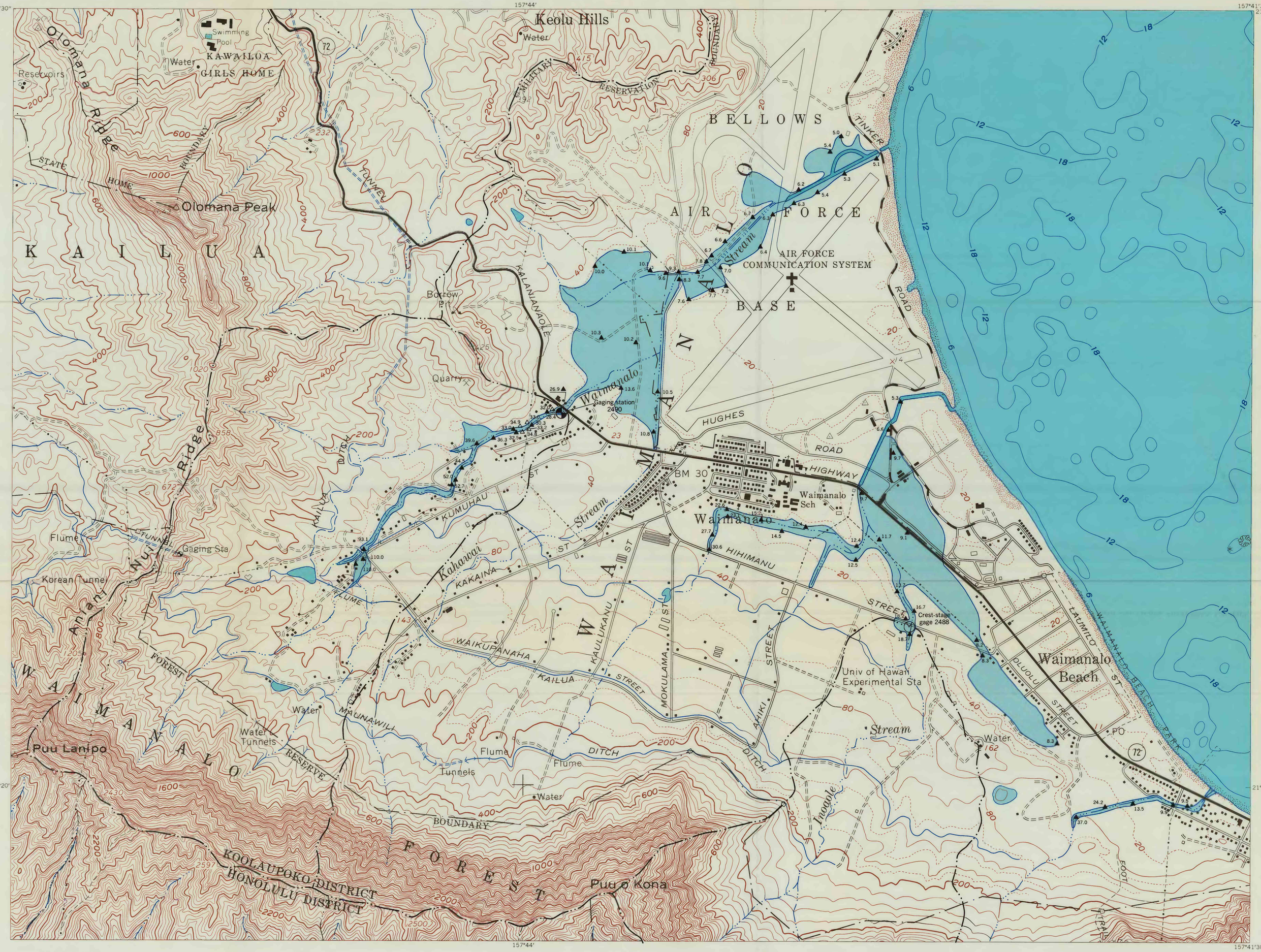
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
HAWAII STATE DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT

HYDROLOGIC INVESTIGATIONS
ATLAS HA-314



Base from U.S. Geological Survey
1:24 000 Koko Head, 1959

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1968

SCALE 1:12 000
0 ½ 1 MILE
0 ½ 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 1 FOOT

EXPLANATION

Area flooded November 12-14, 1965
Flood boundary
Drainage divide

FLOODMARK ELEVATION ABOVE MEAN SEA LEVEL, IN FEET
△8.5 November 12-14, 1965
△24.9 March 6, 1963

FLOODS IN WAIMANALO AREA, OAHU, HAWAII

By
Reuben Lee and William C. F. Chang
1968

FLOODS IN THE WAIMANALO AREA OAHU, HAWAII

This report presents hydrologic data concerning the extent and frequency of flooding in the Waimanalo area, Oahu, Hawaii. The data provide a technical basis for making sound decisions in determining the use and development of flood-plain lands, and will aid individuals, governmental and planning agencies, and others responsible for solving existing flood problems and for formulating effective regulations that would minimize the creation of new flood problems.

