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The hydrology of Ifalik Atoll, Western Caroline Islands

by

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CONTENTS

ILLUSTRATIONS

TABLES

THE HYDROLOGY OF IFALIK ATOLL, WESTERN CAROLINE ISLANDS[1]

By

Ted Arnow [2]

INTRODUCTION

The fieldwork for this report was done as a part of more extensive hydrologic investigations carried on by the U. S. Geological Survey in the Trust Territory of the Pacific Islands and was coordinated with the 1953 Scientific Investigation of Micronesia of the Pacific Science Board of the National Research Council, which was supported by funds granted by the Office of Naval Research by Contract N7onr-29104 (NR 388 001). Logistic support for the work was provided by the U. S. Navy, the U. S. Coast Guard, and the Trust Territory administration. Tide data were analyzed by the U. S. Coast and Geodetic Survey. The writer was on Ifalik from June 22 to 24, and September 12 to 26, 1953.

The Ifalik project was essentially a group undertaking of several specialists, each working in his own field but coordinating his activities with those of the others. The writer would like to express his gratitude to "Tom" Totogoeiti who supervised the digging of the observation wells, to Marston Bates who collected the bulk of the climatic data, and to D. P. Abbott who collected additional climatic and ground-water data after the writer left Ifalik. Geological studies and water-level determinations were made together with J. I. Tracey, Jr. Finally, appreciation is expressed to the people of Ifalik for their hospitality and assistance, without which completion of the project would not have been possible.

The primary purpose of this report is to present the data observed at Ifalik so that they may be available to other workers in the Pacific at an early date. A more comprehensive report of hydrologic conditions on Ifalik will be included in a later report which will cover all phases of the investigations on Ifalik.

GEOGRAPHIC SETTING

Ifalik Atoll is in the Western Caroline Islands, which are part of the Trust Territory of the Pacific Islands (fig. 1). Ifalik lies 360 nautical miles due south of Guam, 440 miles due west of Truk, and 400 miles southeast of Yap.

Ifalik is a small circular atoll having a total land area of 0.569 square statute mile and a lagoon area of 0.939 square mile (Bryan, 1946). The lagoon has one deep-water entrance. There are four islands - Falarik, Falalap, Ella, and Elangalap. (See fig. 2). Approximately 260 people live on Falarik and Falalap, but neither Ella nor Elangalap is regularly inhabited.

1/ Publication authorized by the Director, U. S. Geological Survey.
2/ Geologist, U. S. Geological Survey, Austin, Texas.

CLIMATE

The 1953 expedition to Ifalik obtained measurements of rainfall, atmospheric pressure, temperature, and relative humidity for a period of approximately 4 months. These data are shown in tables 1 to 4. The atmospheric pressure as measured daily between 0800 and 0900 hours ranged from 1004 to 1011 millibars (29.65 to 29.86 inches), 85 percent of the readings falling between 1007 and 1010 millibars. Relative humidity as measured between 0800 and 0900 hours ranged from 77 to 100 percent and averaged 86 percent.

Daily maximum and minimum temperatures were measured in the school building (see table 4) which is a thatched structure open on two sides. The extremes observed were 91 and 73 degrees Fahrenheit. The maximum daily range was 15 degrees, the minimum daily range was 5 degrees, and the average daily range during the 4-month period of observation was 11 degrees.

The rainfall measurements at Ifalik were made during the rainy season (see table 1). At least a trace was recorded on 83 percent of the days of observation, and the rainfall exceeded 1 inch on 11 percent of the days of observation. Although a total of 54.25 inches of rainfall was measured in only 131 days, it is probable that the average annual rainfall at Ifalik is between 100 and 120 inches. This estimate is based on a consideration of annual-precipitation data for Guam (91 inches, length of record, 41 years, Yap (119 inches, length of record, 27 years), Truk (127 inches, length of record, 7 years), and Lamotrek (104 inches, but only a 4-year record).

In general it can be stated that Ifalik has a tropical rainy climate with relatively small seasonal changes of the various climatic factors. The temperature and barometric pressure are monotonously uniform throughout the year and the most variable factors are wind and rainfall.

TIDES

Tide data were obtained for the period September 13 to 25, 1953, by means of a Stevens type-F water-level recorder which was placed in the lagoon near Falarik Island (see fig. 2). Part of the actual tide record is shown in figure 3. The tide data were analyzed by the U. S. Coast and Geodetic Survey, which computed the following elevations shown in feet:

Mean higher high water	0.95
Mean high water	0.75
Mean sea level	0.00
Mean low water	-0.75
Mean lower low water	-1.55

The primary benchmark established in Ifalik is an "X" chiseled in a limestone slab on Falarik Island. The slab is embedded in the ground 20

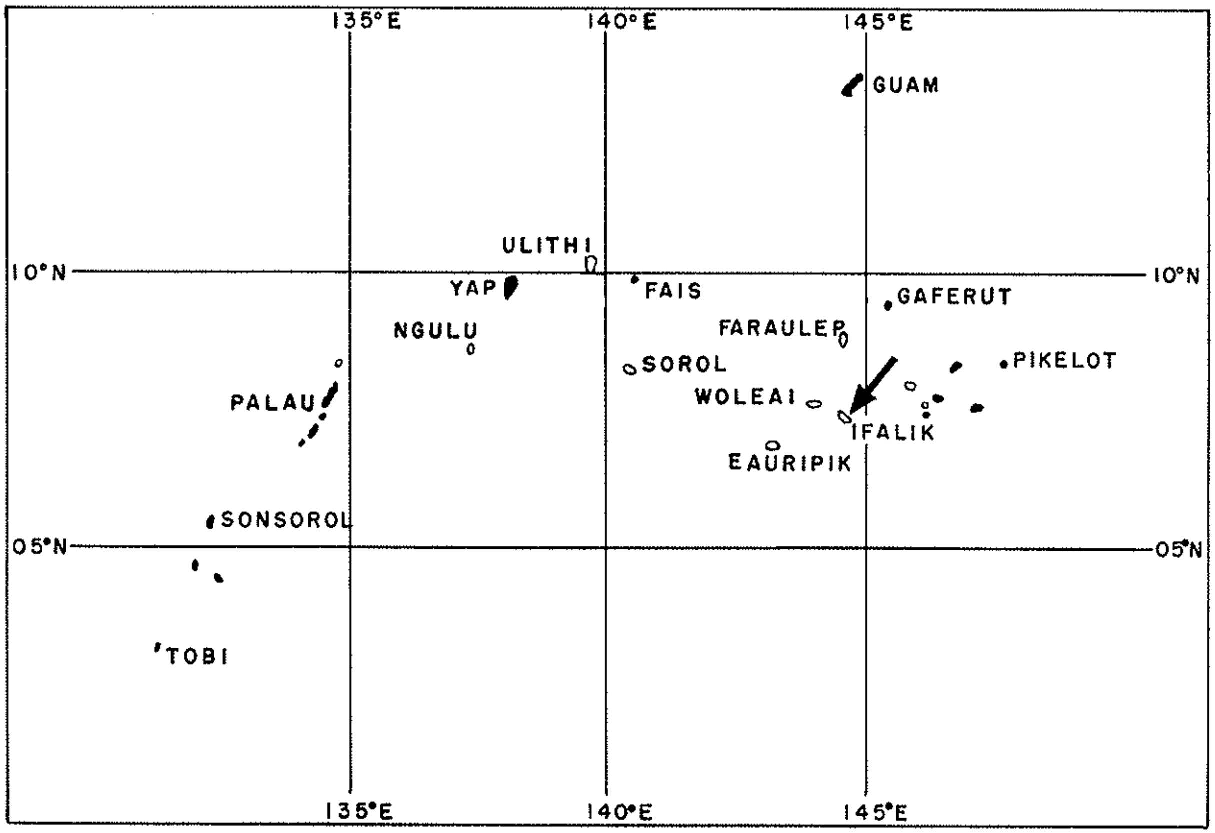

Figure I.– Outline map of the Western Caroline Islands.

