	302	81.5
9:30	102	—	—	—	298	81.5
9:45	102	—	—	—	308	81.5
10:00	102	—	—	—	298	81.5
10:02	Increase engine speed.					
10:05	146	—	—	0.07	302	81
10:10	148	—	—	0.07	—	—
10:10	148	—	—	0.04	308	81
10:35	148	—	—	0.04	308	81
10:50	148	—	—	0.07	308	81
11:05	150	—	—	0	308	81
11:06	Increase engine speed.					
11:09	180	—	—	0.14	308	81
11:25	180	—	—	0.18	302	81
11:40	180	—	—	0.21	302	81
12:00 N	180	—	—	0	302	81
12:30 pm	180	—	—	0.11	302	81
1:00	180	—	—	0.11	308	81
1:30	180	—	—	0.11	308	81
2:00	177	—	—	0.04	308	81
2:30	180	—	—	0.11	302	81
3:00	179	—	—	0.04	308	81
3:30	179	—	—	0.07	305	81
4:00	180	—	—	0.07	302	81
8:00	180	—	—	0.18	302	81
12:00 M	180	—	—	0.34	302	80.5
February 16, 1961						
4:00 am	177	—	—	0.34	298	81
8:00	183	—	—	0.11	298	81
10:00	178	—	—	0	302	81
12:00 N	176	—	—	0.04	305	81
12:10 pm	Short circuit in generator; stop pump.					
12:33	Start pump.					
12:35	178	—	—	—	—	—
1:00	175	—	—	—	—	—
2:00	176	—	—	0	308	81
3:00	175	—	—	0.04	302	81
4:00	174	—	—	0.04	298	81
6:00	178	—	—	0.07	298	81
8:00	174	—	—	0.23	298	81.5
10:00	175	—	—	0.34	298	81.5
12:00 M	176	—	—	0.34	302	81.5
February 17, 1961						
2:00 am	177	—	—	0.34	302	81
4:00	174	—	—	0.34	298	81
6:00	174	—	—	0.41	298	81
8:00	174	—	—	0.41	—	81
8:00	174	—	—	0.39	298	81
10:00	174	—	—	0.18	298	81
12:00 N	172	—	—	0	302	81
3:00 pm	173	—	—	—	298	81
4:00	172	—	—	0.04	302	81
6:00	172	—	—	0.18	298	81
8:00	171	—	—	0.34	302	81
10:00	171	—	—	0.48	302	81
12:00 M	173	—	—	0.34	302	80.5
3:30 am	172	—	—	0.34	302	81
4:00	173	—	—	0.34	302	81
7:00	172	—	—	0.34	302	81
8:00	159	—	—	0.32	302	81
10:00	176	—	—	0.23	302	81
11:10	174	—	—	0.11	302	81
11:11	Stop pump.					
11:11:30	0	—	—	—	—	—

Well No. 15 — KAWAIHAE WELL 2

GENERAL INFORMATION

Contractor:	Samson and Zerbe, Ltd.
Drilling equipment:	Bucyrus Erie 28-L drill rig.
Drilling date:	March 9-June 1, 1961.
Ground elevation:	392.19 ft., msl.
Total depth of well:	420.5 ft.
Size of hole:	15 in.
Casing:	Inner diameter, 10 in.; 420.5 ft. (bottom 40 ft. perforated).

PUMPING TEST DATA

Date of pumping test:	June 6-8, 1961.
Length of airline:	412.60 ft.
Elevation centerline air gage:	392.19 ft.
Static water level:	3.3 ft. (electric sounding probe before test); 5.12 ft. (airline after test).
Salinity (chlorides):	504 ppm.
Drawdown:	0 ft. at 50, 100, 150, and 180 gpm.
Water temperature:	75°F.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
June 6, 1961						
	0	—	—	—	—	—
8:00 am	Start pump.					
8:15	50	—	—	0	504	—
8:30	55	—	—	—	504	—
8:45	55	—	—	—	—	—
9:00	55	—	—	—	504	—
9:06	Increase engine speed.					
9:15	108	—	—	—	504	—
9:30	114	—	—	0.47(?)	498	—
9:45	110	—	—	0	—	—
10:00	112	—	—	—	498	—
10:03	Increase engine speed.					
10:05	152	—	—	—	—	—
10:15	152	—	—	0	504	—
10:30	148	—	—	—	504	—
10:45	147	—	—	—	—	—
11:00	147	—	—	0	498	—
11:02	Increase engine speed.					
11:04	183	—	—	0	—	—
11:15	182	—	—	—	498	—
11:30	177	—	—	0	498	—
11:33	107	Adjust to increase rate.				
12:00 N	183	—	—	—	504	—
12:30 pm	184	—	—	0	504	—
1:00	183	—	—	0	504	—
1:30	184	—	—	0	—	—
2:00	185	—	—	0	498	—
2:30	184	—	—	0	—	—
3:00	185	—	—	0	504	—
3:30	187	—	—	—	—	—
4:00	189	—	—	0	504	—
8:00	189	—	—	0	455	—
10:00	180	—	—	0	—	—
12:00 M	185	—	—	0	504	—
June 7, 1961						
2:00 am	184	—	—	0	—	—
4:00	180	—	—	0	504	—
6:00	181	—	—	0	—	—
8:00	180	—	—	0	498	—
8:25	Install USGS test gage.					
8:30	184	—	—	0	—	78.5
10:00	187	—	—	0	504	79
12:00 N	187	—	—	—	504	79
2:00	185	—	—	—	504	79
4:00	187	—	—	—	504	79
6:00	188	—	—	—	504	79
8:00	181	—	—	0	498	79
10:00	176	—	—	0	504	79
12:00 M	185	—	—	—	504	79
June 8, 1961						
2:00 am	179	—	—	—	504	79
4:00	179	—	—	—	498	79
6:00	179	—	—	0	504	79
8:00	184	—	—	0	504	79
9:06	179	—	—	—	504	79
11:00	185	—	—	—	504	79
11:05	Stop pump.					

Well No. 16 — KAWAIHAE

GENERAL INFORMATION

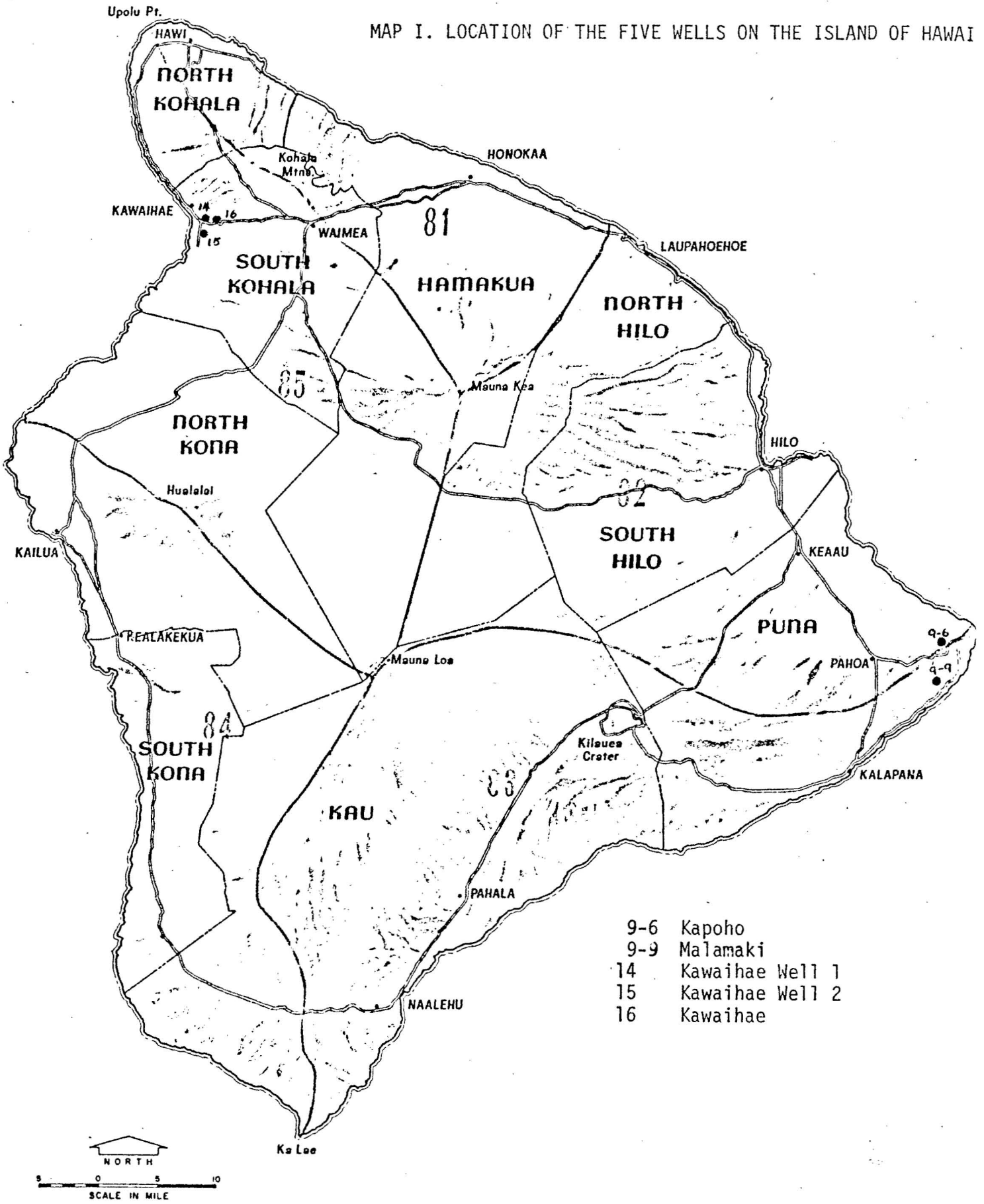
Contractor:	Ocean View Drilling Co., Ltd.
Drilling equipment:	Failing 2500 rotary drill rig.
Drilling date:	May 14-June 10, 1963.
Ground elevation:	842 ft., msl.
Total depth of well:	1,040 ft.
Size of hole:	10 in.
Casing:	Inner diameter, 8 5/8 in.; length, 1041 ft. (bottom 43 ft. perforated).

