Water-Supply Potential From an Asphalt-lined Catchment near Holualoa Kona, Hawaii

By SALWYN S. W. CHINN

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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CONTENTS

ILLUSTRATION

TABLES

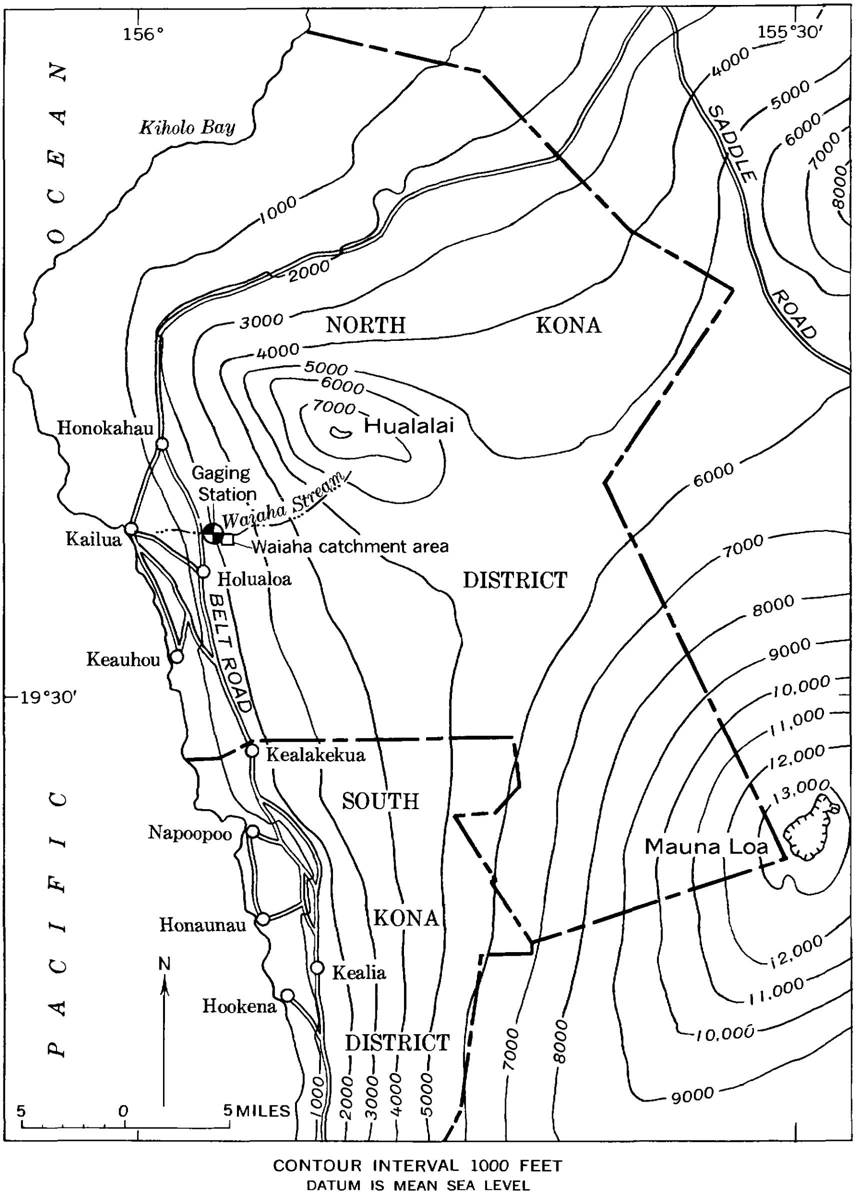

FIGURE 2.—Map of North Kona district showing location of test catchment area, and Waiaha stream-gaging station.

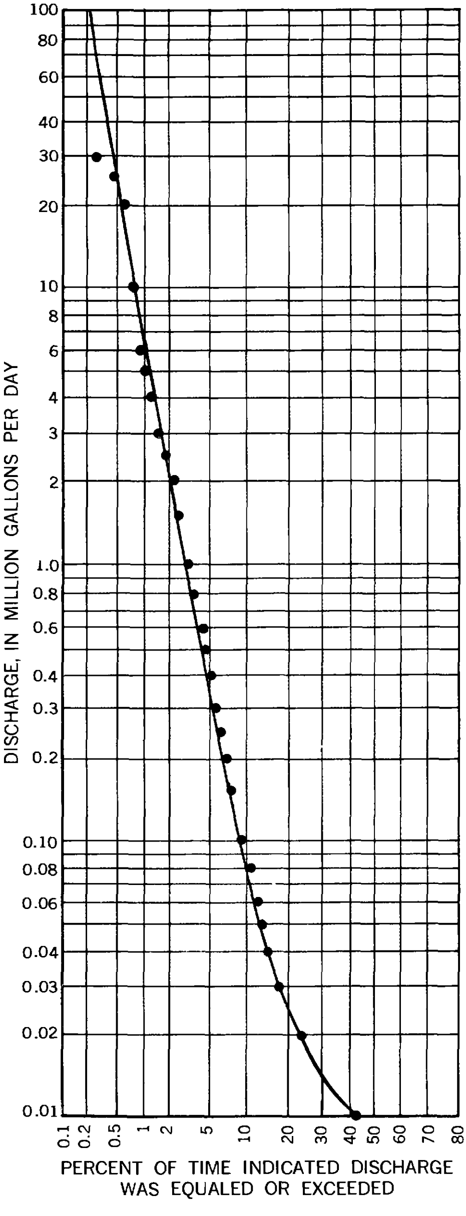

FIGURE 3.—Flow duration of Waiaha Stream near Holualoa.

PURPOSE

The purpose of this report is to present the results of a study of the records collected during the catchment test period (1959–61). The records are presented in the form of tables and graphs.

The study was authorized by a cooperative agreement between the U.S. Geological Survey and the Hawaii Division of Water and Land Development, Department of Land and Natural Resources. The report was prepared under the general supervision of Mearle M. Miller, district engineer, Surface Water Branch, Honolulu, Hawaii. Field investigations during the test period were conducted by Daniel E. Havelka under the general supervision of Howard S. Leak, district engineer. Most of the hydrologic data was collected by Hajime Matsuura.

LOCATION OF TEST CATCHMENT AREA

The asphalt-lined catchment has an area of 16,940 square feet. It is at lat 19°38′14″, long 155°56′30″, 0.6 mile east of the Board of Water Supply office, 1.2 miles north of the Holualoa Post Office, and 3.5 miles east of Kailua, Kona, Hawaii (fig. 2). It is about 1,000 feet east of and within the drainage area of the stream-gaging station on Waiaha Stream near Holualoa. Holualoa is on the southern side of Hulalai Volcano, which slopes from 600 to 1,000 feet per mile. This particular location was chosen for the test catchment area because: (1) It is in an area of high rainfall, (2) the amount of clearing necessary to prepare the site was minimal, (3) the slope of the ground and the amount of soil cover were favorable, (4) it was easy to reach the site, and (5) the potential water-use area was nearby.