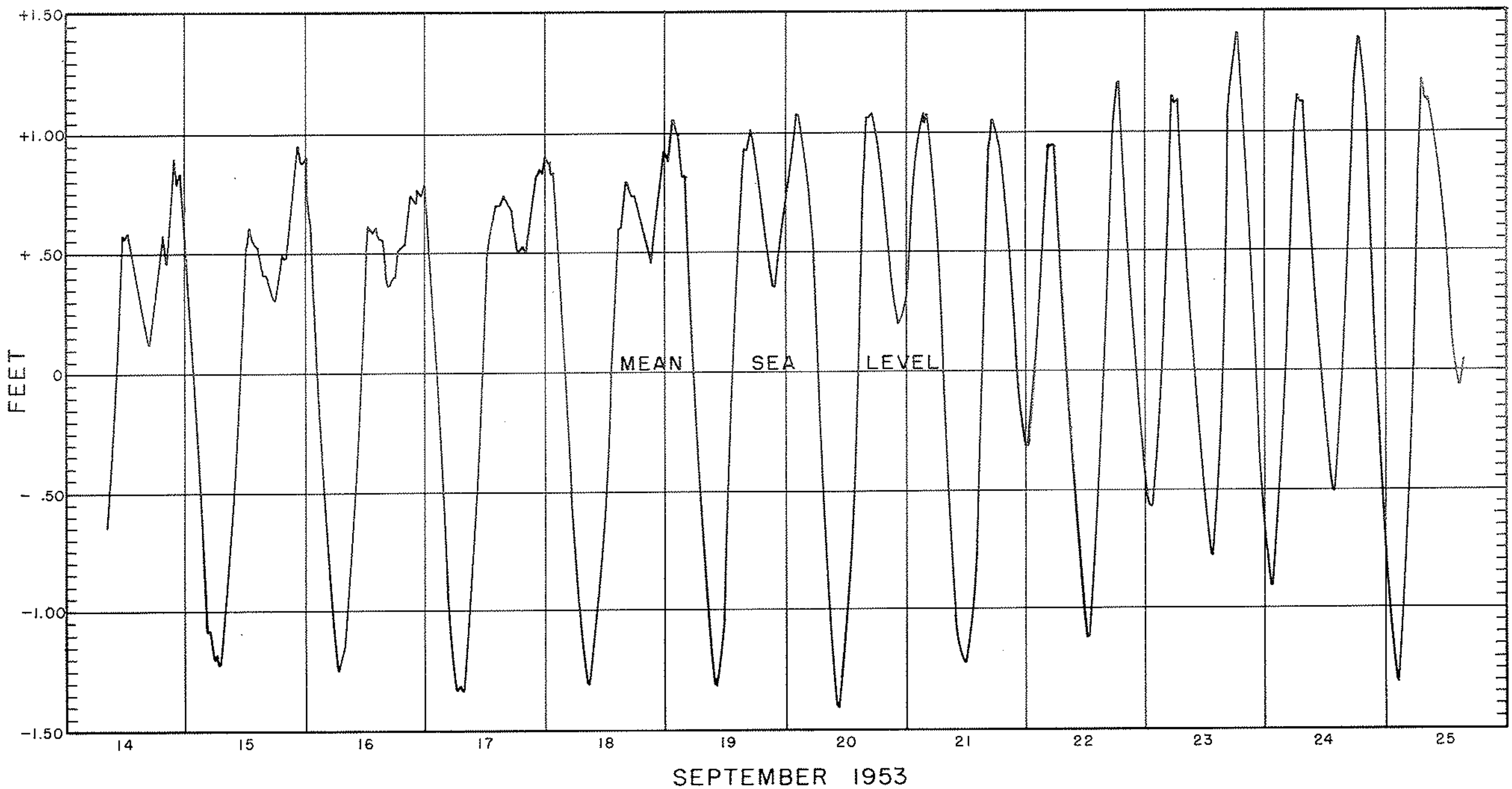

Figure 3.- Tidal graph in lagoon at Ifalik Atoll, September 14-25, 1953.

Table 1.--Rainfall at Ifalik Atoll, 1953, in inches

Day	July	August	September	October	November
1	0	0.24	0.30	0.01	0.18
2	.54	.15	.16	.55	2.03
3	.34	1.90	0	.02	--
4	.12	.54	.19	.12	1.35 1/
5	.20	.18	0	.14	.01
6	0	.95	.74	T	T
7	0	.05	.02	0	.03
8	T	2.55	.39	.10	.05
9	T	3.20	0	.13	
10	.02	.81	.15	.28	
11	.02	1.15	.13	--	
12	.20	.11	--	.84 1/	
13	.25	.25	1.97 1/	.53	
14	.08	.61	.76	.01	
15	0	.50	.91	.70	
16	2.98	1.06	.54	.40	
17	.68	0	.15	.01	
18	1.44	0	2.70	.92	
19	.24	0	1.03	.99	
20	.16	.02	.40	.24	
21	.16	.33	.09	.35	
22	.30	.15	.12	0	
23	0	1.67	0	.32	
24	.05	0	--	.04	
25	.32	0	.87 1/	.51	
26	0	.59	.11	--	
27	.05	.25	T	.13 1/	
28	.11	1.16	0	.47	
29	.10	.09	.25	3.56	
30	.30	0	0	.02	
31	.06	0		0	
TOTAL	8.72	18.51	11.98	11.39	

1/ 48-hour reading.

Table 2.--Atmospheric pressure at Ifalik Atoll, 1953, in millibars observed between 0800 and 0900 hours

Day	July	August	September	October
1	--	1008	1008	1010.5
2	--	1009	1008	1010.5
3	1009	1009	1008.5	1010
4	1009	1007.5	1008.5	1010
5	1010	1009	1009	1009
6	1010	1009	1010	1009.5
7	1010.5	1009	1010	1009
8	1011	1006.5	1008	1009
9	1010	1007.5	1008.5	1008
10	1009	1006	1009	1010
11	1010	1008	1008	--
12	1010	1007	--	1008
13	1010	1008	--	1007
14	1009	1007	1008.5	1006
15	1008	1007	1008.5	1006
16	1008	1008	1008.5	1007
17	1009	1009	1008.5	1007
18	1008	1009	1006	1007
19	1008	1009	1005.5	1007
20	1007.5	1009	1007	1008
21	1007	1008	1008.5	1009
22	1009	1007	1009	1008
23	1007.5	1006	1008	1007
24	1008	1006.5	--	1008
25	1008	1006	1008.5	1009
26	1008	1005	1009.5	--
27	1006	1004	1009.5	1007.5
28	1007	1006	1009.5	1008.5
29	1007.5	1008	1010	1008
30	1007.5	1008	1010	1008
31	1007	1008.5	--	1008

Table 3.--Relative humidity at Ifalik Atoll, 1953, in percent observed between 0800 and 0900 hours

Day	July	August	September	October
1	84	88	87	89
2	88	90	85	96
3	92	100	85	78
4	95	81	90	95
5	90	84	78	92
6	84	85	85	84
7	84	86	81	85
8	84	88	82	82
9	83	100	92	85
10	84	88	82	95
11	92	98	81	--
12	85	83	--	85
13	81	91	93	89
14	84	85	85	82
15	100	90	100	78
16	95	83	83	78
17	100	81	89	80
18	89	85	96	82
19	92	84	91	86
20	82	82	96	84
21	89	88	91	82
22	89	89	82	82
23	85	85	80	--
24	85	86	--	--
25	90	81	85	--
26	79	82	87	--
27	80	81	77	--
28	79	88	88	--
29	85	93	81	--
30	100	85	85	--
31	83	83	--	--