PUMPING TEST DATA

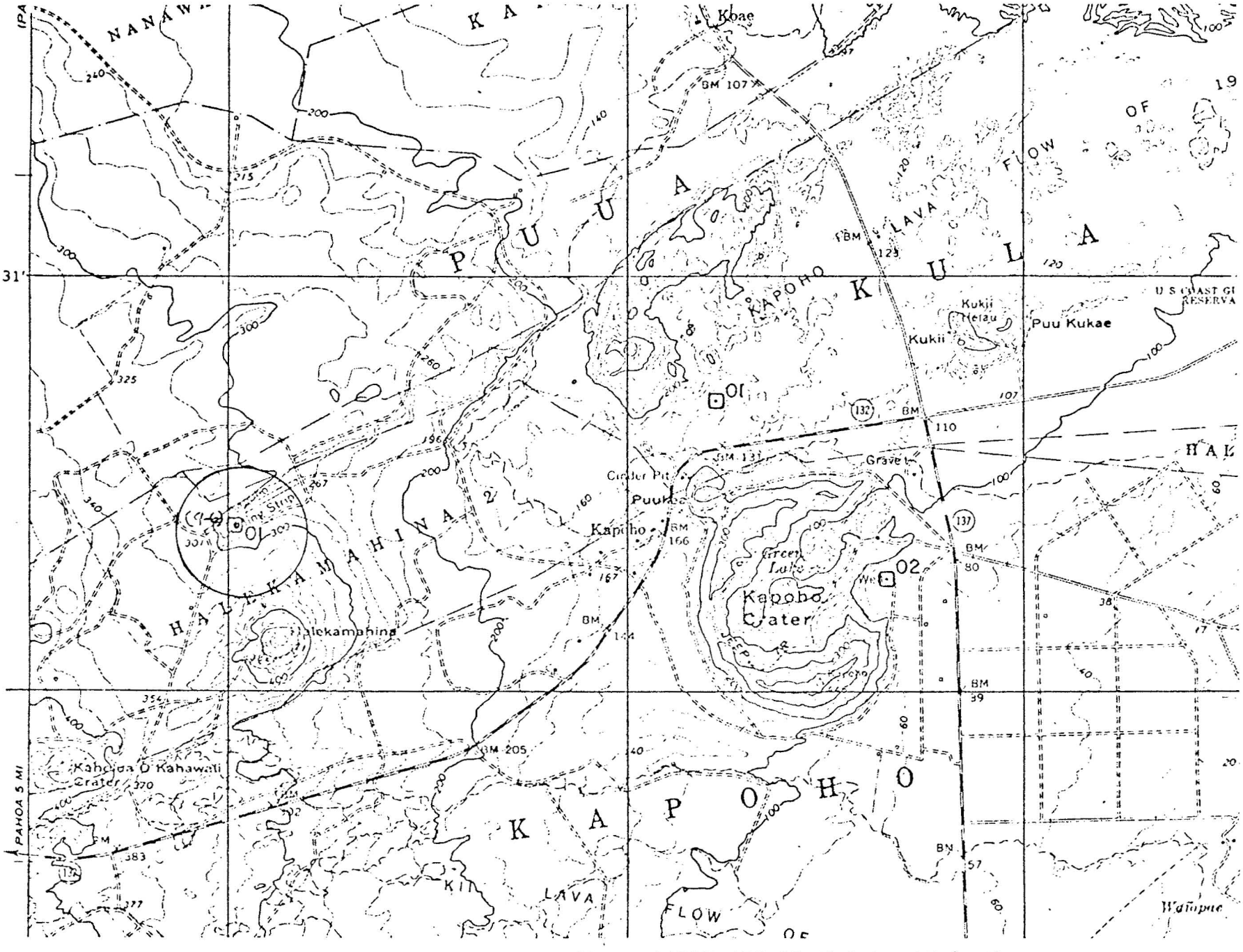
Date of pumping test:	June 24-28, 1963.
Static water level:	4.62 ft. (June 24, 1963).
Salinity (chlorides):	222-264 ppm.
Drawdown:	2.8 ft. at 100 gpm; 8.5 ft. at 250 gpm.
Water temperature:	83-86°F.
Personnel:	Daniel Lum, Linford Chang, Ken Sakuma, Division of Water and Land Development; Jack Rosenau, U.S. Geological Survey.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
June 24, 1963						
1:25 pm	0	—	—	0	—	—
1:34	0	—	—	0	—	—
1:35	Start pump.					
1:45	75	—	—	1.62	229	92
2:00	80	—	—	1.85	234	98.5
2:15	85	—	—	1.90	234	98
2:30	90	—	—	1.96	234	99
2:45	85	—	—	2.06	234	99
3:00	85	—	—	2.03	234	98
3:15	90	—	—	2.09	239	97.5
3:30	90	—	—	2.19	234	97.5
3:45	90	—	—	2.19	234	97
4:00	90	—	—	2.19	234	97
4:30	90	—	—	2.19	234	96.5
5:00	95	—	—	2.31	244	97
8:00	85	—	—	2.47	244	96.5
9:00	100	—	—	2.34	244	97
10:00	100	—	—	2.54	244	96.5
11:00	100	—	—	2.66	244	96.5
12:00 M	100	—	—	2.68	234	96.5
June 25, 1963						
2:00 am	100	—	—	2.65	239	96.5
4:00	100	—	—	2.77	239	96
6:00	100	—	—	2.77	244	95
8:00	100	—	—	2.77	239	96.5
10:00	105	—	—	2.89	244	96
12:00 N	100	—	—	2.77	254	96.5
2:00 pm	100	—	—	2.77	244	96.5
4:00	100	—	—	2.77	244	96.5
7:15	100	—	—	2.77	244	96.5
8:00	100	—	—	2.89	254	96
10:00	100	—	—	2.77	244	96
12:00 M	100	—	—	2.77	244	97
June 26, 1963						
2:00 am	100	—	—	2.77	254	96
4:00	100	—	—	2.77	254	96.5
6:00	95	—	—	2.77	259	96.5
7:50	Adjust pump.					
8:00	108	—	—	3.12	259	93.5
10:00	110	—	—	3.12	254	96.5
10:05	Adjust pump.					
10:20	100	—	—	2.89	—	—
12:00 N	100	—	—	2.89	254	97.5
2:00 pm	100	—	—	2.77	254	96.5
	Increase pumping rate.					
3:17	200	—	—	7.62	—	—
3:24	210	—	—	8.09	254	97
3:35	190	—	—	7.85	254	97
	Pressure gage fluctuating between 4.40 and 4.80 psi.					
3:00	209	—	—	8.76	254	96.5
3:30	200	—	—	8.31	—	97
4:00	200	—	—	8.54	254	97
6:30	200	—	—	8.54	259	96.5
8:00	200	—	—	8.78	254	96
10:00	200	—	—	8.54	254	96
12:00 M	200	—	—	8.31	254	97
June 27, 1963						
2:00 am	200	—	—	8.31	259	96.5
4:00	200	—	—	8.31	254	96
5:522	Stop pump due to lack of fuel					
6:40	0	—	—	0	—	—
7:35	Start pump.					
7:39	—	—	—	8.54	—	—
7:42	202	—	—	8.54	259	—
7:43	Stop pump to repair oil line.					
7:50	—	—	—	0	—	—
10:25	Start pump.					
10:28	—	—	—	8.08	—	—
10:30	1002	—	—	2.54	—	—
10:31	502	—	—	1.62	—	—
10:35	72	—	—	—	264	94.5
10:50	—	—	—	1.96	—	—
10:53	77	—	—	—	—	—
10:57	—	—	—	—	264	97.5
11:30	70	—	—	1.73	264	98
11:40	Increase pumping rate.					
11:45	114	—	—	3.12	—	—
2:15 pm	110	—	—	4.04	254	96.5
5:15	120	—	—	3.69	249	96.5
8:30	120	—	—	4.70	259	96
12:00 M	120	—	—	3.81	259	96
June 28, 1963						
3:00 am	120	—	—	4.04	259	96
6:00	120	—	—	4.04	264	96
9:00	115	—	—	4.04	264	96.5
12:00 N	110	—	—	4.04	264	96.5
12:06	Stop pump.					