METHOD OF STUDY

CONSTRUCTION OF CATCHMENT

A bulldozer was used to clear the area (fig. 4) and to smooth and compact the soil. The weeds, brush, and other debris that remained after bulldozing were cleared by hand. After the area was cleared, a ridge of earth was placed around the perimeter to contain all rainwater and to prevent water from entering the catchment from the outside. The catchment area of 16,940 square feet was an oval 210 feet long and 120 feet wide whose natural topography provided a drop of 15 feet along its length.

After the area was prepared and all weeds that came up after compaction were burned off (fig. 5*A*), the area was sprayed with a water-soluble soil sterilant. After the application of the soil sterilant, the area was primed with liquid asphalt and then sprayed with membrane asphalt (fig. 5*B*) at temperatures of 375°–425°F.

FIGURE 4.—Clearing Waiaha catchment site.

The specifications for the membrane asphalt were as follows:

Property		*Minimum*	*Typical*	*Maximum*
Softening point (R and B)	°F	175	------	200
Ductility at 77°F	cm per min	3. 5	------	-------
Solubility CCl_4	percent	97	------	-------
Loss on heating (325°F, 5 hrs)	do	------	------	1
Penetration after loss	percent of original	60	------	-------
Pounds per gallon at 60°F		------	8. 5	-------
Viscosity at 325°F	SSF	------	300	-------
Flash (C.O.C.)	°F	425	------	-------

The membrane asphalt was applied at rates ranging from 1 to 4 gallons per square yard. Due to the uneven surface of the ground, the thickness of the membrane varied from place to place, but the average thickness was about one-half inch.

After the asphaltic membrane was applied, it was painted with asphalt-based aluminum paint to retard photochemical damage. No other protective covering was placed on the catchment surface during the test.

The total cost of preparing the catchment area was $5,000, or about 30 cents per square foot.

A

B

FIGURE 5.—Construction of catchment. *A*, After clearing and before compaction. *B*, spraying asphaltic membrane on catchment.

PROBLEMS ENCOUNTERED

During construction, frequent rains soaked the soil and caused delays because it was necessary after each rain to let the soil dry before it could be smoothed and compacted properly. Cattle walking across the catchment area caused extensive damage to the asphaltic membrane before the problem was recognized and the area was enclosed by fencing. Numerous punctures in the membrane had to be repaired with heated asphalt. A third problem was caused by inadequate or incomplete sterilization of the soil beneath the membrane. The result was some vegetation grew and became vigorous enough in a few months to penetrate the membrane in a few places. In time, more and more vegetation penetrated the membrane, and at the end of the 3-year period an extensive part of the catchment area was affected. However, no attempt was made to eliminate the vegetation because one of the objectives of the study was to see how the efficiency of the catchment area changed under minimum maintenance.

INSTRUMENTATION

A gaging station was established at the downstream end of the catchment area to measure the runoff. The control for this station was a combination of a 22° sharp-crested weir and a 2-foot rectangular weir (fig. 6). A 1:1 scale model of the control was tested in the laboratory. From this test a rating curve for the combined control was developed for heads below 1.5 feet.

A Stevens continuous recorder was used to measure the head on the control, which rarely exceeded the capacity of the 22° sharp-crested weir. The runoff figures, therefore, are considered good.

Rainfall on the catchment area was measured by two nonrecording (Weather Bureau-type 8-inch) gages, and one recording (tipping-bucket) gage. The nonrecording gages were placed on the perimeter of the catchment, one at the upper end and the other near the middle. The recording rain gage was located at the weir. These gages were read at intervals of about 6 weeks, and the average of the readings from the three gages was assumed to be the total rainfall on the catchment area over the period. The total was adjusted by appropriate ratios, determined from the daily record from the tipping-bucket gage, to show the daily rainfall on the catchment.

The tipping-bucket rain gage recorded the rainfall in 0.05-inch increments which was not sufficiently small to record some light rains. Thus, runoff at times was recorded when apparently no rain fell, and at other times precipitation appeared to be greater than indicated by runoff. A float- or weighing-type rain gage might have more accurately recorded these light rains.

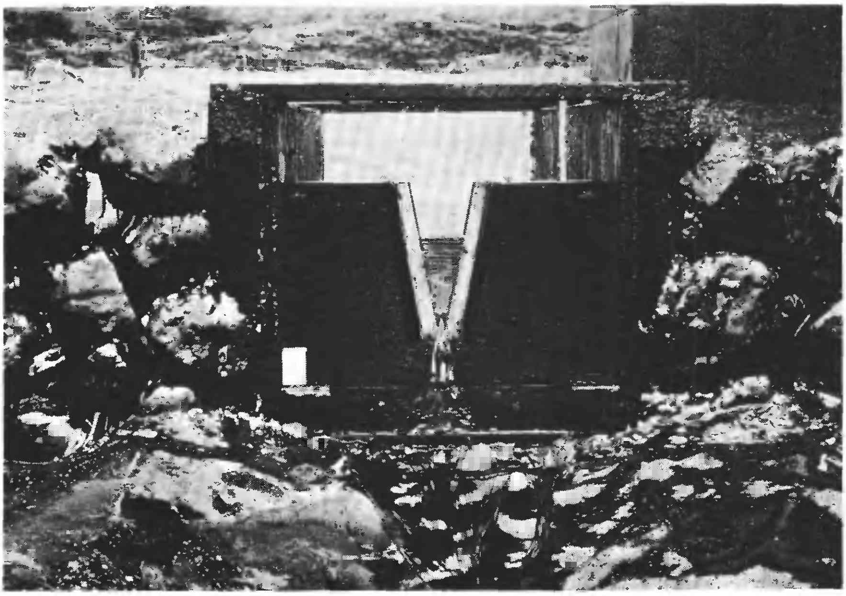

FIGURE 6.—Measuring weir.

RAINFALL

A detailed study made by Taliaferro (1958) shows that in the Kona district rainfall increases with altitude at a fairly uniform rate up to an altitude of about 2,500 feet. Above 2,500 feet, however, rainfall decreases as altitude increases (fig. 7).

Figure 7 indicates that the rainfall at the Waiaha catchment area, which is at an altitude of 2,040 feet, should average about 100 inches a year. However, rainfall records collected at the catchment show that for each of the calendar years 1959, 1960, and 1961, the rainfall was less than 100 inches. The total rainfall for calendar year 1959 was 78.9 inches; for 1960, 70.5 inches; and for 1961, 88.4 inches (table 1). The average for the 3 years was 79.2 inches.

