STUDIES OF HAWAIIAN RAINFALL

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In the estimation of the run-off for which provision must be made in sewer design, the frequencies with which rainfall occurs at a given rate during different intervals of time constitute one of the most important of the factors that have to be taken into consideration. In the first section of this paper, formulae are derived for the relation between duration and rate of rainfall at Honolulu for four values of frequency of occurrence.

The second section of the paper presents some data for the rainfall at Mount Waialeale, one of the wettest places on the globe.

RAINFALL INTENSITIES AT HONOLULU

From a chronological list of the excessive rainfalls that occurred at Honolulu during 1905–33, inclusive,[1] for 5, 10, 15, 30, 60, and 120 minutes, a table was compiled in which the observed intensities for each of these intervals, reduced to inches per hour, were arranged in order of magnitude; the average number of times per year that each intensity was equalled or exceeded during the 28 years is given by dividing the serial number of the intensity in this table by 28.

A condensed statement of the results is given in table 1. A 5-year storm, e. g., is defined as a storm that occurs once in 5 years, or 0.2 times per year. In figures 1 and 2 are plotted the data of table 1, together with the best fitting curves of the type

$$R=\frac{C}{(t+d)^e},$$

in which R denotes rainfall in inches per hour, t is duration in minutes, and d, C, e are constants (1).

TABLE 1.—*Excessive rainfalls, Honolulu, 1905–33*

Average times per year / Character of storms	0.5 2-year	0.2 5-year	0.1 10-year	0.04 25-year
Duration:	*In./hr.*	*In./hr.*	*In./hr.*	*In./hr.*
5 minutes	3.12	3.82	4.56	4.77
10 minutes	2.88	3.43	3.85	4.59
15 minutes	2.36	2.88	3.07	3.96
30 minutes	2.04	2.47	2.75	3.01
60 minutes	1.50	1.87	2.24	2.43
120 minutes			1.44	1.47

To determine the values of the constants, the equation was written in the form

$$\log R=\log C-e \log (t+d),$$

and the value of d which would give most nearly a straight line on a logarithmic plot was found by trial; this value of d was then inserted, and the values of log C and e found by the method of least squares. The results are shown in table 2.

In order to obtain results by using the data as a whole, instead of only the selected values in table 1, duration curves were also computed for the more intense rainfalls by the method of H. Alden Foster (2): Figures 3 and 4 show the intensities plotted against the observed average annual frequencies, together with the calculated duration curves; the duration curve is essentially the result of integrating the frequency curve, and shows the percentage of the time that any given rainfall intensity has been equalled or exceeded.

Table 3 gives a comparison of the observed values with those from figures 1 and 2 and figures 3 and 4. The curves of figures 1 and 2 are in slightly better accord with the observed values; but the duration curves are supposed to fit both past and future data, and are preferable for use in estimating the rainfall intensity that corresponds to any given frequency.

TABLE 2.—*Equations of rainfall curves, Honolulu, 1905 to 1933, inclusive*

Character of storms	Equation
2-year	$R=\frac{18.88}{(t+20)^{0.57}}$
5-year	$R=\frac{21.38}{(t+20)^{0.55}}$
10-year	$R=\frac{44.55}{(t+25)^{0.59}}$
25-year	$R=\frac{264.1}{(t+45)^{1.02}}$

TABLE 3.—*Rainfall intensities*

Duration (minutes)	Years per occurrence	Occurrences per year	Intensity from $R=\frac{C}{(t+d)^e}$	Intensity from duration curves	Observed intensities
			In./hr.	*In./hr.*	*In./hr.*
5	25	0.04	4.89	4.59	4.77
10	25	.04	4.42	4.13	4.59
15	25	.04	4.06	3.49	3.96
30	25	.04	3.23	2.85	3.01
60	25	.04	2.28	2.31	2.43
5	10	.10	4.28	4.16	4.56
10	10	.10	3.83	3.73	3.85
15	10	.10	3.49	3.12	3.07
30	10	.10	2.81	2.63	2.75
60	10	.10	2.08	2.06	2.24
5	2	.50	3.01	3.18	3.12
10	2	.50	2.71	2.91	2.88
15	2	.50	2.49	2.41	2.36
30	2	.50	2.03	2.14	2.04
60	2	.50	1.55	1.49	1.50

The writer here acknowledges the kind interest taken in this study by Mr. John F. Kunesh, assistant chief engineer of the Honolulu Board of Water Supply, who provided access to literature, and criticized the manuscript.

THE RAINFALL AT MOUNT WAIALEALE

The wettest place in the world is reputed to be Cherrapunji, in the Khasi Hills of Assam, India; the average annual rainfall at this station, 1851–1920, was 458 inches, and for 11 months of 1861 (March excluded) the rainfall reached the incredible total of 905 inches.

Mount Waialeale of the island of Kauai of the Hawaiian group is also one of the wettest regions on earth. Rain-

[1] The U. S. Weather Bureau defines a rainfall as excessive when the rate of fall equals or exceeds 0.01 inch per minute plus 0.20 inch. The average of the annual rainfalls at the Weather Bureau Office, 1905–1933 inclusive, is 25.25 inches.

fall measurements have been taken there from time to time since 1911 by the United States Geological Survey. The annual average from 12 years of record in the interval between 1911 and 1933 is 456 inches.