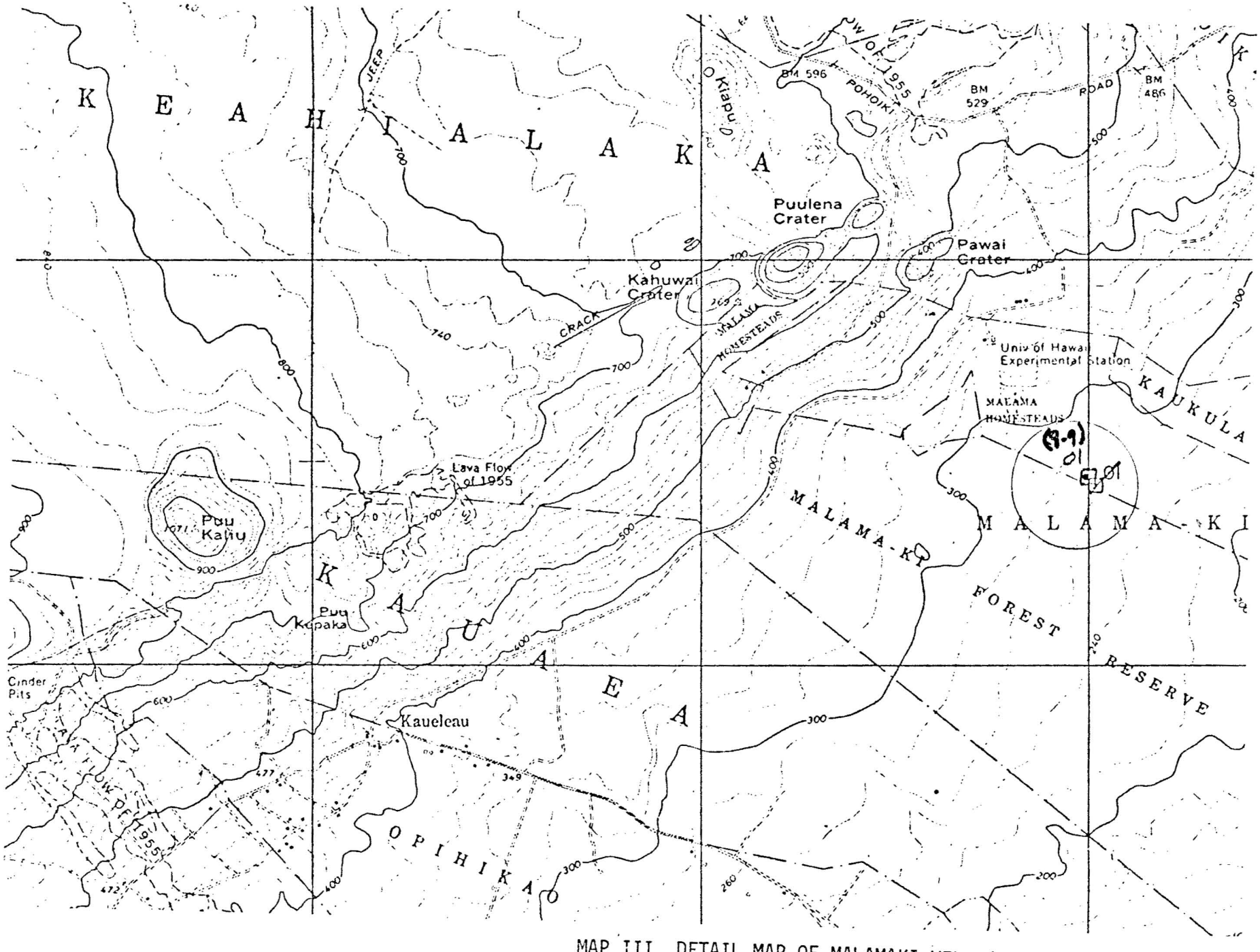
MAP I. LOCATION OF THE FIVE WELLS ON THE ISLAND OF HAWAI



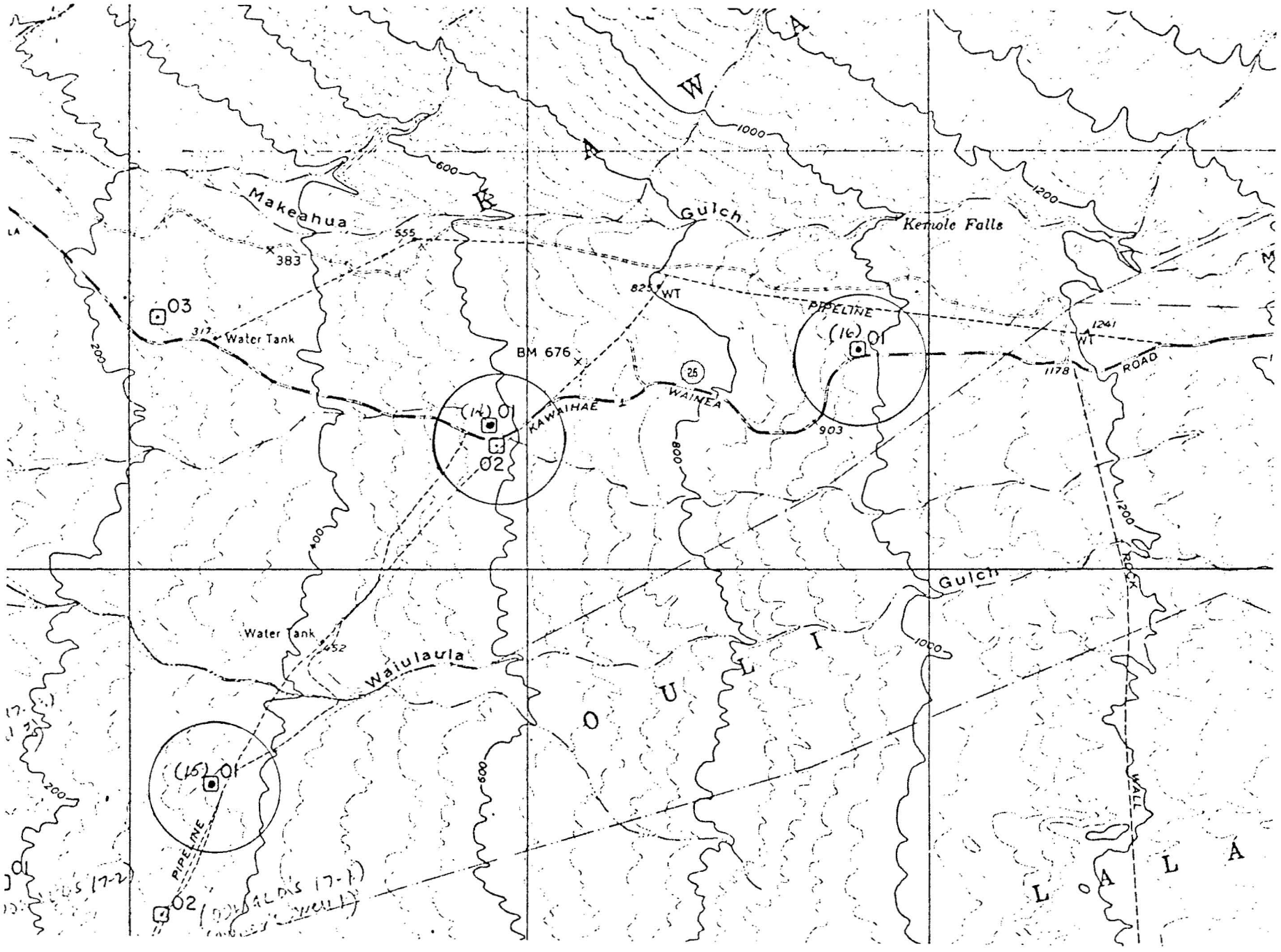
9-6 Kapoho
9-9 Malamaki
14 Kawaihae Well 1
15 Kawaihae Well 2
16 Kawaihae