Table 4.--Air-temperature data at Falarik Island, Ifalik Atoll, 1953
Maximum and minimum measurements in degrees Fahrenheit.
All measurements made in the school building

Day	July		August		September		October	
	Max	Min	Max	Min	Max	Min	Max	Min
1	--	--	91	76	90	77	91	79
2	86	76	90	77	90	80	88	75
3	87	76	88	74	90	80	87	77
4	89	76	84	73	90	76	91	77
5	87	76	82	75	89	77	90	77
6	90	77	82	76	88	75	89	78
7	88	77	82	77	85	77	90	78
8	90	78	86	75	88	78	90	78
9	90	78	80	74	91	76	90	77
10	88	77	82	74	88	76	90	77
11	90	76	84	74	86	76	--	--
12	89	78	84	76	--	--	90	75
13	89	77	87	78	90	76	88	76
14	89	78	88	76	86	76	87	79
15	90	75	82	76	89	74	--	--
16	80	73	83	74	84	74	84	77
17	88	76	88	78	87	76	87	80
18	81	73	86	77	88	73	85	86
19	88	75	89	76	82	75	87	76
20	82	76	89	77	86	76	86	76
21	88	77	88	77	84	76	87	77
22	89	76	88	77	--	76	87	78
23	85	78	86	75	89	79	89	75
24	86	76	86	77	--	--	87	78
25	89	76	85	80	88	77	90	76
26	87	77	88	75	87	77	--	--
27	90	78	88	77	88	77	90	76
28	89	77	85	74	90	77	88	77
29	91	77	88	78	90	76	87	74
30	91	77	87	80	91	78	82	77
31	88	78	90	78	--	--	86	79

feet west of the west end of the Fan Nap, which is the chief's clubhouse. The altitude of the "X" is 3.57 feet above mean sea level as determined from the tide data.

Tide data were not obtained for the ocean. A comparison was made between the tide data obtained in the lagoon and the predicted ocean tides as published by the Coast and Geodetic Survey for Woleai Atoll, which is about 45 miles from Ifalik. No direct correlation was observed, other than that the observed tide in the lagoon preceded the predicted tide in the ocean 90 percent of the time. The averaged calculated precedence of the lagoon tides was 45 minutes and the maximum precedence was 1 hour 48 minutes. This order of sequence is a reversal of what would normally be expected, and at present no explanation can be offered other than possibly that the actual tides in the open ocean at Ifalik are considerably different from the predicted tides.

WATER SUPPLY

Rainwater

There is practically no artificial catchment of rainwater on Ifalik. Only two catchment systems were observed, each consisting of an oil drum receiving water from the trunk of a palm tree. One provided a household with water for cooking and the other supplied water to irrigate half a dozen puny tobacco plants which were being carefully nurtured to alleviate the island's tobacco shortage.

Three sample of rainwater were obtained for analysis, one from the rain gage, the second from catchment on the roof of a canvas tent, and the third from a drum fed by catchment on a palm tree. The sample from the rain gage had a chloride content of 5 parts per million (ppm) and a hardness of 12 ppm. The sample from the tent had a chloride content of 10 ppm and a hardness of 10 ppm. The sample from the drum had a chloride content of 52 ppm and a total hardness of 36 ppm. The sample from the drum had a higher salt content than those from the gage and the tent because, in the course of running through the crown of the tree and down the trunk, the water presumably had greater opportunity to dissolve salt crystals blown in by the wind from the ocean.

Ground Water

Occurrence.--The only source of fresh water on any island in Ifalik Atoll is the rain that falls directly on that island. Part of the rainfall evaporates or is transpired by plants, and the remainder, because of the high permeability of the island sediments, seeps directly into the ground. There is no significant surface runoff. The fresh water, which is only about 40/41 as heavy as salt water, floats on the surface of the salt water roughly in the shape of a dome, the edges of which coincide approximately with the edges of the island. The fresh water displaces a volume of salt water equal to its own weight and depresses the fresh-salt-water interface below sea level under the island. Under ideal conditions in a homogeneous island, because of the 40/41 weight relationship of fresh to salt water, for every foot the water table is above sea level the interface is about 40 feet below sea level. Actually the shape of the fresh-water body varies, depending upon local geologic conditions and variations in rainfall, and the 40-to-1 depth ratio is modified by a transition zone of variable thickness in which there is a mixture of fresh and salt water. This double-convex fresh-water body floating on sea water is known as the Ghyben-Herzberg lens. It is the only source of potable ground water in Ifalik and is tapped by means of shallow dug wells.

Three lines of wells for ground-water observations were established on Falarik Island - the Fan Nap line, the Fan Ni Wa line, and the Maia Channel line, as shown in figure 2. Benchmarks for determination of altitudes of water levels at 15 of the wells were tied in with mean sea level as determined by the tide gage. The surveying was done with a telescopic alidade, but because of difficulty with the instrument some of the water-level determinations may be inaccurate by several tenths of a foot. Water-level measurements were made on Falarik Island only. Wells on the other islands were used only for sampling purposes.

Continuous measurements of water levels by means of a Stevens type-F recorder were made at nine wells on Falarik Island. The length of observation at each well was 1 day (figure 4 shows a representative day's record), and the mean water levels determined at each well by the day's observation are shown in figure 5. The value of the mean water levels is somewhat doubtful because records of water levels in the wells were obtained on separate days during the rainy season over a period of 11 days, during which more than 7 inches of rain fell. The effect of rainfall on the water level in each well was variable and depended on the day during the 11-day period on which the well was measured. The mean water levels, therefore, are not completely comparable and also probably are not representative of the means that would be determined if measurements were made over a period of time long enough to average seasonal fluctuations. The configuration of the ground-water body as determined by the water-level measurements does not agree with the configuration suggested by chloride determinations, which are discussed in the next section of this report. The chloride data are believed to be more reliable.

The mean water levels, however, do give an indication of the thickness of the Ghyben-Herzberg lens on Falarik. Even allowing for errors due to surveying and shortness of record, the lens on Ifalik undoubtedly attains a head of at least 1 foot and possibly 1-1/4 feet above mean sea level. The depth to salt water below mean sea level, therefore, probably is 40 feet or more. The area of maximum thickness in general is in the center of the island or on the lagoon side of the center and from there the thickness of the lens diminishes to zero at both shorelines. The 40-foot figure is a