The summit of Mount Waialeale rises to a height of well over 5,000 feet above sea level, and it is situated near the geographic center of the island of Kauai. At the top the country is generally rolling in all directions

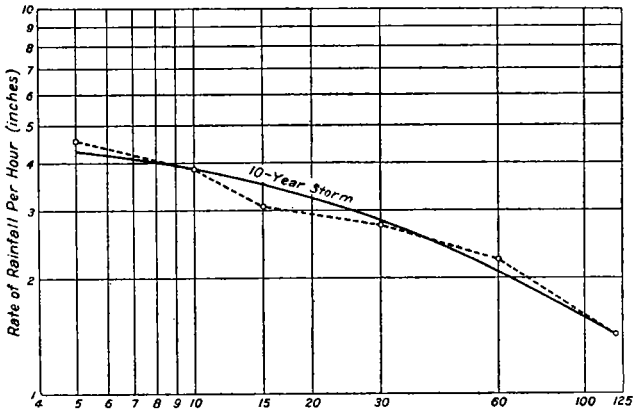

FIGURE 1.—Duration of rainfall in minutes.

except to the east where it breaks down abruptly from the rain gage and drops about 4,000 feet to form the east scarp. Due to the almost incessant rains, the region around it is a marsh, open in some places and in others covered with a forest of low trees.

A topographic map of the region discloses a long ridge that extends northeastward from the summit. East and northeast winds blowing over the plains to the south sweep into the gorge bounded by this ridge and another

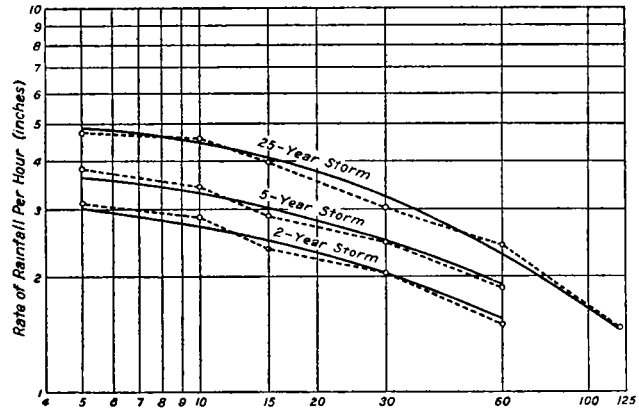

FIGURE 2.—Duration of rainfall in minutes.

shorter ridge further south and, after reaching the head of the gorge ascend the precipitous east scarp of Mount Waialeale. In ascending the winds are cooled and the moisture precipitated. The falling rain is then blown up to the top by the upward draft.

The following table, for which the writer is indebted to Mr. Max H. Carson of the Honolulu office of the United States Geological Survey, gives the annual rainfall, for either calendar or fiscal years as designated, at Mount Waialeale.

Mount Waialeale annual rainfall

Year:	Inches	Year:	Inches
1912	414	1923	360
1913	451	1924–25	362
1916	521	1928–29	354
1920	549	1930–31	528
1921	367	1931–32	527
1922	452	1932–33	592

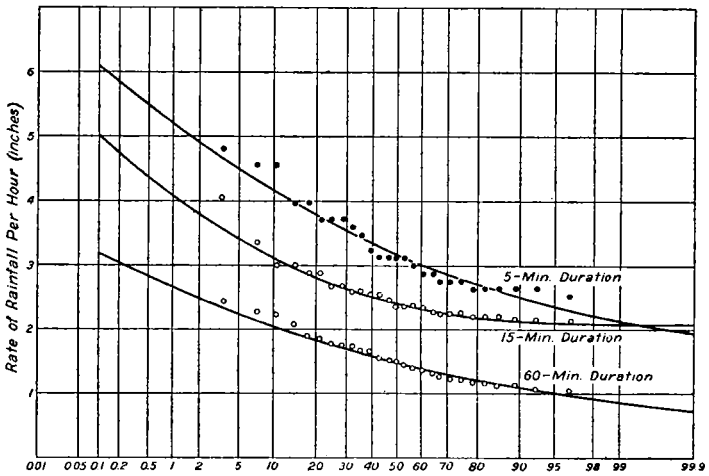

FIGURE 3.—Average number of storms per 100 years that will equal or exceed corresponding rate of rainfall.

The range is from 360 inches to 592 inches. The writer has found that on the Island of Oahu the variation of annual rainfall from the average is least in the mountainous, and therefore wettest, spots of the island (**3**). The measure of variation used was the coefficient of variation, which was 19 percent for a station with the

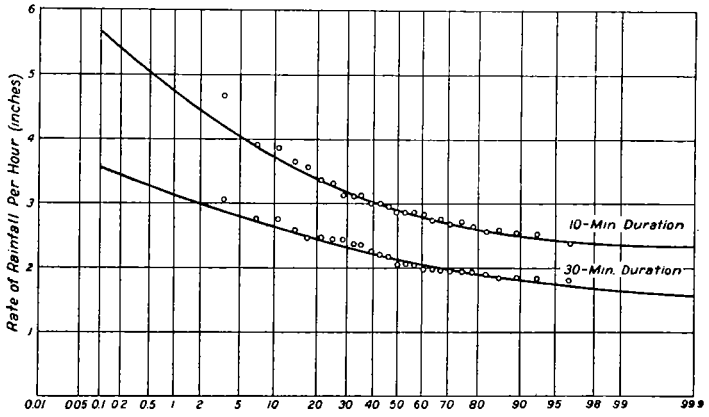

FIGURE 4.—Average number of storms per 100 years that will equal or exceed corresponding rate of rainfall.

least variation. At Mount Waialeale, also, the coefficient of variation is 19 percent.

LITERATURE CITED

(1) Bleich, S. D. Rainfall studies for New York, N. Y. Proc. Amer. Soc. Civil Engineers, February 1934.
(2) Foster, H. Alden. Theoretical frequency curves and their application to engineering problems. Trans. Amer. Soc. Civil Engineers, 1924, p. 142.
(3) Nakamura, Winters T. Study of the variation in annual rainfall of Oahu Island. Monthly Weather Review, December 1933, pp. 354–360.