MAP II. DETAIL MAP OF KAPOHO WELL (9-6)



MAP III. DETAIL MAP OF MALAMAKI WELL (9-9)



MAP IV. DETAIL MAP OF KAWAIHAE WELLS (14, 15, 16)

TABLE III

WATER QUALITY RECORDS[1]

FOR MALAMA-KI (#9-9) AND KAWAIHAE (#16) WELLS

	#9-9	#16	
	1962	1961	1963
pH 25°C	--	--	--
pH 30°C	6.92	7.7	7.3
Color	20	0	5
Ordor	musty	0	chem. hyd.
Turbidity	8	10	1
Nitrites	0.005	0	0.001
Nitrates	0.5	0	2.89
Hydroxide Alkalinity	0	0	0
Bicarbonate Alkalinity	215	78	89
Total Alkalinity	215	78	89
Total Hardness	1790	250	214
Total Solids	11700	1200	796
Loss on Ignition	1730	212	240
Silica	59.0	30	89.2
Iron and Aluminum	104.8	--	--
Iron	3.16	--	--
Aluminum	101.2	--	0.05
Calcium	182	53.6	31.5
Magnesium	324	27.8	32.8
Sulfate	681	90.8	54
Sodium and Potash	3090	0	149.5
Chlorides	5850	550	250
Arsenic	0.01	--	0.01
Fluoride	1.5	--	0.2
Manganese	0.05	0.1	0.05
Lead	0.01	--	0.01
Copper	0.2	--	0.13
Zinc	0.2	--	0.1
Selenium	0.08	--	0.01
Phenols	0.001	--	0.001

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R34 (Honolulu, HI: State of Hawaii, 1970), pp. 186-187.

TABLE IV

MAXIMUM ALLOWABLE CHEMICAL CONCENTRATIONS (PPM)[1]

IN DRINKING WATER BY THE UNITED STATES PUBLIC HEALTH SERVICE

Arsenic	0.01
Chlorides	250
Copper	1
Iron	0.3
Manganese	0.05
Nitrates	45
Phenols	0.001
Sulfate	250
Total Solids	500
Zinc	5

[1]Parts per million
State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R34 (Honolulu, HI: State of Hawaii, 1970), p. 181.

TABLE V

ELEMENTS IN SEA WATER[1]

Element	PPM[2]
SILICON[3]	4
ALUMINUM	0.5
IRON	0.02
CALCIUM	408
SODIUM	10,769
POTASSIUM	387
MAGNESIUM	1,297
MANGANESE	0.01
Phosphorus	0.1
CARBON	28
SULPHUR	901
CHLORINE	19,353
STRONTIUM	13
Barium	0.05
Rubidium	0.2
FLUORINE	1.4
Chromium	p[4]
COPPER	0.01
Nickel	0.0001
Vanadium	0.0003
Lithium	0.1
Cerium	0.0004
Cobalt	p
Tin	p
Zinc	0.005
Yttrium	0.0003
Lanthanum	0.0003
LEAD	0.004
Molybdenum	0.0005
Thorium	<0.0005
Cesium	0.002
ARSENIC	0.02
Sandium	0.00004
BROMINE	66
BORON	4.7
Uranium	0.015
SELENIUM	0.004
Cadmium	p
Mercury	0.00003
Iodine	0.05
Silver	0.0003
Gold	$0.0_{5}6$
Radium	$0.0_{9}3$

[1]Assuming salinity of 35 parts per thousand and volume of 1.37×10^{9} km^{3} H.U. Sverdrup, M. W. Johnson, R. H. Fleming, THE OCEANS (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1942), p. 220.

[2]Parts per million

[3]Capitalization indicates elements referred to on preceeding tables

[4]Present

HAWAII GEOTHERMAL PROJECT

ENGINEERING PROGRAM

TECHNICAL MEMORANDUM #1

JANUARY 1, 1974

Prepared Under

NATIONAL SCIENCE FOUNDATION

RESEARCH GRANT NO. GI-38319

By

Susan Shito

College of Engineering
University of Hawaii
Honolulu, Hawaii 96822

A literature search on the location and other characteristics of wells producing 79°F (26°C) water or hotter on the island of Hawaii turned up one pertinent publication, THE INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII.[1]

According to this publication, five drilled wells meeting this requirement are located in the Puna and South Kohala districts. They produce water with temperatures ranging from 79°F to 129°F (26°C to 54°C) with chloride contents of 254 ppm to 6200 ppm from elevations of 274 feet to 982.4 feet and static water levels of .56 to 5.24 feet. The diameters of these wells range from 10 inches to 15 inches.

Tables and maps follow. Included are a drilled well index, well location maps, and water quality tables.

---

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R 34 (Honolulu, Hawaii: State of Hawaii, 1970).

TABLE I

TABLE OF DRILLED WELLS EQUAL TO OR GREATER THAN 79°F[1]

USGS[2] NO.	WELL	OWNER	DISTRICT	LAT./LONG.	ELEV. (ft.)	YEAR DRILLED	DEPTH (ft.)	DIAM. (in.)	STATIC WATER LEVEL (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)	USE	DATA LOCATION
9-6	KAPOHO	County Hawaii BWS[3]	Puna	19 30 30 154 52 23	286.75	1960	337.15	12	3.15	338	93		DOWALD[4]
9-9	MALAMA-KI	Hawaii State DOWALD	Puna	19 27 30 154 53 00	274	1962	316	13	.56	6200	129	Not	DOWALD
14	KAWAIHAE WELL 1	Hawaii State DOWALD	S. Kohala	20 01 50 155 48 05	580	1961	620	15	3.3	302	81	Domes-tic	DOWALD
15	KAWAIHAE WELL 2	"	"	20 10 00 155 48 33	392.19	"	429.5	15	5.12	504	79	"	"
16	KAWAIHAE	"	"	20 01 47 155 47 13	982.4	1963	1046	10	5.24	254	97	Not	"

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R34 (Honolulu, HI: State of Hawaii, 1970), pp. 145-146.

[2] United States Geological Survey

[3] Board of Water Supply

[4] Department of Water and Land Development

TABLE II

WELL PUMPING TEST RECORDS[1]

Well No. 9-8 — KAPOHO

GENERAL INFORMATION

Contractor:	Ocean View Drilling Co.
Drilling equipment:	Percussion (cable tool) Walker beer WS 31; Keystone 5D.
Drilling date:	September 18, 1960-December 22, 1960.
Ground elevation:	286.75 ft.
Total depth of well:	337.15 ft.
Size of hole:	11-3/4 in.
Elevation bottom of well:	-50.40 ft.

PUMPING TEST DATA

Date of pumping test:	January 27-30, 1961
Duration of pumping test:	76 hrs.
Depth to water level:	283.60 ft.
Length of airline:	303.02 ft.
Elevation centerline air-gage:	290.46 ft.
Elevation bottom airline	-12.56 ft.
Static water level above msl:	3.15 ft.
Maximum drawdown:	1.02 ft. at 317 gpm.
Rate of recovery:	Immediate.
Salinity (chlorides):	331-345 ppm.
Water temperature:	92-94°F

Well No. 9-9 — MALAMA-KI

GENERAL INFORMATION

Contractor:	Ocean View Drilling Co., Ltd.
Drilling equipment:	Bucyrus-Erie 22-W percussion rig.
Drilling date:	August 30, 1962 (completion).
Ground elevation:	274 ft. above msl.
Total depth of well:	316 ft.
Size of hole:	13 in.
Casing:	Outer diameter, 8-5/8 in.; length, 319 ft. (bottom 48 ft. perforated).