The figures of rainfall indicate that the test was conducted during a period of less than average rainfall. This conclusion was verified by comparing rainfall at the catchment with that at a nearby rain gage which has a long period of record. The nearest long-term rain gage is about 1 mile east of the catchment area and at an altitude of 3,100 feet. The 30-year mean annual rainfall at this gage is 85.4 inches. However, for the 3 calendar years 1959, 1960, and 1961, the yearly rainfall was 61.1, 52.0, and 82.8 inches, respectively. The average for the 3 years was 65.3 inches.

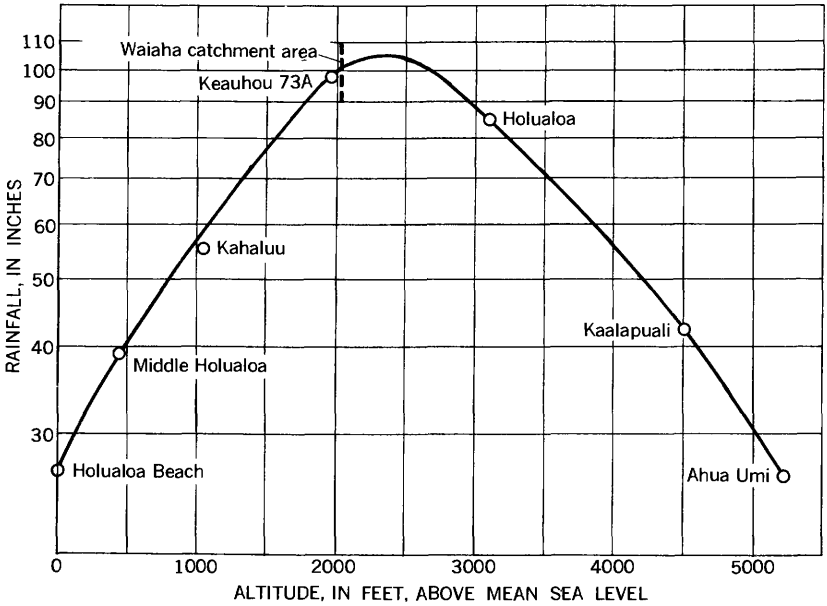

FIGURE 7.—Relation between annual rainfall and altitude, Kona district.

TABLE 1.—*Daily rainfall, in inches, at Waiaha catchment area, 1959–61*

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959												
1	0	0	0	0	0.09	0	0.55	0.14	0	0.13	1.60	0
2	0	0	0	.42	.22	.05	.27	.05	0	0	.09	.05
3	.16	0	0	1.55	.36	.09	.27	0	1.36	0	.27	.16
4	0	0	0	.05	.04	.09	.14	0	.09	0	.18	0
5	.04	0	0	.04	.04	0	.73	0	.04	0	.14	0
6	0	0	0	0	0	0	0	0	0	.76	.09	0
7	0	.09	0	0	.04	.59	.96	0	.31	.44	.04	.42
8	0	0	0	0	0	0	.41	.57	.04	.67	.04	.11
9	0	.42	0	.04	.27	.05	0	.04	0	.04	.85	0
10	0	.26	(1)	0	.31	.05	.14	.44	.22	0	.05	0
11	0	.09	(1)	.18	.22	.14	.23	.13	.09	0	0	.16
12	0	.09	(1)	.40	.36	0	0	.22	.13	.27	0	0
13	5.95	.88	(1)	0	0	.23	0	0	.09	0	.09	0
14	.53	0	(1)	0	0	0	0	0	.22	.31	0	0
15	.04	0	(1)	0	(1)	.05	0	0	.09	0	0	0
16	0	0	1.58	0	(1)	.14	.36	.18	0	0	0	0
17	0	0	.26	0	(1)	.96	.23	.04	0	0	0	.05
18	12.15	0	.09	(1)	.13	.09	.59	0	0	0	.04	0
19	0	0	.09	(1)	.09	0	.27	.13	.04	0	0	0
20	0	.53	.09	(1)	.32	0	0	.13	.30	0	0	0
21	0	1.23	0	(1)	0	.05	.18	0	0	.22	0	0
22	0	.44	0	(1)	.28	0	.92	.40	0	.44	0	0
23	0	0	.08	(1)	.19	.05	.32	.04	0	0	0	0
24	0	0	0	(1)	0	.55	0	.40	0	.22	0	0
25	0	0	.42	(1)	1.07	.18	.05	1.85	0	0	0	0
26	0	0	0	(1)	.32	0	.69	1.06	.04	0	0	0
27	0	.18	0	(1)	1.25	.18	1.01	1.63	.43	0	0	0
28	0	0	.38	(1)	.05	.14	.14	.62	0	0	0	.21
29	0	------	0	(1)	0	.05	.32	.09	0	0	0	0
30	0	------	.09	3.83	1.44	0	.64	1.32	2.24	0	0	0
31	0	------	0	------	0	------	.28	0	------	1.82	------	.05
Total	18.87	4.21	3.08	6.51	7.09	3.73	9.70	9.48	5.73	5.32	3.48	1.21

See footnote at end of table.

TABLE 1.—*Daily rainfall, in inches, at Waiaha catchment area, 1959–61*—Con.