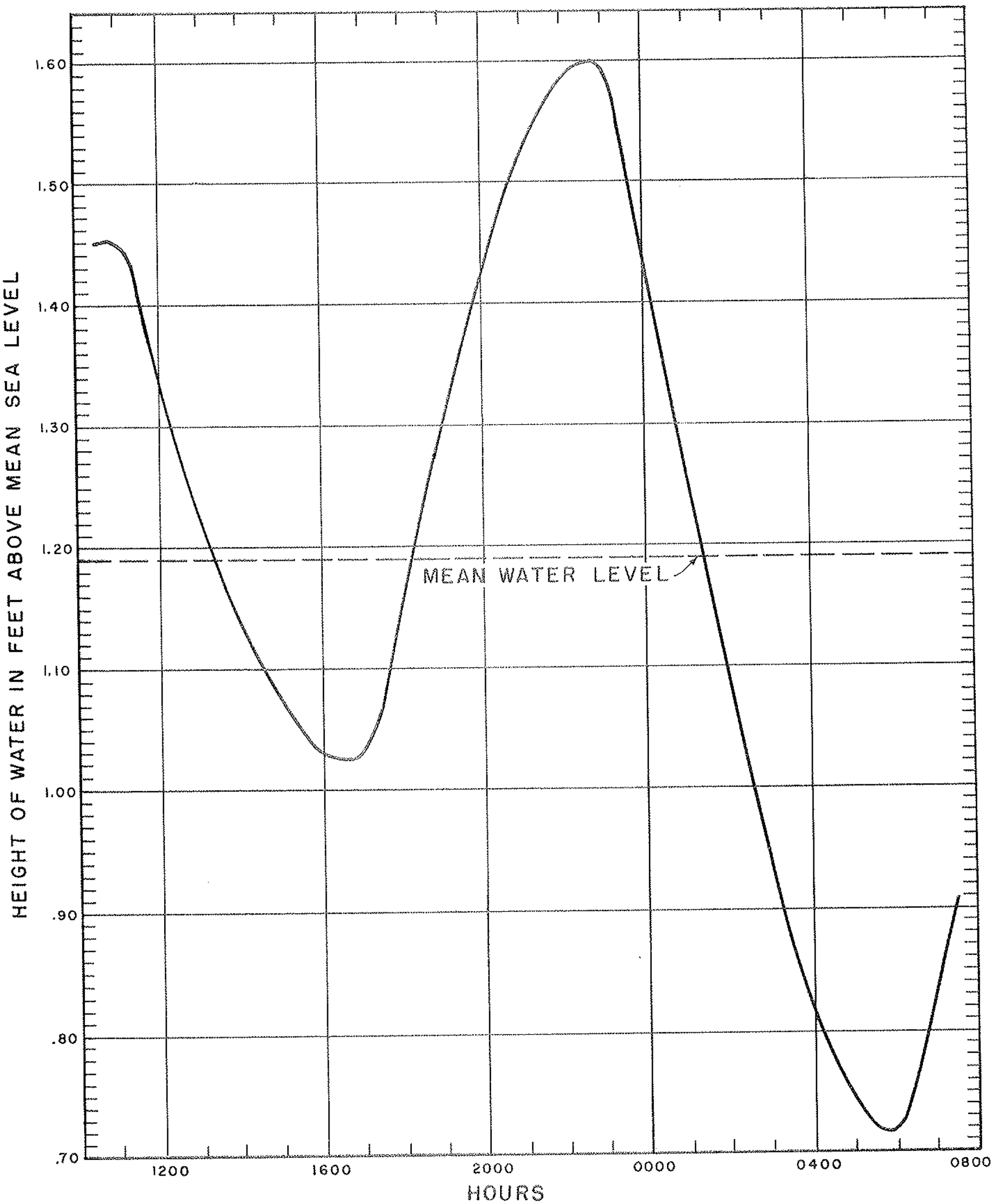

Figure 4.- Hydrograph for well 6, Ifalik Atoll.

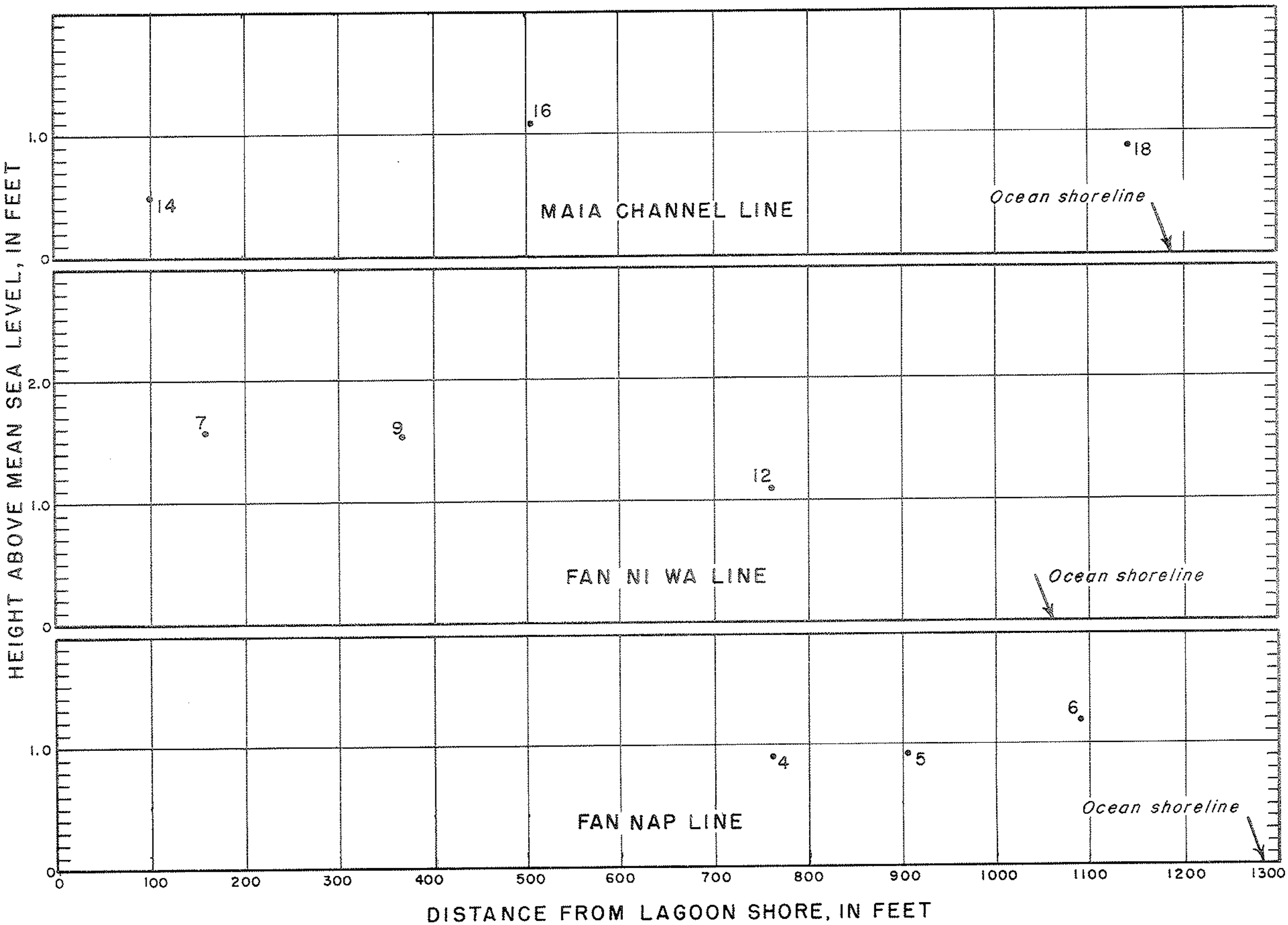

Figure 5.— Mean water levels in wells, Falarik Island, Ifalik Atoll.

wet-season figure, and the depth undoubtedly decreases during normal dry seasons and during extended periods of drought. Native informants state that they have no recollection of a drought on Ifalik. It is assumed, therefore, that the lenses on Falarik and Falalap have never shrunk to the point where food plants or well-water supply have been noticeably affected.

The amount of damping and lag of the tides as they move through Falarik Island is shown in figures 6 and 7 by a comparison of the tidal curve obtained in the lagoon and the tidal fluctuations of the water table observed in wells on Falarik. The data for each well were obtained by means of continuous observations over a period of 1 day. Both the damping and lag increase progressively from the lagoon shore toward the ocean shore. The full significance of this progressive change cannot be completely explained because of the lack of tidal data from the ocean side of the island. If such data were integrated with the tidal data obtained in the lagoon, a significant change might result in the slope of the curves shown in figures 6 and 7.

The Ghyben-Herzberg lens is incompletely developed on Ella Island and apparently not developed at all on Elangalap Island. These islands are discussed more fully in the section on Quality of water.

Quality.--The extent of development of the Ghyben-Herzberg lens controls the quality of the ground water in the islands in Ifalik Atoll. The lens is well developed in Falarik and Falalap Islands.