PUMPING TEST DATA

Date of pumping test:	September 6-7, 1962.
Static water level above msl:	+0.56 to +0.88 ft.
Drawdown:	0.07 ft. at 100 gpm; 0.30 ft. at 380 gpm; 0.76 ft. at 480 gpm.
Salinity (chlorides):	6,400 -7,000 ppm.
Water temperature:	129°F.
Personnel:	Dan Davis, U.S. Geological Survey; Stanley Shin, Sam Wong, State Division of Water and Land Dev.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
September 6, 1962						
10:50 am	Start pump.					
10:52	—	—	—	0	7,240	127.50
10:57	130	—	—	0	—	—
	Decrease engine speed.					
11:03	108	—	—	0	5,690	128.25
11:15	56	—	—	0	5,530	129.00
	Adjust motor.					
11:23	98	—	—	0	5,690	129.50
11:45	106	—	—	0	5,690	129.75
12:00 N	128	—	—	0	5,900	129.50
12:30 pm	101	—	—	0	6,180	129.75
1:00	80	—	—	0	5,370	130.50
	Increase engine speed.					
1:10	114	—	—	—	—	—
1:30	128	—	—	0	5,690	129.50
2:00	137	—	—	0	5,610	129.50
2:30	120	—	—	0.05	5,780	130.00
3:00	80	—	—	0.05	5,610	130.00
	Increase engine speed.					
3:15	106	—	—	—	—	—
3:30	101	—	—	0.07	5,860	129.50
4:00	110	—	—	0.11	6,020	129.50
4:03	Increase engine speed.					
4:05	350	—	—	0.18	—	—
4:15	360	—	—	0.16	6,840	129.25
5:00	360	—	—	0.18	6,590	129.00
5:20	—	—	—	0.23	—	129.00
5:30	370	—	—	0.23	6,670	129.00
6:00	380	—	—	0.23	6,670	129.00
7:00	355	—	—	0.23	6,590	129.00
8:00	380	—	—	0.23	6,590	129.00
9:00	335	—	—	0.23	6,750	129.00
10:00	380	—	—	0.23	6,670	129.00
11:00	380	—	—	0.30	6,830	129.00
12:00 M	380	—	—	0.30	6,830	129.00
September 7, 1962						
1:00 am	400	—	—	0.42	6,910	128.50
2:00	430	—	—	0.53	7,000	128.75
3:00	450	—	—	0.60	6,910	128.75
4:00	480	—	—	0.65	6,910	128.75
5:00	480	—	—	0.76	6,910	128.50
6:00	430	—	—	0.69	6,830	128.50
7:00	480	—	—	0.65	6,750	128.50
8:00	450	—	—	0.60	6,670	128.50
9:00	480	—	—	0.67	6,590	127.50
10:00	480	—	—	0.30	6,670	127.25
10:08	Stop pump.					
	Recovery test.					
10:08:30	0	—	—	0.18	—	—
10:09:00	0	—	—	0.18	—	—
10:09:30	0	—	—	0.18	—	—
10:10:00	0	—	—	0.18	—	—
10:10:30	0	—	—	0.18	—	—
10:11:00	0	—	—	0.18	—	—
10:11:30	0	—	—	0.18	—	—
10:12:00	0	—	—	0.18	—	—
10:12:30	0	—	—	0.18	—	—
10:13:00	0	—	—	0.18	—	—

[1] State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R 34, (Honolulu, HI: State of Hawaii, 1970), pp. 149-150, 153-154.

TABLE II (con't)

Well No. 14 — KAWAIHAE WELL 1

GENERAL INFORMATION

Contractor:	Samson and Zerbe, Ltd.
Drilling equipment:	Bucyrus Erie 28-L drill rig.
Drilling date:	October 8, 1960-January 26, 1961.
Ground elevation:	579.37 ft., msl.
Total depth of well:	620 ft.
Size of drilled hole:	15 in.

PUMPING TEST DATA

Date of pumping test:	February 15-18, 1961.
Length of airline:	615.83 ft.
Elevation centerline air gage:	579.37 ft.
Static water level:	3.27 ft.
Salinity (chlorides):	298-308 ppm.
Drawdown:	0 ft. at 50 gpm; 0 ft. at 100 gpm; 0.04-0.07 ft. at 150 gpm; 0.04-0.11 ft. at 180 gpm.
Water temperature:	81°F.
Personnel:	Sam Wong, Hawaii Division of Hydrography.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
February 15, 1961						
7:45 am	0	—	—	(static)	—	—
7:55	0	—	—	(static)	—	—
8:00	Start pump.					
8:10	52	—	—	—	—	—
8:15	54	—	—	—	302	—
8:20	55	—	—	—	—	82
8:30	57	—	—	—	298	82
8:37	57	—	—	—	—	—
8:45	50	—	—	—	302	82
8:48	Increase engine speed.					
8:53	100	—	—	0	—	82
9:00	100	—	—	—	298	81.5
9:15	100	—	—	—	302	81.5
9:30	102	—	—	—	298	81.5
9:45	102	—	—	—	308	81.5
10:00	103	—	—	—	298	81.5
10:02	Increase engine speed.					
10:05	146	—	—	0.07	302	81
10:10	148	—	—	0.07	—	—
10:20	148	—	—	0.04	308	81
10:35	148	—	—	0.04	308	81
10:50	148	—	—	0.07	308	81
11:05	150	—	—	0	308	81
11:06	Increase engine speed.					
11:09	180	—	—	0.14	308	81
11:25	180	—	—	0.18	302	81
11:40	180	—	—	0.21	302	81
12:00 N	180	—	—	0	302	81
12:30 pm	180	—	—	0.11	302	81
1:00	180	—	—	0.11	308	81
1:30	180	—	—	0.11	308	81
2:00	177	—	—	0.04	308	81
2:30	180	—	—	0.11	302	81
3:00	179	—	—	0.04	308	81
3:30	179	—	—	0.07	305	81
4:00	180	—	—	0.07	302	81
8:00	180	—	—	0.28	302	81
12:00 M	180	—	—	0.34	302	80.5
February 16, 1961						
4:00 am	177	—	—	0.34	298	81
8:00	183	—	—	0.11	298	81
10:00	179	—	—	0	302	81
12:00 N	176	—	—	0.04	305	81
12.10 pm	Short circuit in generator; stop pump.					
12:33	Start pump.					
12:35	178	—	—	—	—	—
1:00	175	—	—	—	—	—
2:00	176	—	—	0	308	81
3:00	175	—	—	0.04	302	81
4:00	174	—	—	0.04	298	81
6:00	179	—	—	0.07	298	81
8:00	174	—	—	0.23	298	81.5
10:00	175	—	—	0.34	298	81.5
12:00 M	176	—	—	0.34	302	81.5
February 17, 1961						
2:00 am	177	—	—	0.34	302	81
4:00	174	—	—	0.34	298	81
6:00	174	—	—	0.41	298	81
7:10	174	—	—	0.41	—	81
8:00	174	—	—	0.34	298	81
10:00	174	—	—	0.18	298	81
12:00 N	172	—	—	0	302	81
2:00 pm	173	—	—	—	298	81
4:00	172	—	—	0.04	302	81
6:00	172	—	—	0.18	298	81
8:00	171	—	—	0.34	302	81
10:00	171	—	—	0.28	302	81
12:00 M	173	—	—	0.34	302	80.5
3:30 am	172	—	—	0.34	302	81
4:00	173	—	—	0.34	302	81
7:00	172	—	—	0.34	302	81
8:00	169	—	—	0.32	302	81
10.00	176	—	—	0.23	302	81
11:10	174	—	—	0.11	302	81
11:11	Stop pump.					
11:11:30	0	—	—	—	—	—

Well No. 15 — KAWAIHAE WELL 2

GENERAL INFORMATION

Contractor:	Samson and Zerbe, Ltd.
Drilling equipment:	Bucyrus Erie 28-L drill rig.
Drilling date:	March 9-June 1, 1961.
Ground elevation:	392.19 ft., msl.
Total depth of well:	429.5 ft.
Size of hole:	15 in.
Casing:	Inner diameter, 10 in., 428.5 ft. (bottom 40 ft. perforated).