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1960												
1	0	0	0.16	0	0.28	0.24	0	0.74	0.36	0	0	0
2	0	0	.05	0	0	.48	0	.61	.09	.04	0	0
3	0	0	.21	0	0	0	0	.94	.31	0	.20	0
4	0	0	.05	.26	.06	.29	0	0	.31	0	.04	0
5	0	0	.70	.22	.33	1.10	0	0	.44	.62	0	1.29
6	0	0	.05	.04	0	1.06	0	.42	.04	.25	0	0
7	0	0	.11	.73	0	.29	0	.28	1.16	0	0	0
8	.21	0	0	0	0	.62	0	0	.04	2.66	0	0
9	.16	.05	0	0	1.06	.10	.26	.05	.31	.04	0	0
10	.90	.16	0	0	.77	0	.48	.05	.27	.04	0	0
11	0	.05	0	0	1.06	0	.04	(1)	0	.41	.08	0
12	0	0	0	0	1.25	.19	0	(1)	.04	.04	.61	0
13	0	.05	0	0	1.15	.16	0	(1)	.27	0	.13	0
14	0	0	0	.04	0	.11	0	(1)	0	0	0	.09
15	0	0	.11	2.71	0	0	0	(1)	.18	0	0	.77
16	0	0	0	0	.05	0	0	(1)	0	0	.13	.30
17	0	0	.30	.34	.05	0	0	(1)	1.87	0	.26	.09
18	0	0	1.16	1.72	.19	.54	0	(1)	.09	0	0	0
19	0	0	.05	1.38	.38	0	0	(1)	.04	.66	0	.09
20	0	0	.30	.09	.24	0	0	2.80	.49	1.31	0	0
21	0	0	.34	.13	.34	0	0	0	.18	.33	.04	0
22	0	0	.60	.47	.38	0	0	.13	0	.08	0	0
23	0	0	0	0	0	1.78	0	0	.13	0	(1)	0
24	0	0	0	0	3.17	.17	.35	2.22	0	0	(1)	0
25	0	0	.52	0	.10	.13	.22	.36	0	.16	(1)	0
26	0	0	0	.33	.24	.04	.83	.18	0	0	(1)	0
27	0	0	0	0	0	0	.13	.13	0	0	(1)	.09
28	0	0	0	.06	.14	0	0	0	0	0	.22	0
29	0	0	.60	0	.19	0	.04	0	0	.78	.04	.04
30	0	------	0	.06	.53	.39	0	0	.44	.57	0	0
31	0	------	2.97	------	.43	------	.26	.93	------	0	------	0
Total	1.27	0.31	8.28	8.58	12.39	7.69	2.61	9.84	7.06	7.99	1.75	2.76
1961												
1	1.76	0	0.08	0.24	0	0.57	0	(1)	0	0.34	3.33	0
2	0	0	.08	.05	.10	.28	.05	(1)	.25	.15	3.12	0
3	0	0	0	.33	.28	.10	.30	(1)	.20	0	.83	.24
4	.43	.04	.29	.62	.38	.19	0	.30	.15	.05	0	0
5	0	0	.04	.05	.05	.52	0	.45	1.05	.29	0	.05
6	0	0	.71	0	.33	.43	0	.45	0	0	0	.56
7	0	0	0	.14	.48	.62	1.10	.40	.25	0	0	0
8	0	0	0	0	.50	4.47	0	0	0	.64	0	(1)
9	0	0	0	0	.14	0	2.94	0	0	0	0	(1)
10	0	0	.04	0	.18	0	1.21	.05	.10	.59	0	(1)
11	0	.50	.76	0	.04	.20	.10	0	.60	.29	.09	.33
12	0	1.09	.17	.24	0	.25	0	.10	.10	1.37	0	0
13	0	1.47	0	.14	.54	.10	0	.45	.20	0	0	0
14	0	.08	0	.14	.25	.70	0	.20	.05	0	.09	.14
15	0	0	0	.10	.86	.35	0	0	.15	0	0	.05
16	0	0	0	0	.14	.25	0	0	.10	.10	.09	0
17	0	0	.05	.19	.18	.2	0	.25	0	.05	.09	.19
18	0	0	0	.71	.65	.5	0	.30	0	.0	.14	.85
19	0	0	.26	.14	.05	0	.42	.15	1.67	0	0	0
20	0	0	0	.19	.05	.25	0	0	.10	0	.33	0
21	0	0	.05	2.04	.40	0	.42	.35	0	.10	0	0
22	.04	0	0	.33	.40	.3	(1)	.20	0	.15	0	.19
23	0	.04	.13	1.90	.15	0	(1)	.15	.24	.10	0	0
24	0	.63	.34	.48	0	0	.7	.45	.10	.98	.33	0
25	0	0	.13	0	.05	0	0	0	.39	.15	.05	0
26	.71	.25	.08	.19	.40	0	0	0	.15	0	0	0
27	0	.29	4.62	.10	0	0	0	0	0	.05	.05	0
28	0	0	5.71	0	.50	0	.10	.05	.15	0	.05	.05
29	0	------	.78	0	1.80	.45	.10	.25	.34	0	.05	0
30	0	------	.33	0	.40	0	.30	0	.98	.05	0	0
31	0	------	.05	------	1.10	------	.05	.55	------	.31	------	0
Total	2.94	4.39	14.70	8.32	10.40	10.73	7.79	5.10	7.32	5.76	8.64	2.65

[1] Included in following measurement.

From the ratio of the 3-year (1959–61) average at the catchment site to that at the long-term rain gage site, it is estimated that the long-term mean annual rainfall at the catchment would be about 104 inches $\left(\frac{79.2}{65.3}\times 85.4\right)$. Thus the rainfall and the resultant runoff from the catchment area were less than would be expected in an average year.

Data on monthly rainfall and runoff are shown graphically on figure 8.

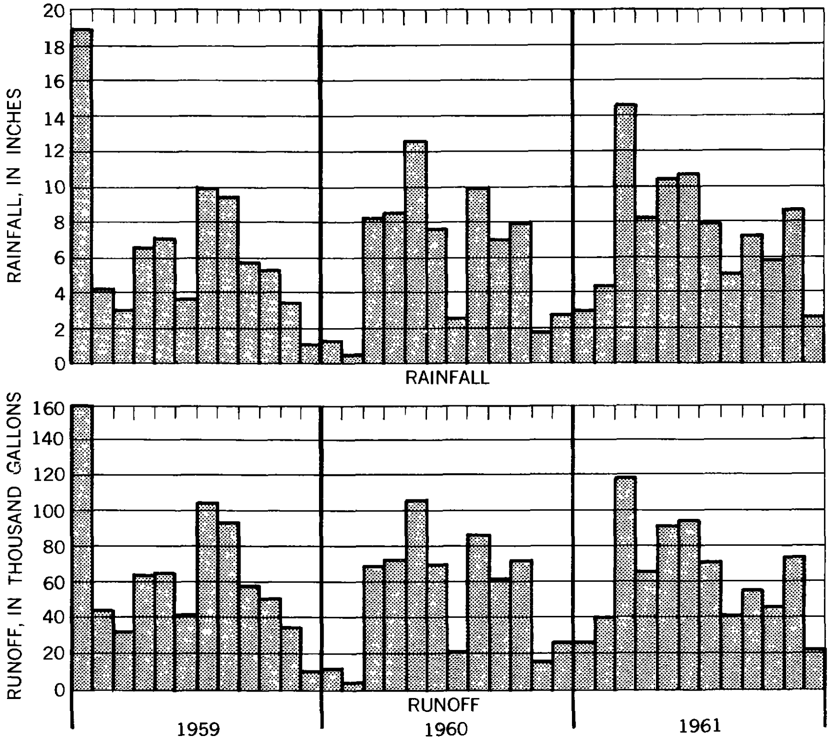

FIGURE 8.—Monthly rainfall and runoff from Waiaha catchment area during calendar years 1959–61.