The three lines of wells on Falarik Island were sampled on September 21, 1953, and again during the period November 1 - 3. Partial chemical analyses were made for all samples and the results are shown in table 5. The relation of chloride content to distance from the shore is shown in figure 8 for the samples obtained on September 21, and in figure 9 for the samples obtained November 1 - 3. The chloride content of the water along the Fan Nap and Maia Channel lines is greatest near the ocean shore, decreases to a minimum about two-thirds of the way across the island, and rises again near the lagoon shore. These relationships suggest that the Ghyben-Herzberg lens has its thickest development about one-third of the way inland from the lagoon shore and from there thins toward both shores. The displacement of the point of maximum development of the lens from the center of the island toward the lagoon shore could be the result of high permeability in the rocks on the ocean side. The chloride content of the water along the Fan Ni Wa line of wells suggests that the maximum development of the lens along this line may be nearer the ocean side of the island than it is along the other two lines. If this is so, it may be due to the presence along the ocean shore of well-cemented beach rock which acts as a relatively impermeable barrier which retards the mixing of fresh and salt water that results from tidal fluctuations. The beach rock is not exposed throughout, but according to J. I. Tracey, personal communication (1954) it probably extends along most of the northeast coast of Falarik. It terminates, however, before reaching the Fan Nap and Maia Channel well lines.

Table 5.--Partial chemical analyses (ppm) and temperature (°F) of water from various sources in Ifalik Atoll
(Field determinations by Ted Arnow)

No.	Source	Date (1953)	Chloride	Total hardness as $CaCO_3$	Calcium hardness as $CaCO_3$	Temperature
	Falarik Island					
1	Shallow pond, 30 feet in diameter	Sept. 21	28	240	132	79.5
		Nov. 1	35	210	129	--
2	Taro pit	Sept. 21	12	290	242	79.5
3	Dug well	Sept. 21	16	100	71	77.5
		Nov. 1	5	170	88	--
4	do.	Sept. 21	52	170	132	79
		Nov. 3	5	100	82	---
5	do.	Sept. 21	44	230	181	--
		Nov. 1	55	190	132	--
6	do.	Sept. 21	84	250	132	79
		Nov. 1	95	210	66	--
7	do.	Sept. 21	48	320	275	79
		Nov. 1	50	320	269	--
8	do.	Sept. 21	8	220	170	76
9	do.	Sept. 21	8	140	132	77
		Nov. 1	20	220	170	--
10	Taro pit	Sept. 21	10	--	--	79
11	Dug well	Sept. 21	6	210	93	78
		Nov. 1	10	120	104	--
12	do.	Sept. 18	8	140	93	78
		Nov. 1	25	170	132	--
13	do.	Sept. 21	14	120	93	79
		Nov. 3	40	340	286	--
14	do.	Sept. 21	28	290	192	79.5
		Nov. 1	35	190	104	--
15	do.	Sept. 21	16	240	187	80
		Nov. 1	15	210	176	--
16	do.	Sept. 21	24	240	105	81
		Nov. 1	27	160	124	--
17	do.	Sept. 21	44	220	165	79
		Nov. 1	35	230	165	--

Table 5.--Partial chemical analyses (ppm) and temperature (°F) of water from various sources in Ifalik Atoll--Continued

No.	Source	Date (1953)	Chloride	Total hardness as $CaCO_3$	Calcium hardness as $CaCO_3$	Temperature
18	Dug well	Sept. 21	68	290	132	80
		Nov. 1	1,160	660	242	--
24	Coconut retting pit	Sept. 21	28	340	302	--
--	Rain sample from canvas tent	Sept. 18	10	10	7	--
-	Rain sample from palm tree	Sept. 26	52	36	17	--
-	Rain sample from rain gage	Sept. 26	5	12	9	--
	Falalap Island					
19	Dug well	Sept. 21	252	390	215	--
		Nov. 3	445	400	247	--
20	Taro swamp	Sept. 21	12	170	148	--
21	Dug well	Sept. 21	40	180	121	--
		Nov. 3	10	110	104	--
22	Taro swamp	Sept. 21	16	140	71	--
23	Mangrove swamp	Sept. 21	5,500	2,020	462	--
30	Shallow pond, 12 by 25 feet	Sept. 21	24	200	132	--
31	Dug well	Sept. 23	44	320	247	--
32	do.	Sept. 23	32	270	198	--
33	do.	Sept. 23	20	280	264	--
34	do.	Sept. 23	48	280	214	81
	Ella Island					
26	Shallow pond, 50 by 350 feet	Sept. 20	10,200	4,100	660	--
27	Dug well	Sept. 20	108	230	170	--
		Nov. 4	80	210	165	--
28	do.	Sept. 20	1,090	1,090	330	--
		Nov. 4	3,060	1,270	407	--
29	do.	Sept. 20	204	280	181	79
		Nov. 4	180	250	176	--
	Elangalap Island					
25	Dug well	Sept. 20	10,900	3,920	616	--
		Nov. 4	15,000	3,800	616	--

The chloride content of the ground water throughout Falarik Island rose slightly between the two periods of sampling, but the only significant change was at well 18, where the chloride content rose from 68 to 1,160 ppm. This sharp rise indicates that the lens is thinner in the vicinity of well 18 than elsewhere along the three lines of wells. According to native informants, the northwest corner of Falarik Island was once separated from the remainder of the island by a narrow channel. The channel was filled during a typhoon early in the 20th century and is now marked by the Maia Channel line of wells. Well 18, however, is east of the filled channel which, north of well 17, curves toward the northwest (J. I. Tracey, personal communication). According to Tracey, well 18 is in bedded sands and gravels that are typical of bar or beach deposits. These deposits are very permeable and permit free movement of water during the tidal cycle. The high permeability coupled with the fact that the shoreline is only 110 feet away may well explain the poor development of the fresh-water lens in the vicinity of well 18.

The relation of total hardness of the ground water to distance from the shoreline for the three lines of wells on Falarik in general follows the same pattern observed for the chloride data (fig. 10). Because of the acid environment created by decaying vegetation, sampling points 2 and 24, a small taro pit and a coconut retting pit, yield water harder than that of nearby wells.

In addition to the partial analyses discussed above, a set of water samples from the Fan Ni Wa line was analyzed for all major dissolved constituents (see table 6). The results in general agree with those discussed above. The only significant departure from what would generally be expected in the composition of ground water from a coralline atoll is the high silica content, which in four of the six wells exceeded that of sea water. The source of the excess silica may possibly be a concentration of sponge spicules or large amounts of drift pumice.

Analyses of water samples obtained on Falalap Island indicate that the Ghyben-Herzberg lens is as well developed there as it is on Falarik Island. Much of the central part of the island is a fresh-water swamp (see samples 20 and 22 in table 5), but closer to the coasts where boulder ramparts exist the ground water becomes more saline as the lens becomes thinner (see sample 19 in table 5). The northwest coast of Falalap, however, is formed by finer grained sediments which are conducive to the formation of a well-developed Ghyben-Herzberg lens. Samples from wells 30 to 34, which are 125 to 180 feet from the coast, all showed less than 50 ppm of chloride. The fresh-water lens in Falalap Island is disrupted along the ocean shore by brackish or saline areas in which mangrove trees grow. A ground-water sample obtained from one such mangrove swamp (see sample 23 in table 5) had a saline content approximately one-third that of sea water.