PUMPING TEST DATA

Date of pumping test:	June 6-8, 1961.
Length of airline:	412.60 ft.
Elevation centerline air gage:	392.19 ft.
Static water level:	3.3 ft. (electric sounding probe before test); 5.12 ft. (airline after test).
Salinity (chlorides):	504 ppm.
Drawdown:	0 ft. at 50, 100, 150, and 180 gpm.
Water temperature:	75°F.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
June 6, 1961						
	0	—	—	—	—	—
8:00 am	Start pump.					
8:15	52	—	—	0	504	—
8:30	55	—	—	—	504	—
8:45	55	—	—	—	—	—
9:00	55	—	—	—	504	—
9:05	Increase engine speed.					
9:15	108	—	—	—	504	—
9:30	114	—	—	0.47(?)	496	—
9:45	110	—	—	0	—	—
10:00	112	—	—	—	496	—
10:03	Increase engine speed.					
10:05	152	—	—	—	—	—
10:15	152	—	—	0	504	—
10:30	148	—	—	—	504	—
10:45	147	—	—	—	—	—
11:00	147	—	—	0	496	—
11:03	Increase engine speed.					
11:04	163	—	—	0	—	—
11:15	182	—	—	—	496	—
11:30	177	—	—	0	496	—
11:33	187	Adjust to increase rate.				
12:00 N	193	—	—	—	504	—
12:30 pm	164	—	—	0	504	—
1:00	183	—	—	0	504	—
1:30	184	—	—	0	—	—
2:00	185	—	—	0	496	—
2:30	184	—	—	0	—	—
3:00	185	—	—	0	504	—
3:30	187	—	—	—	—	—
4:00	189	—	—	0	504	—
8:00	189	—	—	0	496	—
10:00	180	—	—	0	—	—
12:00 M	185	—	—	0	504	—
June 7, 1961						
2:00 am	184	—	—	0	—	—
4:00	180	—	—	0	504	—
6:00	181	—	—	0	—	—
8:00	180	—	—	0	496	—
8:25	Install USGS test gage.					
8:30	184	—	—	0	—	78.5
10:00	187	—	—	0	504	79
12:00 N	187	—	—	—	504	79
2:00	185	—	—	—	504	79
4:00	187	—	—	—	504	79
6:00	188	—	—	—	504	79
8:00	181	—	—	0	496	79
10:00	176	—	—	0	504	79
12:00 M	189	—	—	—	504	79
June 8, 1961						
2:00 am	179	—	—	—	504	79
4:00	179	—	—	—	496	79
6:00	179	—	—	0	504	79
8:00	184	—	—	0	504	79
10:00	179	—	—	—	504	79
11:00	185	—	—	—	504	79
11:05	Stop pump.					

Well No. 16 — KAWAIHAE

GENERAL INFORMATION

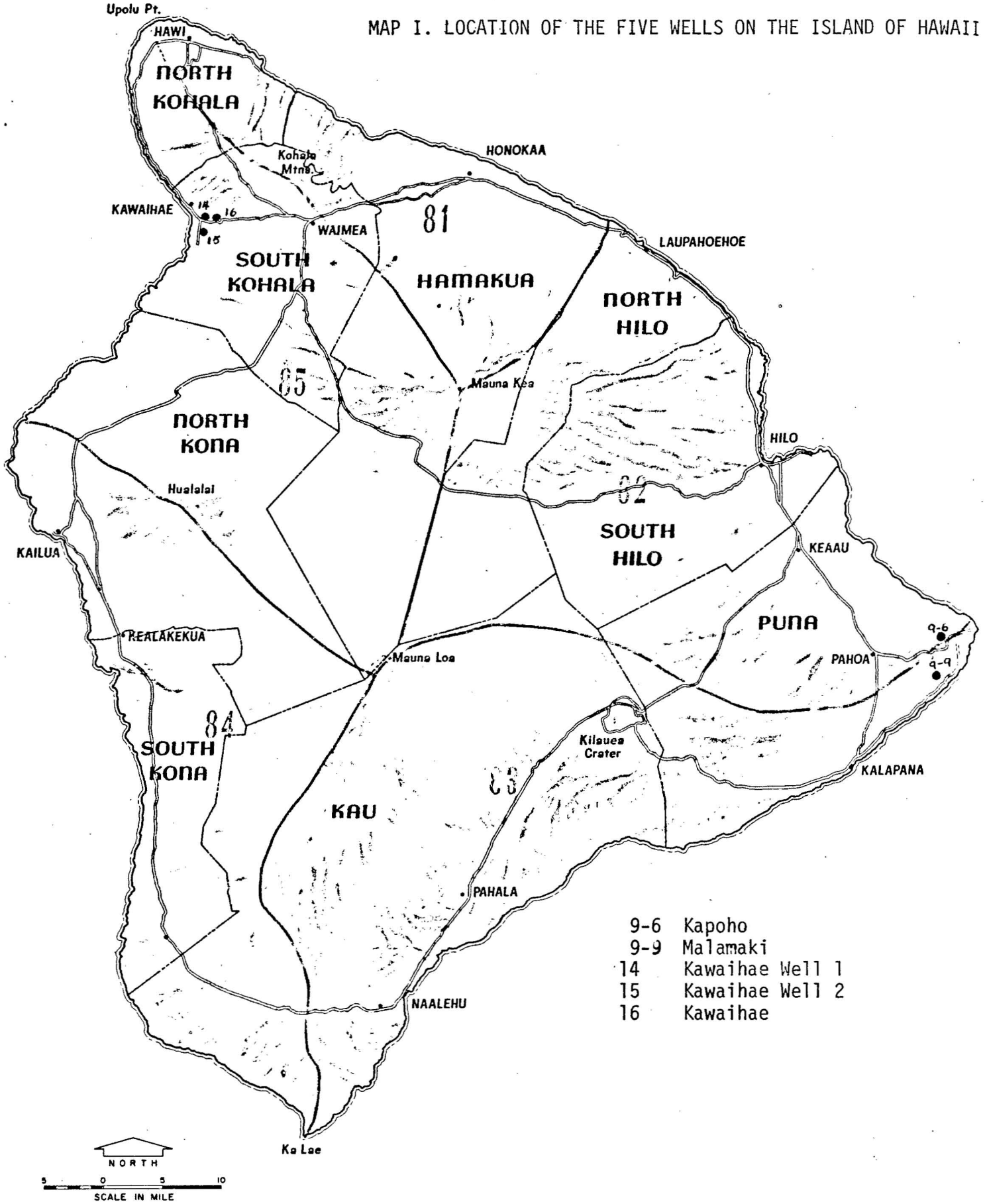
Contractor:	Ocean View Drilling Co., Ltd.
Drilling equipment:	Failing 2500 rotary drill rig.
Drilling date:	May 18-June 10, 1963.
Ground elevation:	982 ft., msl.
Total depth of well:	1,040 ft.
Size of hole:	10 in.
Casing:	Inner diameter, 8 1/8 in.; length, 1041 ft. (bottom 43 ft. perforated).

PUMPING TEST DATA

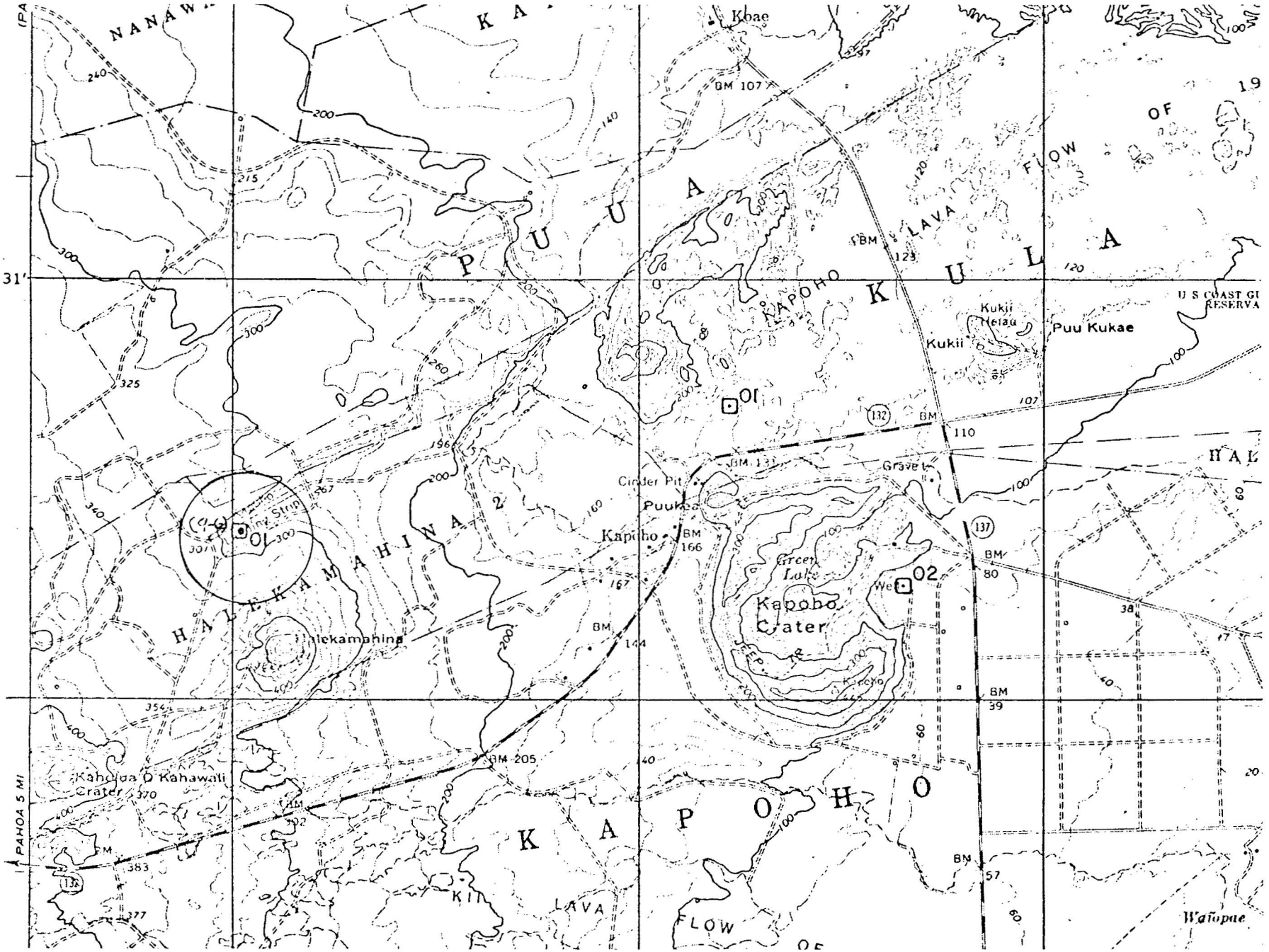
Date of pumping test:	June 24-28, 1963.
Static water level:	4.62 ft. (June 24, 1963).
Salinity (chlorides):	229-254 ppm.
Drawdown:	2.8 ft. at 100 gpm; 8.5 ft. at 250 gpm.
Water temperature:	93-96°F
Personnel:	Daniel Lum, Linford Chang, Ken Sakuma, Division of Water and Land Development; Jack Rosenau, U.S. Geological Survey.