Figure 8 shows that except for January 1959, rainfall during the cooler months of the year (December, January, and February) is less than that of the warmer months (May–September). The January 1959 rainfall was unusually high owing to an intense rainstorm which produced more than 12 inches of rain on January 18. A rainfall-duration curve (showing the greatest amount of precipitation for different time periods) for this storm is shown in figure 9. Although

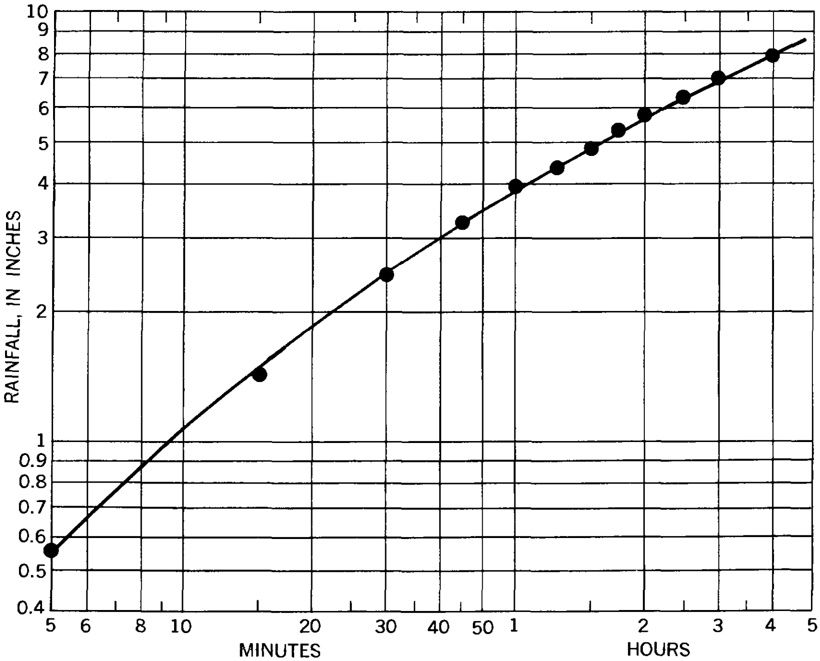

FIGURE 9.—Duration of rainfall of storm of January 18, 1959.

this storm appeared to be unusual, much greater intensities have been experienced in Hawaii. These facts suggest a knowledge of the rainfall intensity is needed in the design of conduits to carry catchment water to storage tanks.

RESULTS OF STUDY

WATER YIELD FROM CATCHMENT

In the 3-year period, 1959–61, the rainfall on the catchment area amounted to 2,500,000 gallons. The runoff was 2,090,000 gallons, or 84 percent of the rainfall, which is equivalent to 42 gallons of water per square foot of catchment surface.

The efficiency (ratio of runoff to rainfall) of the catchment decreased with time. It dropped from 0.93 in 1959, to 0.82 in 1960, and to 0.78 in 1961 (fig. 10). The decrease was probably due to leakage through the cracks that formed as the asphaltic membrane deteriorated with age, to interception of light rains by the vegetation which penetrated the asphaltic membrane, and to depressions that intercepted part of the flow (figs. 11–14). Some of the loss in efficiency could have been prevented by additional maintenance.

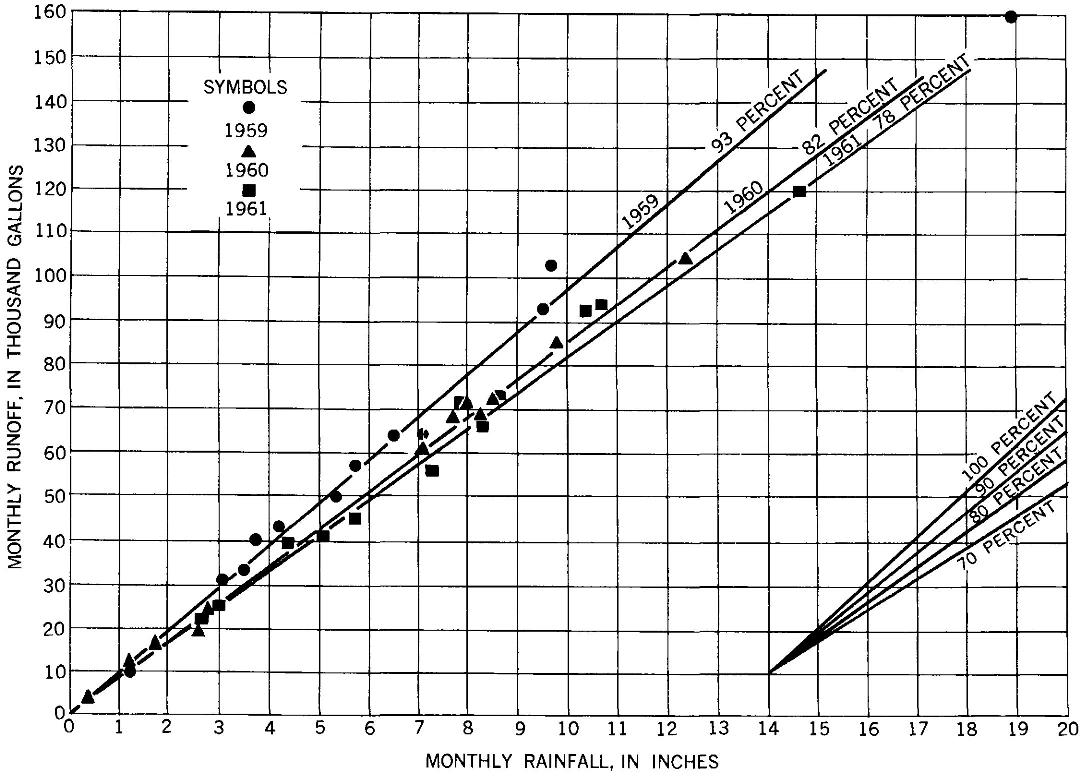

FIGURE 10.—Rainfall-runoff relations.

FIGURE 11.—Catchment after completion in June 1958.

FIGURE 12.—Catchment in December 1961.

FIGURE 13.—Asphaltic membrane 3½ years after completion.

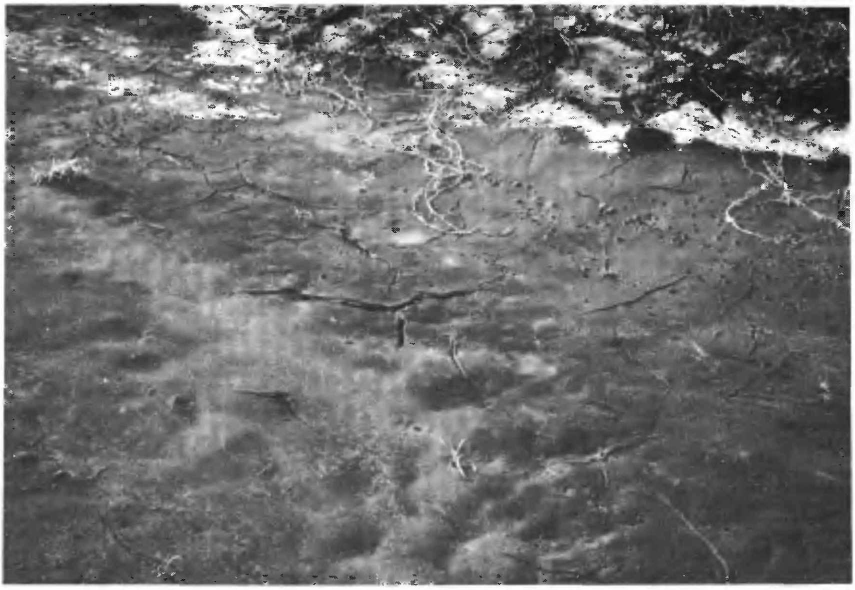

FIGURE 14.—A closeup view showing cracks and weeds in asphaltic membrane 3½ years after completion.