Three wells were dug on Ella Island along a line where the island is approximately 700 feet wide (fig. 2). The two outer wells, numbers 27 and

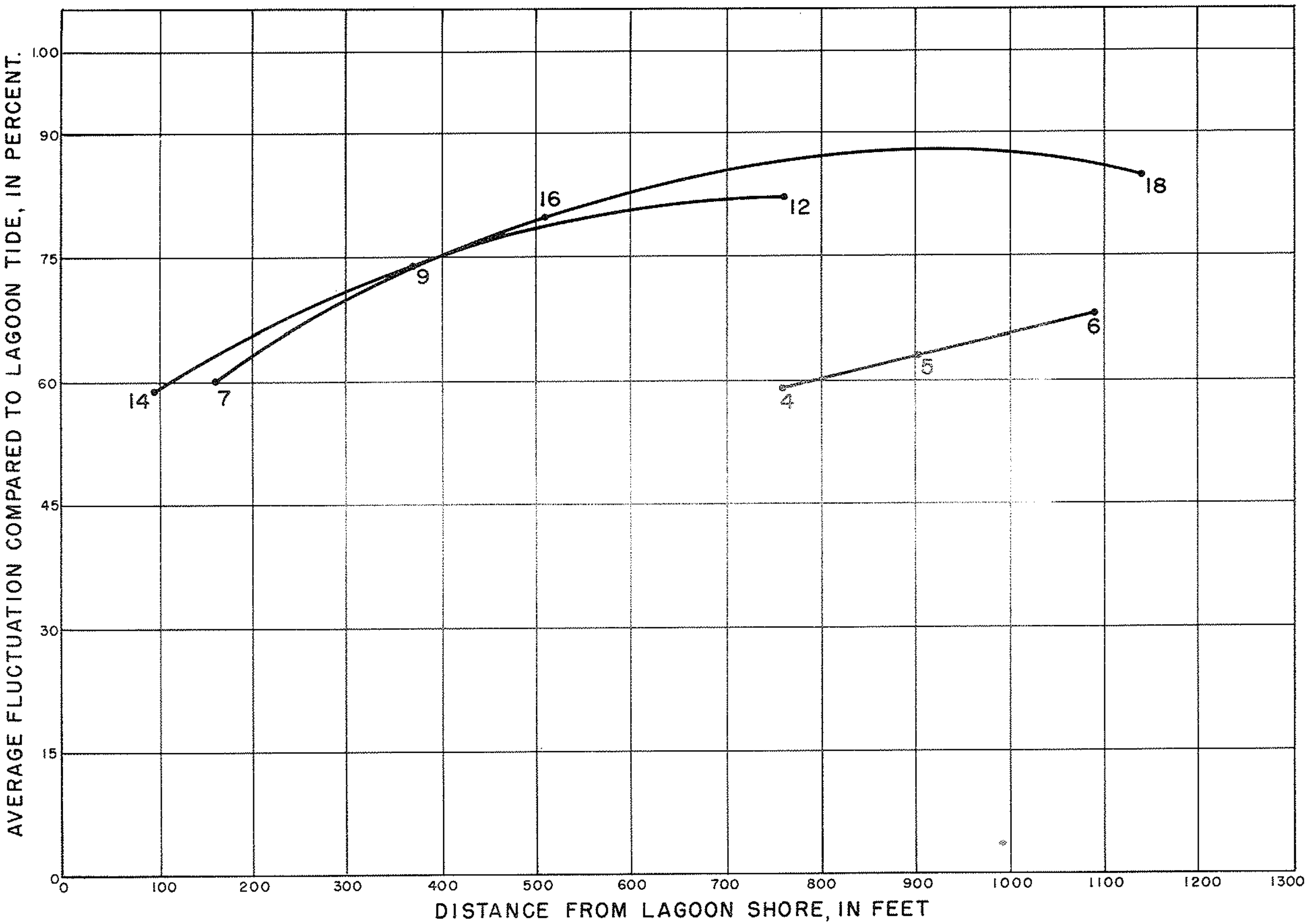

Figure 6.— Relation of damping of tidal fluctuations in wells to distance of wells from shoreline, Falarik Island, Ifalik Atoll.

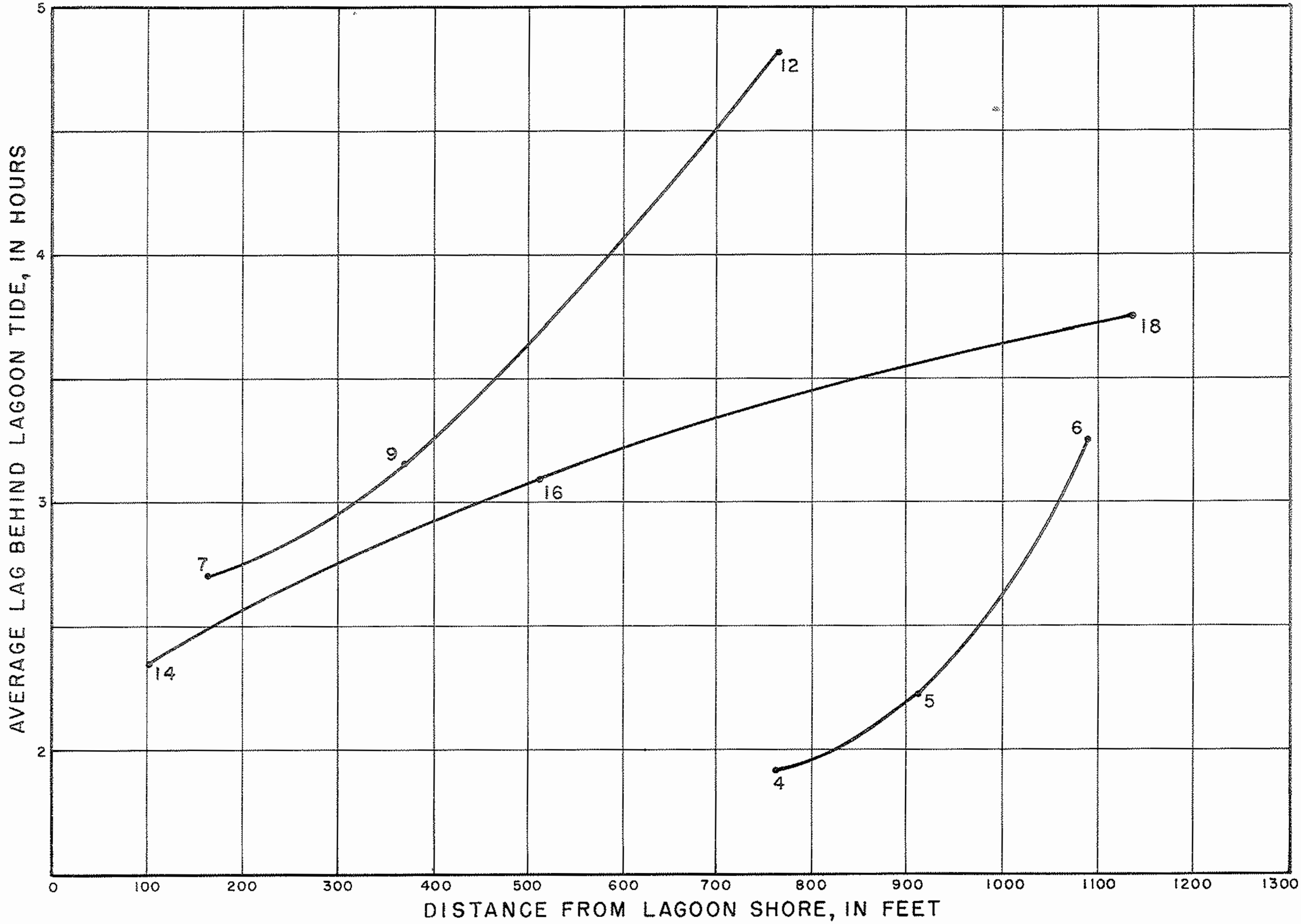

Figure 7.– Relation of lag of tidal fluctuations in wells to distance of wells from shore line, Falarik Island, Ifalik Atoll.