TIME	PUMPING RATE (gpm)	WATER LEVEL Elev. (ft.)	WATER LEVEL Depth (ft.)	DRAW-DOWN (ft.)	CHLORIDE CONTENT (ppm)	WATER TEMP. (°F)
June 24, 1963						
1:25 pm	0	—	—	0	—	—
1:34	0	—	—	0	—	—
1:35	Start pump.					
1:45	75	—	—	1.63	229	95
2:00	80	—	—	1.85	234	98.5
2:15	85	—	—	1.96	234	98
2:30	90	—	—	1.96	234	99
2:45	85	—	—	2.08	234	98
3:00	85	—	—	2.03	234	98
3:15	90	—	—	2.03	239	97.5
3:30	90	—	—	2.19	234	97.5
3:45	90	—	—	2.19	234	97
4:00	90	—	—	2.19	234	97
4:30	90	—	—	2.12	234	96.5
5:00	95	—	—	2.21	244	97
8:00	85	—	—	2.42	244	96.5
9:00	100	—	—	2.54	244	97
10:00	100	—	—	2.54	244	96.5
11:00	100	—	—	2.66	244	96.5
12:00 M	100	—	—	2.66	234	96.5
June 25, 1963						
2:00 am	100	—	—	2.66	239	96.5
4:00	100	—	—	2.77	259	96
6:00	100	—	—	2.77	249	95
8:00	100	—	—	2.77	259	96.5
10:00	105	—	—	2.89	244	96
12:00 N	100	—	—	2.77	254	96.5
2:00 pm	100	—	—	2.77	244	96.5
4:00	100	—	—	2.77	244	96.5
7:15	100	—	—	2.77	244	96.5
8:00	100	—	—	2.89	254	96
10:00	100	—	—	2.77	244	96
12:00 M	100	—	—	2.77	244	97
June 26, 1963						
2:00 am	100	—	—	2.77	254	96
4:00	100	—	—	2.77	254	96.5
6:00	95	—	—	2.77	259	96.5
7:30	Adjust pump.					
8:00	106	—	—	3.12	259	96.5
10:00	110	—	—	3.12	254	96.5
10:05	Adjust pump.					
10:20	100	—	—	2.89	—	—
12:00 N	100	—	—	2.89	254	96.5
2:00 pm	100	—	—	2.77	254	96.5
	Increase pumping rate.					
2:17	200	—	—	7.82	—	—
2:24	210	—	—	8.89	254	97
2:35	198	—	—	7.85	254	97
	Pressure gage fluctuating between 4.40 and 4.80 psi.					
3:00	209	—	—	8.76	254	96.5
3:30	200	—	—	8.31	—	97
4:00	200	—	—	8.54	254	97
6:30	200	—	—	8.58	259	96.5
8:00	200	—	—	8.76	254	96
10:00	200	—	—	8.54	254	96
12:00 M	200	—	—	8.31	254	97
June 27, 1963						
2:00 am	200	—	—	8.31	259	96.5
4:00	200	—	—	8.31	264	96
5:52±	Stop pump due to lack of fuel.					
6:40	0	—	—	0	—	—
7:35	Start pump.					
7:39	—	—	—	8.54	—	—
7:42	202	—	—	8.54	259	—
7:42	Stop pump to repair oil line.					
7:50	—	—	—	0	—	—
10:25	Start pump.					
10:26	—	—	—	8.08	—	—
10:30	100±	—	—	2.54	—	—
10:31	50±	—	—	1.62	—	—
10:35	72	—	—	—	264	96.5
10:50	—	—	—	1.96	—	—
10:53	77	—	—	—	—	—
10:57	—	—	—	—	264	97.5
11:30	70	—	—	1.73	264	98
11:40	Increase pumping rate.					
11:45	114	—	—	3.12	—	—
2:15 pm	110	—	—	4.04	254	96.5
5:15	120	—	—	3.69	249	96.5
9:30	120	—	—	4.70	259	96
12:00 M	120	—	—	3.81	259	96
June 28, 1963						
3:00 am	120	—	—	4.04	259	96
6:00	120	—	—	4.04	264	95
9:00	125	—	—	4.04	264	96.5
12:00 N	120	—	—	4.04	264	96.5
12:05	Stop pump.					