NATURAL BASIN VERSUS CATCHMENT RUNOFF

In 1960, there was no flow at the Waiaha Stream gaging station for the months of January, February, July, and December (table 2), but there was runoff from the catchment area during each of these months (table 3 and fig. 8). In general it was observed that little or no runoff occurred at the Waiaha Stream gaging station when precipitation recorded at the catchment area was less than 3 inches per month (tables 1 and 2). However, the data indicate that the amount of runoff at the Waiaha Stream gage was dependent not only on the amount and rate of rainfall but also on the degree of saturation of the drainage area prior to the rainfall.

TABLE 2.—*Daily discharge, in million gallons a day, at Waiaha Stream near Holualoa, Hawaii, 1959–61*

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959												
1	0	0	0	0	0.01	0.02	0.01	0.04	0.01	0.06	0.12	0
2	0	0	0	0	0	.01	.01	.02	.01	.01	2.32	0
3	0	0	0	.31	.01	.01	.01	.01	.20	.01	.02	0
4	0	0	0	.10	.01	.01	.02	.01	.31	.01	.02	0
5	0	0	0	.01	.01	.01	.04	.01	.07	0	.01	0
6	0	0	0	.01	.01	.01	.04	.01	.02	0	.01	0
7	0	0	0	.01	.01	.01	.04	.01	.01	.01	.01	0
8	0	0	0	.01	.01	.01	.04	.01	.01	.06	0	0
9	0	0	0	0	.01	.01	.03	.01	.01	.04	.31	0
10	0	0	0	0	.01	.01	.01	.01	.01	.01	.04	0
11	0	0	0	0	.01	.01	.01	.01	0	.01	.01	0
12	0	0	0	0	.01	0	.01	.01	0	.01	.01	0
13	25	0	0	0	.01	0	.01	.02	0	.01	0	0
14	6.9	0	2.25	0	.01	0	.02	.02	0	.01	0	0
15	.22	0	.02	0	.01	0	.02	.02	0	0	0	0
16	.01	0	.01	0	.01	0	.02	.02	0	0	0	0
17	.01	0	.01	0	0	.01	.02	.02	0	0	0	0
18	156	0	.01	0	0	.02	.03	.01	0	0	0	0
19	1.45	0	.01	0	0	.01	.02	.01	0	0	0	0
20	.08	0	0	.02	0	.01	.01	.01	0	0	0	0
21	.02	.19	0	.01	0	.01	.01	.01	0	0	0	0
22	.01	.22	0	.02	0	.01	.33	.01	0	0	0	0
23	.01	.03	0	.11	0	.01	.11	.01	0	0	0	0
24	.01	.01	0	.02	0	.01	.04	.01	0	0	0	0
25	0	.01	0	.02	.01	.01	.01	1.03	0	0	0	0
26	0	.01	0	.04	.03	.01	.04	1.16	0	0	0	0
27	0	0	0	.02	.57	.01	.21	1.67	0	0	0	0
28	0	0	0	.01	.04	.01	.46	3.23	0	0	0	0
29	0	------	0	.01	.01	.01	.25	.21	0	0	0	0
30	0	------	0	.01	.26	.01	.14	3.53	.26	0	0	0
31	0	------	0	------	.17	------	.27	.65	------	0	------	0
Total	189.72	0.47	2.31	0.74	1.24	0.27	2.29	11.81	0.92	0.25	2.88	0
1960												
1	0	0	0	0.12	0	0.05	0	0	0.12	0	0.01	0
2	0	0	0	.02	0	.03	0	0	.02	0	0	0
3	0	0	0	.01	0	.02	0	.12	.02	0	0	0
4	0	0	0	.01	0	.01	0	.02	.02	0	0	0
5	0	0	0	.01	0	.10	0	.01	.03	0	0	0
6	0	0	0	.01	0	.55	0	0	.04	0	0	0
7	0	0	0	.01	0	.04	0	.01	.14	0	0	0
8	0	0	0	.02	0	.04	0	.01	.06	.95	0	0
9	0	0	0	.01	0	.04	0	.01	.03	.08	0	0
10	0	0	0	.01	0	.01	0	0	.03	.02	0	0
11	0	0	0	.01	.11	.01	0	0	.02	.01	0	0
12	0	0	0	.01	6.52	.01	0	0	.01	.01	0	0
13	0	0	0	.01	.45	0	0	.69	.01	.01	0	0
14	0	0	0	.01	.04	0	0	.06	.01	.01	0	0
15	0	0	0	.41	.01	0	0	.03	.01	0	0	0
16	0	0	0	.08	.01	0	0	.02	.01	0	0	0
17	0	0	0	.02	.01	0	0	.01	.07	0	0	0
18	0	0	0	.39	0	1.62	0	.01	.12	0	0	0

TABLE 2.—*Daily discharge, in million gallons a day, at Waiaha Stream near Holualoa, Hawaii, 1959–61*—Continued