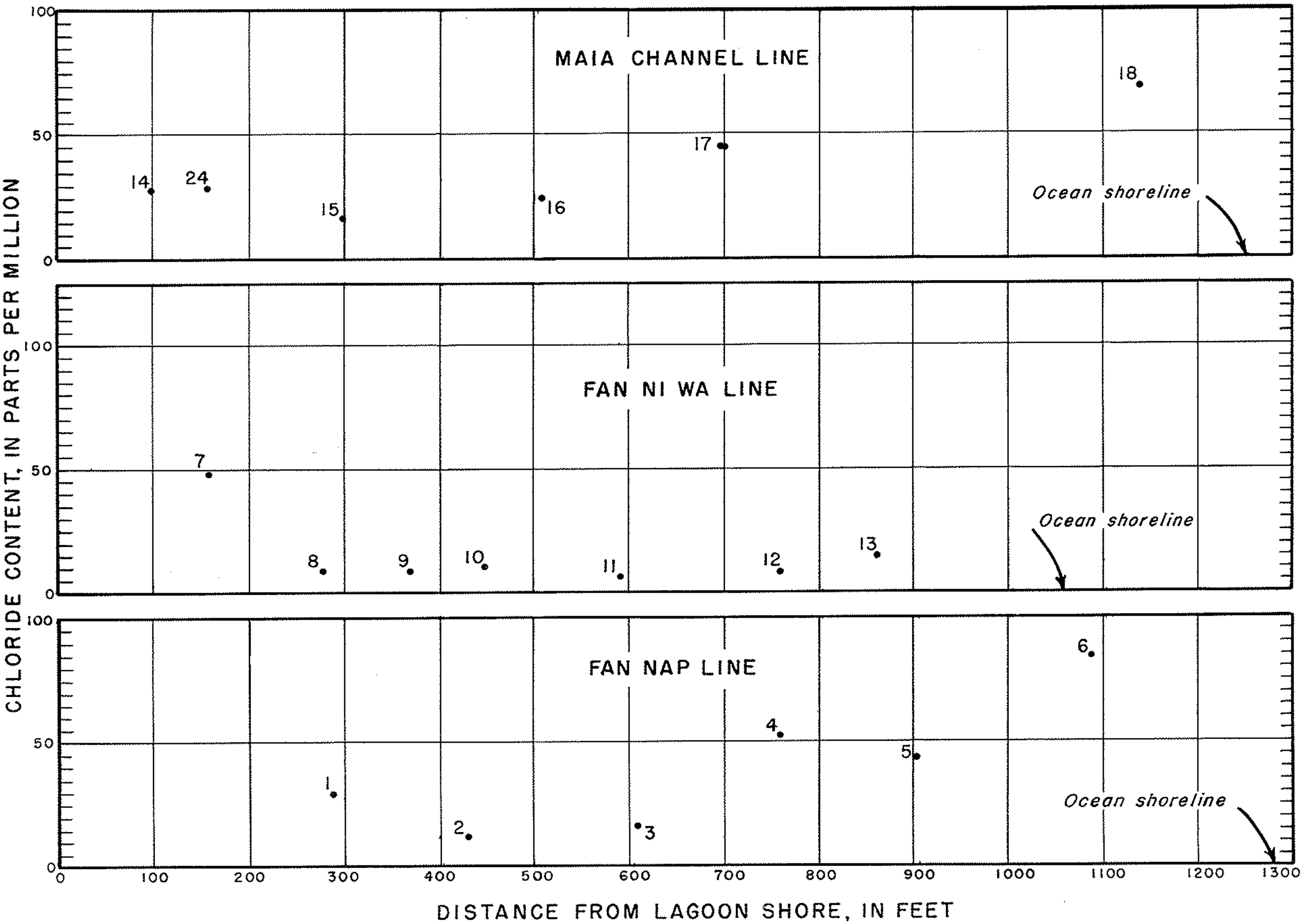

Figure 8.— Relation of chloride content of ground water to distance from shore, Falarik Island, Ifalik Atoll, September 21, 1953.

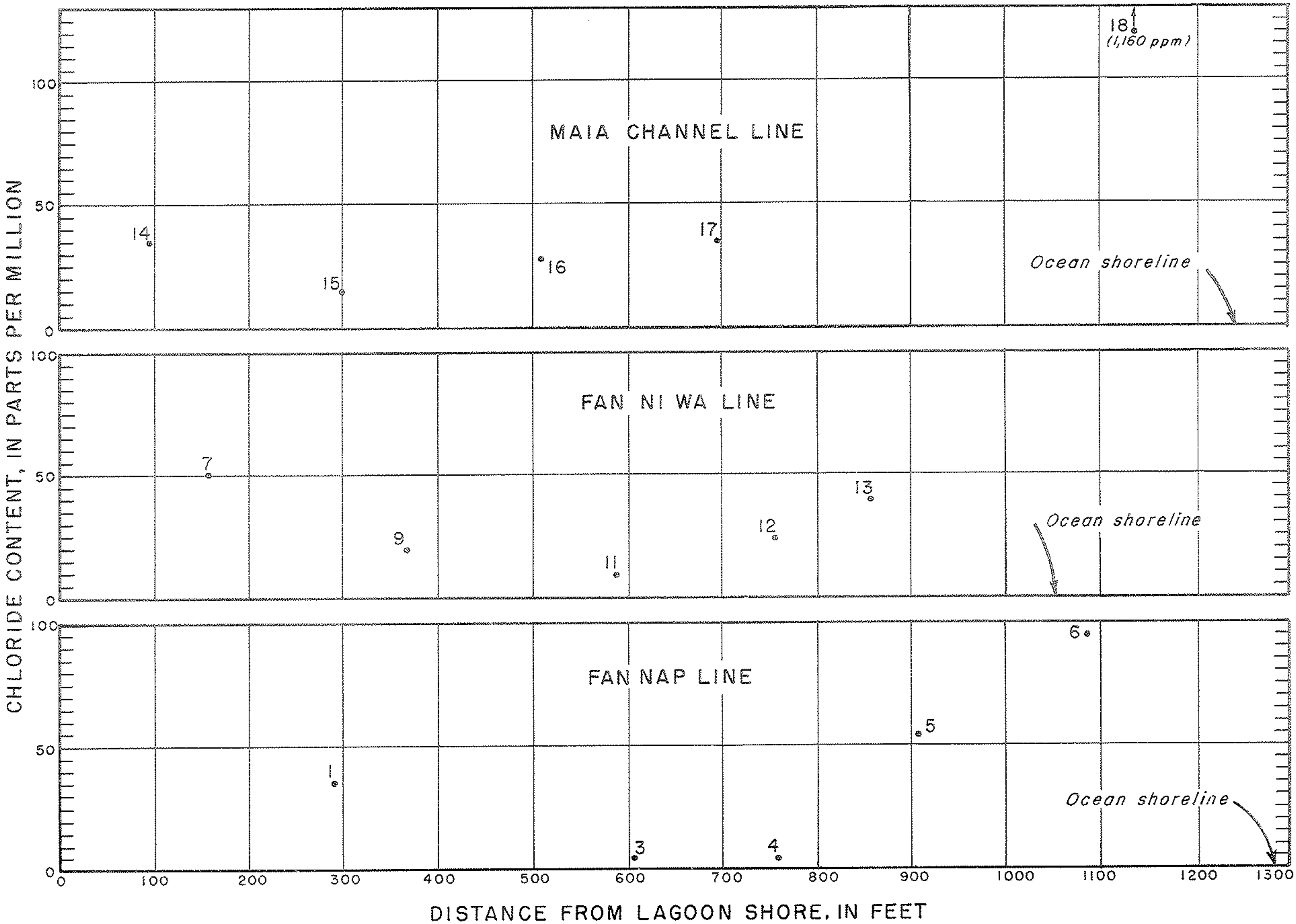

Figure 9.— Relation of chloride content of ground water to distance from shore, Falarik Island, Ifalik Atoll, November 1-3, 1953