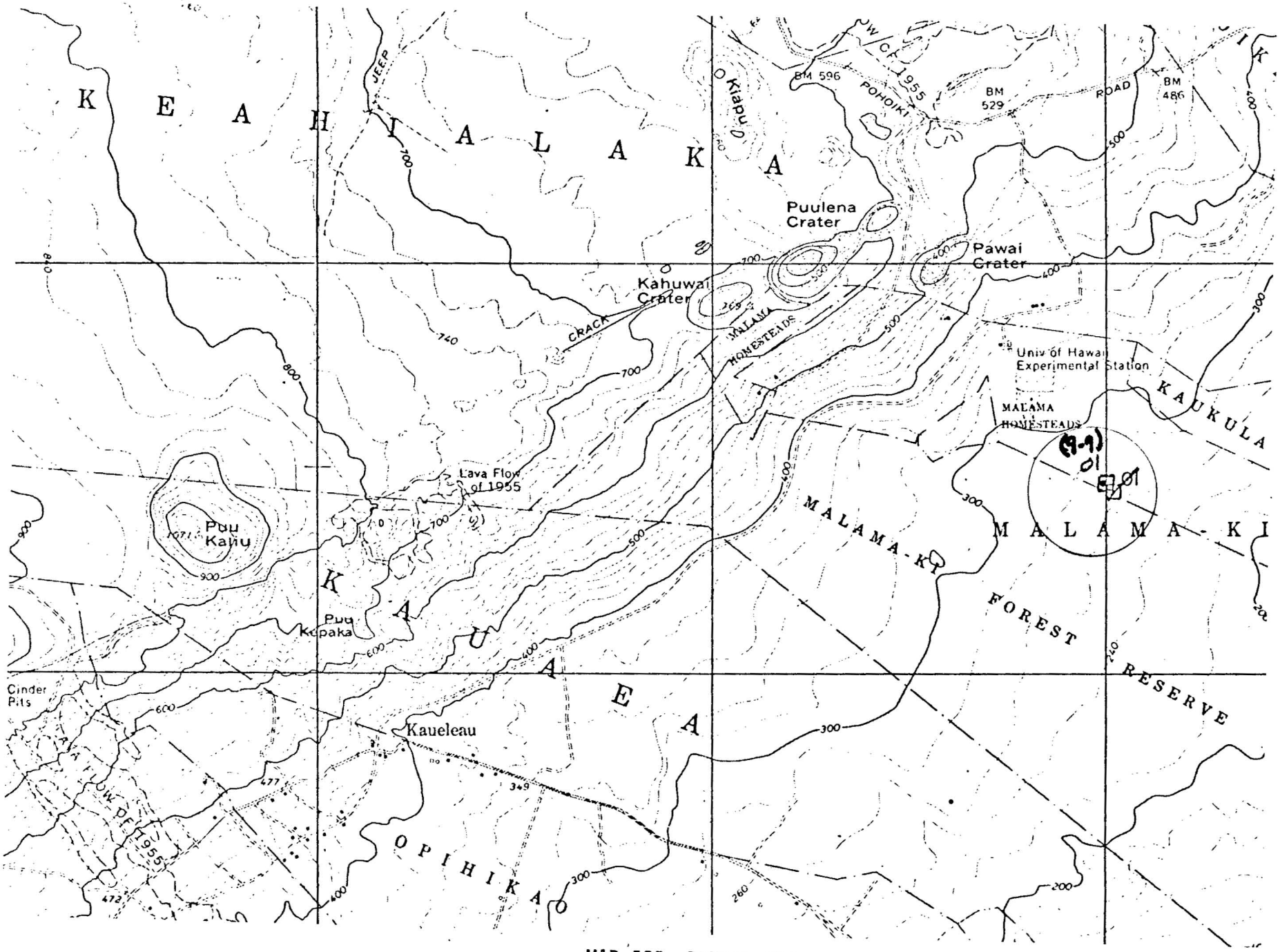
MAP I. LOCATION OF THE FIVE WELLS ON THE ISLAND OF HAWAII



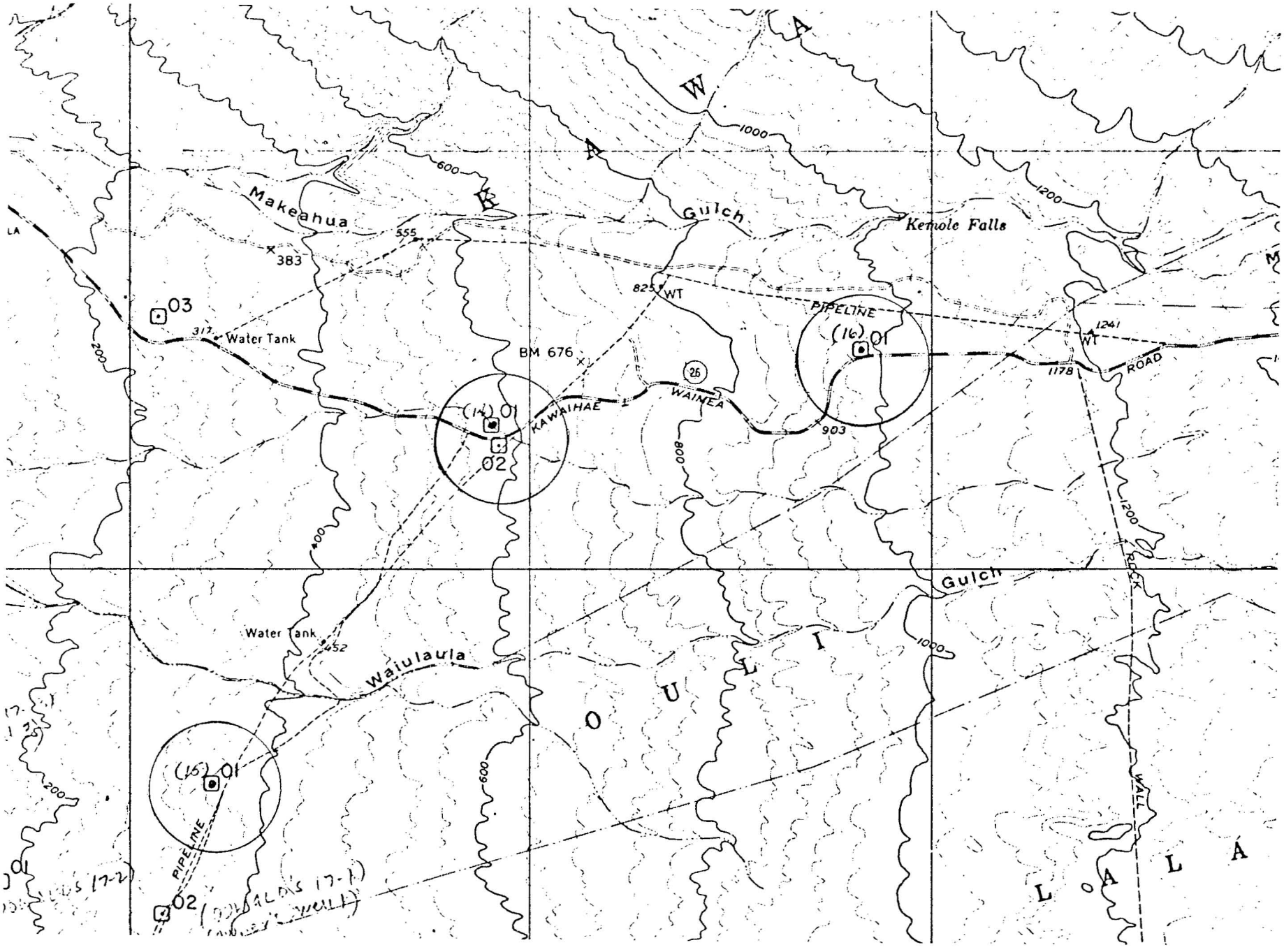
9-6 Kapoho
9-9 Malamaki
14 Kawaihae Well 1
15 Kawaihae Well 2
16 Kawaihae



MAP II. DETAIL MAP OF KAPOHO WELL (9-6)



MAP III. DETAIL MAP OF MALAMAKI WELL (9-9)



MAP IV. DETAIL MAP OF KAWAIHAE WELLS (14, 15, 16)

TABLE III

WATER QUALITY RECORDS[1]

FOR MALAMA-KI (#9-9) AND KAWAIHAE (#16) WELLS

	#9-9	#16	
	1962	1961	1963
pH 25°C	--	--	--
pH 30°C	6.92	7.7	7.3
Color	20	0	5
Ordor	musty	0	chem. hyd.
Turbidity	8	10	1
Nitrites	0.005	0	0.001
Nitrates	0.5	0	2.89
Hydroxide Alkalinity	0	0	0
Bicarbonate Alkalinity	215	78	89
Total Alkalinity	215	78	89
Total Hardness	1790	250	214
Total Solids	11700	1200	796
Loss on Ignition	1730	212	240
Silica	59.0	30	89.2
Iron and Aluminum	104.8	--	--
Iron	3.16	--	--
Aluminum	101.2	--	0.05
Calcium	182	53.6	31.5
Magnesium	324	27.8	32.8
Sulfate	681	90.8	54
Sodium and Potash	3090	0	149.5
Chlorides	5850	550	250
Arsenic	0.01	--	0.01
Fluoride	1.5	--	0.2
Manganese	0.05	0.1	0.05
Lead	0.01	--	0.01
Copper	0.2	--	0.13
Zinc	0.2	--	0.1
Selenium	0.08	--	0.01
Phenols	0.001	--	0.001

[1]State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R34 (Honolulu, HI: State of Hawaii, 1970), pp. 186-187.

TABLE IV

MAXIMUM ALLOWABLE CHEMICAL CONCENTRATIONS (PPM)[1]

IN DRINKING WATER BY THE UNITED STATES PUBLIC HEALTH SERVICE

Arsenic	0.01
Chlorides	250
Copper	1
Iron	0.3
Manganese	0.05
Nitrates	45
Phenols	0.001
Sulfate	250
Total Solids	500
Zinc	5

[1]Parts per million
State of Hawaii Department of Land and Natural Resources, Division of Water and Land Development, AN INVENTORY OF BASIC WATER RESOURCES DATA: ISLAND OF HAWAII, Report R34 (Honolulu, HI: State of Hawaii, 1970), p. 181.

TABLE V

ELEMENTS IN SEA WATER[1]

Element	PPM[2]
SILICON[3]	4
ALUMINUM	0.5
IRON	0.02
CALCIUM	408
SODIUM	10,769
POTASSIUM	387
MAGNESIUM	1,297
MANGANESE	0.01
Phosphorus	0.1
CARBON	28
SULPHUR	901
CHLORINE	19,353
STRONTIUM	13
Barium	0.05
Rubidium	0.2
FLUORINE	1.4
Chromium	p[4]
COPPER	0.01
Nickel	0.0001
Vanadium	0.0003
Lithium	0.1
Cerium	0.0004
Cobalt	p
Tin	p
Zinc	0.005
Yttrium	0.0003
Lanthanum	0.0003
LEAD	0.004
Molybdenum	0.0005
Thorium	<0.0005
Cesium	0.002
ARSENIC	0.02
Sandium	0.00004
BROMINE	66
BORON	4.7
Uranium	0.015
SELENIUM	0.004
Cadmium	p
Mercury	0.00003
Iodine	0.05
Silver	0.0003
Gold	$0.0_{5}6$
Radium	$0.0_{9}3$

[1]Assuming salinity of 35 parts per thousand and volume of 1.37×10^9 km^3 H.U. Sverdrup, M. W. Johnson, R. H. Fleming, THE OCEANS (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1942), p. 220.

[2]Parts per million

[3]Capitalization indicates elements referred to on preceeding tables

[4]Present