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1960												
19	0	0	0	0.85	0.01	0.29	0	0.01	0.03	0	0	0
20	0	0	0	.14	.01	.01	0	.01	.02	.61	0	0
21	0	0	0	.02	.01	0	0	0	.02	.33	0	0
22	0	0	0	.01	.01	0	0	0	.02	.03	0	0
23	0	0	0	.01	.01	.18	0	0	.01	.02	0	0
24	0	0	0	.01	2.42	.26	0	.31	.01	.01	0	0
25	0	0	0	.01	.60	.01	0	.15	.01	0	0	0
26	0	0	0	0	.02	.01	0	.05	.01	0	0	0
27	0	0	0	0	.01	.01	0	.03	.01	0	0	0
28	0	0	0	0	.01	.01	0	.02	0	0	0	0
29	0	0	0	0	.01	0	0	.01	0	0	0	0
30	0	------	0	0	.01	0	0	.01	0	.02	0	0
31	0	------	.41	------	.01	------	0	.01	------	.03	------	0
Total	0	0	0.41	2.22	10.29	3.31	0	1.61	0.91	2.14	0.01	0
1961												
1	0	0	0	0.13	0	0.39	0	0	0.02	0.20	9.0	0
2	0	0	0	.20	0	.25	0	0	.01	.06	15	0
3	0	0	0	.10	0	.05	0	0	.01	.03	3.0	0
4	0	0	0	2.73	0	.03	0	0	.01	.11	.06	0
5	0	0	0	.67	0	.38	0	0	.03	.13	.02	0
6	0	0	0	.02	0	.54	0	0	.01	.01	.02	0
7	0	0	0	.01	0	.95	0	.01	.01	0	.01	0
8	0	0	0	.01	.04	33.0	.01	.02	0	.01	0	0
9	0	0	0	0	.03	1.68	3.43	.01	0	.01	0	0
10	0	0	0	0	.03	.03	2.19	.01	0	.37	0	0
11	0	0	0	0	.02	.02	1.43	0	0	.08	0	0
12	0	0	.01	0	.01	.02	.05	0	0	.57	0	0
13	0	.10	.01	0	.01	.02	.02	0	0	.08	0	0
14	0	.03	.01	0	.08	.32	.01	.01	0	.03	0	0
15	0	.01	.01	0	.87	.58	0	.01	0	.02	0	0
16	0	0	.01	0	.15	.60	0	0	0	.01	0	0
17	0	0	.01	0	.03	.09	0	0	0	.01	0	0
18	0	0	0	0	.05	.05	0	0	0	0	0	.01
19	0	0	0	0	.03	.05	0	.01	.31	0	0	0
20	0	0	0	0	.02	.03	0	.01	.10	0	0	0
21	0	0	0	1.49	.03	.02	0	.01	.03	0	0	0
22	0	0	0	.18	.02	.02	0	.01	.02	0	0	0
23	0	0	0	5.71	.03	.01	0	.01	.01	.01	0	0
24	0	0	0	4.55	.02	.01	0	.02	.01	.90	0	0
25	0	0	0	.07	.01	.01	0	.08	.07	1.8	0	0
26	0	0	0	.02	.01	0	0	.04	.01	.02	0	0
27	0	0	22.7	.01	.01	0	0	.02	.01	0	0	0
28	0	0	37.4	.01	.01	0	0	.01	0	0	0	0
29	0	------	26.2	0	2.57	0	0	.01	.08	0	0	0
30	0	------	3.24	0	1.11	0	0	.02	.11	0	0	0
31	0	------	.16	------	1.44	------	0	.02	------	0	------	0
Total	0	0.14	89.76	15.91	6.63	39.15	7.14	0.34	0.86	4.46	27.11	0.01

TABLE 3.—*Runoff, in gallons, from Waiaha catchment area near Holualoa, Hawaii, 1959–61*

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1959												
1	0	0	9	48	670	12	5,810	1,310	191	1,540	14,780	0
2	0	72	0	4,060	2,280	401	3,450	309	30	130	1,300	213
3	2,110	40	0	14,800	3,190	654	2,770	70	13,770	50	2,480	1,300
4	126	21	0	1,490	261	626	1,410	52	1,430	15	1,690	21
5	375	5	0	69	239	50	7,840	207	415	0	1,470	0
6	212	0	372	4	138	0	83	30	121	6,160	752	0
7	45	1,100	170	5	122	5,965	10,480	55	3,020	5,060	658	3,530
8	20	21	60	0	1	323	4,340	5,820	512	6,700	331	577
9	6	3,700	20	411	2,440	514	180	289	55	322	8,100	5
10	109	2,780	(1)	22	2,920	563	1,750	4,630	1,970	70	400	2
11	30	683	(1)	1,340	2,300	1,230	2,110	1,620	834	16	71	846
12	10	1,030	(1)	3,970	3,290	187	130	2,540	1,810	2,280	28	6
13	46,080	10,080	(1)	13	194	2,420	100	130	835	177	829	101
14	4,860	62	(1)	0	30	70	50	55	2,620	2,830	22	8

See footnote at end of table.

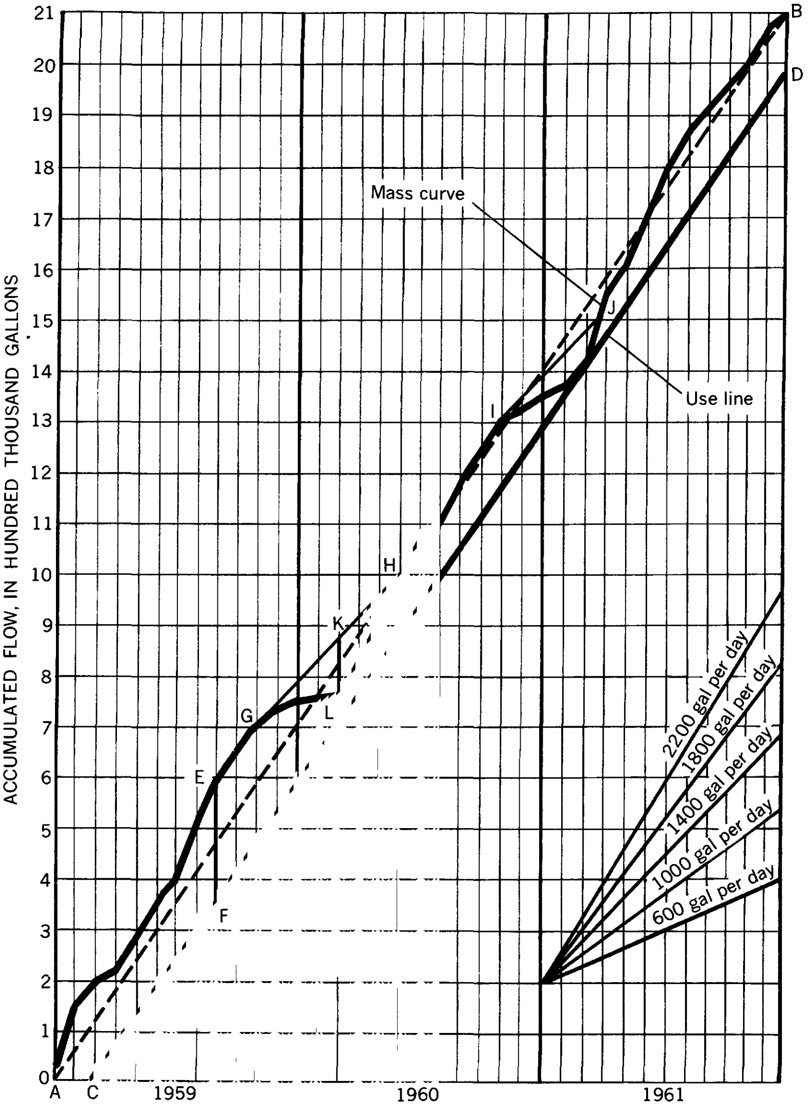

FIGURE 15.—Mass curve of runoff for Waiaha catchment (1959–61).