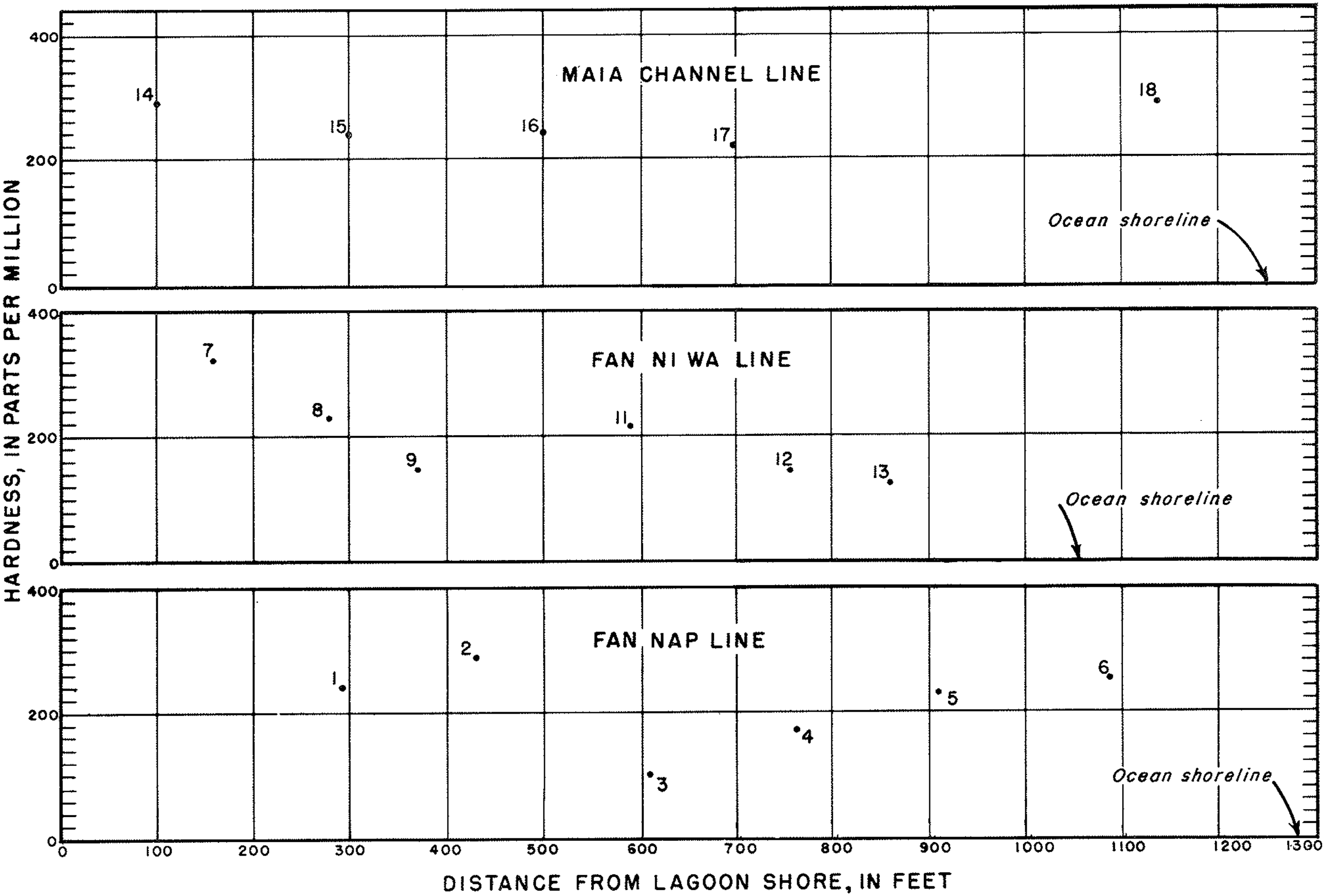

Figure 10.— Relation of hardness of ground water to distance from shore, Falarik Island, Ifalik Atoll, September 21, 1953.

Table 6.--Chemical analyses of water samples (ppm) from Fan Ni Wa well line, Ifalik Atoll
Analyses by U. S. Geological Survey, Quality of Water Branch

Well number	Well 7	Well 8	Well 9	Well 11	Well 12	Well 13
Date of collection	9/23/53	9/23/53	9/23/53	9/23/53	9/23/53	9/23/53
Dissolved solids	446	271	232	157	233	174
Specific conductance (micromhos at 25°C)	748	467	290	272	399	311
Hardness (as $CaCO_3$)	331	242	204	134	172	132
Non-carbonate hardness (as $CaCO_3$)	0	0	10	8	13	0
Silica (SiO_2)	15	8.8	13	4.0	9.5	3.6
Iron (Fe)	.17	.37	.06	.03	.07	.03
Calcium (Ca)	103	82	68	47	59	44
Magnesium (Mg)	18	9.2	8.3	4.1	6.0	5.4
Sodium (Na)	29	4.7	5.8	3.9	15	12
Potassium (K)	8.3	1.7	3.0	.4	1.7	2.5
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	408	298	237	154	194	163
Sulfate (SO_4)	5.8	3.5	4.1	2.6	8.7	7.7
Chloride (Cl)	47	6	10	5	26	14
Fluoride (F)	.2	.3	.4	.5	.5	.2
Nitrate (NO_3)	.6	.5	.2	3.8	.3	.6

29, which are about 175 feet from the ocean and lagoon shores respectively, contain fresh water, whereas, oddly enough, the middle well, number 28, contains water averaging about 2,000 ppm in chloride. (See table 5.) The higher salinity at well 28 may be due to the presence of a section of underlying reef which has a more permeable matrix or a larger number of cracks than the sections of reef underlying wells 27 and 29. The greater tidal mixing would permit the development of a thicker zone of mixture within the Ghyben-Herzberg lens. Presumably at well 28 the edges of the zone of mixture extend to the water table. The lens is practically undeveloped in the southwest end of Ella Island where the land is only about 350 feet wide. There a shallow ground-water pond, with dimensions of about 50 by 350 feet, has salinity greater than half that of sea water (see sample 26 in table 5).

Elangalap Island is divided into two roughly equal segments which are independent hydrologic units. The larger segment has maximum dimensions of about 75 by 150 feet and an area of 0.0004 square mile. It does not support a fresh-water lens. Two samples obtained from a well in the center of that land unit ranged in chloride content from 60 to 80 percent of that of sea water (see sample 25 in table 5).

The temperature of the ground water at Ifalik ranged from 76° to 81° Fahrenheit and averaged 79° Fahrenheit.

Use of Water

Ground water is used by the people on Ifalik for drinking, cooking, and washing. Bathing is done in the lagoon or in wells. The ground water is obtained from shallow dug wells which, for the most part, are uncased and uncurbed. Several wells which are reserved for drinking and cooking purposes have wooden covers and curbs and are cased with limestone blocks. Practically no rainwater is caught or used directly. This is in contrast to the Marshall Islands, where the people prefer rainwater to well water for all purposes (Cox, 1951; Arnow, 1954).

Ground water is equally important to the people of the atoll through its control of vegetation. The existence of extremely fresh ground water permits the growth of taro and breadfruit in widespread areas in Falarik and Falalap. Breadfruit will not grow successfully in certain parts of Falarik - notably in the filled Maia Channel and along a narrow strip of gravelly sand which parallels the lagoon shore and expands to cover about half of the southwest corner of the island. The ground water underlying these areas is fresh however, and the failure of the breadfruit is apparently due to a soil deficiency. The explanation offered by the people of Ifalik is that not enough "brown soil" is present.

The coconut palm, the backbone of the Ifalikian way of life, grows successfully almost wherever planted on the three larger islands in Ifalik and is even found on tiny Elangalap. There is no fresh-water lens in Elangalap, but because of the heavy rainfall the palms evidently obtain sufficient fresh water directly from the zone of soil moisture.

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