METHOD OF ESTIMATING CATCHMENT SIZE AND STORAGE

The yield from the catchment averaged about 2,000 gallons a day during the 3-year period 1959–61. Distribution of rainfall was such that uniform use (2,000 gal a day) of all the water would require storage equivalent to a 120-day supply (one-third of the annual yield).

A nomograph (fig. 16) based on the preceding data was prepared. From this nomograph, the size of the catchment and the storage required may be estimated if the annual rainfall and the efficiency of the water-proofing material are known. Its use is shown by the following examples:

Example A:

Given:

Rainfall=80 inches a year.

Efficiency of water-proofing material=95 percent.

Desired yield=2,600 gallons a day.

To find:

Area of catchment needed.

Storage required to permit full use of developed water.

Solution:

1. Draw a line from 80 on the R scale through 95 on the E scale and project the line to locate a point on line P.
2. Draw a line from this point to 2,600 on the Q scale.
3. Read the required area of catchment (20,000 sq ft) where the line crosses the A scale.
4. Read the storage required (310,000 gal) on the S scale opposite 2,600 on the Q scale.

Note: For areas where dry spells are longer than at Waiaha, the required storage would be larger than 310,000 gallons.

Example B:

Given:

Rainfall=90 inches a year.

Efficiency of roof catchment=75 percent.

Desired yield=300 gallons a day.

To find:

Area of roof catchment and storage required.

Solution:

1. Draw a line from 90 on the R scale through 75 on the E scale and project the line to find a point on P scale.
2. Connect the point on the P scale to 300 on the Q scale.
3. Read the required area (2,700 sq ft) where the line crosses the A scale.
4. Read the required storage (36,000 gal) on the S scale opposite 300 on the Q scale.

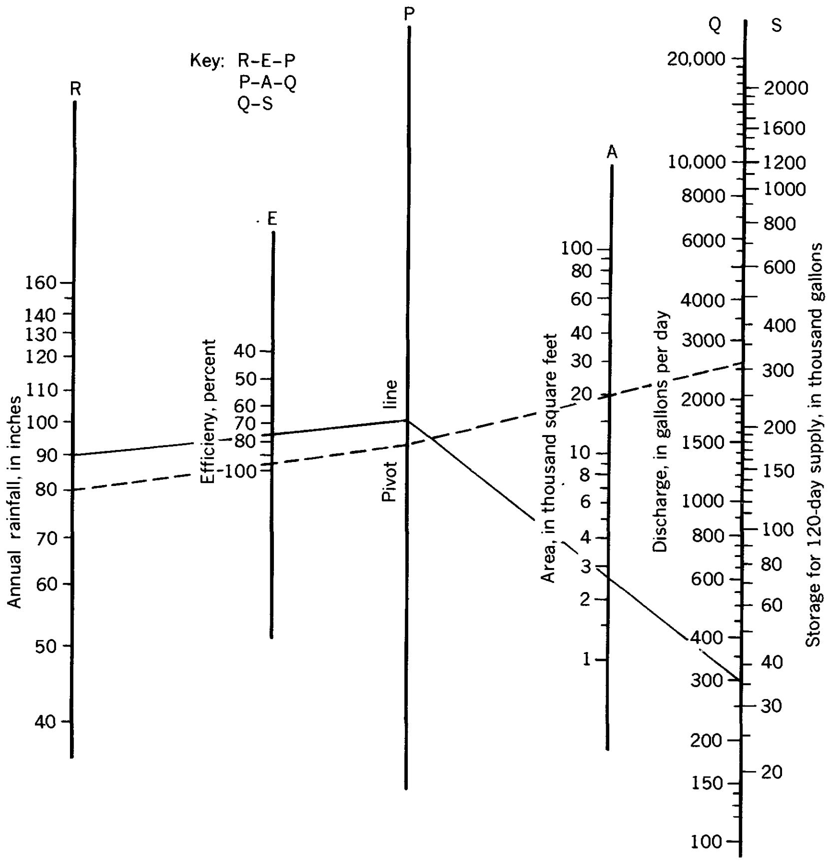

FIGURE 16.—Nomograph showing relation between rainfall, efficiency, area, and runoff.

COST OF WATER DEVELOPED

The cost of water developed by the Waiaha catchment area, excluding distribution and storage, is about $1.30 per thousand gallons. This estimate is based on the initial cost of catchment construction, a small maintenance charge, and the assumption that the catchment area will last for 6 years and have no salvage value thereafter. The cost of water would be lower substantially if (1) a larger catchment were utilized so as to reduce the unit cost of the catchment area, and (2) the asphaltic membrane were resprayed periodically so as to maintain the efficiency and extend the life of the catchment covering. The average cost would also be somewhat less during a period of normal rainfall because additional water would be developed at no increase in cost.

SUMMARY

In areas where there are no perennial streams or where ground-water supplies are expensive to develop, the use of water-proofed catchments may offer one solution to the problem of obtaining a water supply.

In a 3-year (1959–61) test of an asphalt-lined catchment area near Holualoa in the North Kona District, it was found that the rainfall on the catchment averaged 79.2 inches a year. The runoff averaged about 2,000 gallons a day or 42 gallons a year per square foot of catchment surface. From the mass curve of runoff from the catchment, it was determined that to obtain a steady supply of 2,000 gallons a day of the water developed, carry-over storage equivalent to a 120-day supply is needed.

Efficiency (ratio of runoff to rainfall) of the asphalt-lined catchment, under minimum maintenance conditions, decreased rapidly with time. It decreased from 93 percent in 1959 to 82 percent in 1960 and to 78 percent in 1961. The average for the 3-year period was 84 percent. The decrease in efficiency was due to (1) seepage loss through the cracks in the asphaltic membrane which formed as the membrane deteriorated with age, (2) interception of light rains by the vegetation which penetrated the membrane, and (3) interception by depressions in the catchment surface that lost water between storms.

A nomograph showing the relation between annual rainfall, the efficiency of the water-proof lining of a catchment, the area of catchment, and the runoff was prepared. The size of catchment needed to develop a given water supply can be estimated by using this nomograph if the annual rainfall and the efficiency of the water-proof covering of a catchment are known.

For areas where the rainfall distribution throughout the year is similar to that at Holualoa, the average runoff from the catchment can be made available if a storage tank having a capacity equal to one-third of the annual runoff volume is provided. However, for areas having longer dry spells than at Holualoa, the required storage will be larger.

The cost of water developed by this catchment area, excluding cost of distribution and storage, is about $1.30 per thousand gallons. The cost of water would be lower substantially if (1) a larger catchment was utilized to reduce the unit cost of the catchment area or (2) the asphaltic membrane was resprayed periodically so as to maintain the efficiency and extend the life of the catchment covering.

The use of aluminum sheeting, polyethylene, or vinyl or other plastic films, not discussed in this report, might also be considered for cover-

ing catchment areas. The material selected should be economical as well as practical for large-scale installation.

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