The approximate areas inundated by the floods of November 12-14, 1965, in the Waimanalo area are delineated on a topographic map. Location of the Waimanalo area is shown in figure 1. The flood boundaries shown along the lower reaches of Waimanalo Stream and two nearby streams were surveyed from floodmarks identified in the field immediately after the floods. Streamflows were generally contained in the channels upstream from the inundated areas shown on the map. There are some depressions in the lowland areas where surface water accumulates because of inadequate drainage into the streams. Frequency and depth of flooding in these areas are unrelated to the water-surface elevation along the streams. Some of these areas are flooded only briefly depending largely on the intensity and duration of rainfall and the rates of evaporation and seepage into the ground. Flood boundaries are shown for all such areas that were detected during this investigation.

The flood boundaries shown on the map are not those for the highest floods expected. They provide a record of an actual event that reflects channel conditions when the floods occurred. Protective works, which are planned, may reduce the frequency of flooding in the area but will not necessarily eliminate all future flooding. The inundation pattern of future floods may be affected by new highways and bridges, relocation and improvement of stream channels, and other cultural changes.

Tsunamis, which cause flood hazards along the shore, are described by Cox and Mink (1963).

Cooperation and acknowledgment.— This report was prepared by the U.S. Geological Survey under the direction of Mearle M. Miller, district chief, Water Resources Division, as part of a water-resources investigation program under a cooperative agreement with the Hawaii State Department of Land and Natural Resources, Division of Water and Land Development. The cooperative program is administered on behalf of the State by the Board of Land and Natural Resources, Jim P. Ferry, Chairman and Member, and is directly coordinated by Robert T. Chuck, Manager-Chief Engineer and Chief Hydrographer, Division of Water and Land Development. Streamflow records at the gaging stations have been collected in cooperation with the State of Hawaii and the City and County of Honolulu.

Some information on past floods was obtained from interviews with local residents.

Flood height.—The height of a flood at a gaging station is usually stated in terms of gage height or stage, which is the elevation of the water surface above a selected datum plane. Elevations shown in this report are in feet above mean sea level. Gage heights for the two stations pertinent to this investigation can be converted to elevation above mean sea level by adding the gage height to the appropriate datum of gage listed in the following table. The size of drainage basin for each station is also shown in the table, and the subbasin divides from which the areas were determined are shown on the flood map.

Gaging station		Datum of gage above mean sea level (feet)	Drainage area (square miles)
Number	Site		
2488	Inoaole Stream near Waimanalo[1]	12.72	1.21
2490	Waimanalo Stream near Waimanalo[2]	18.89	2.16

[1]Crest-stage station, established October 1967.
[2]Recording station, established January 1967.

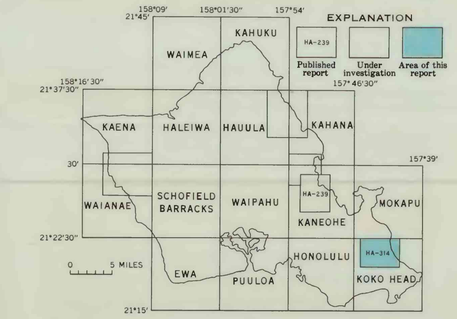


FIGURE 1.—*Index map of Oahu, Hawaii, showing areas included in flood-plain mapping program and U.S. Geological Survey 7½-minute quadrangles.*

The extent of overflow in the lowland areas may not be directly related to the peak rate of runoff from the upper reaches of the streams. The total volume and duration of runoff, the amount of rainfall over the lowland areas, and the timing of the runoff with respect to the tide-water stage, will influence the extent of inundation. For example, the storm of March 6, 1963, on Waimanalo Stream resulted in a flash flood with a maximum discharge of 4,560 cfs (cubic feet per second) at Kalanianaole Highway. The maximum discharge during the flood of November 12-14, 1965, at the same site was only about half as much and occurred at a stage more than 2 feet lower than that of the 1963 flood. In the wide overflow area west of Bellows Air Force Base, however, the 1965 flood was about 1.5 feet higher than the 1963 flood.

There are no continuous records of flow during either flood on Waimanalo Stream, but the U.S. Weather Bureau precipitation record at Waimanalo is indicative of the greater volume of runoff during the 1965 flood. More than 21 inches of rain fell during the period November 10-15, 1965. The flood of March 6, 1963, was accompanied by only 2 inches of rain in a similar period. These rainfall figures were recorded at a site about half a mile southeast of Waimanalo Stream and do not necessarily represent the average rainfall on Waimanalo Stream watershed but are sufficiently close to be used as a basis for comparison.

Flood discharge.— Discharge of a stream is the rate of flow in the stream; that is, the volume of water that passes a particular cross section in a given period of time. Discharge is usually expressed in cubic feet per second (cfs). In Hawaii, it is also expressed in million gallons per day (mgd). To convert cubic feet per second to million gallons per day multiply by 0.646.

Peak discharge is the maximum discharge attained by a flood and generally occurs at the time of the maximum height (stage) of the flood. However, if streamflow is affected by backwater, such as when a culvert entrance is blocked by uprooted trees, the maximum stage may occur at a time other than that of maximum discharge.

The history of floods for West Branch Manoa Stream near Honolulu (2400) is shown in figure 2 and clearly indicates the irregular distribution of floods. It also shows that floods of selected recurrence intervals do not necessarily occur at regular intervals of time. The gaging station on West Branch Manoa Stream is about 6 miles west of Waimanalo on the leeward side of Oahu. Its record, therefore, is not directly representative of the history of floods in the Waimanalo area which is on the windward side of Oahu. The record does serve to illustrate the erratic distribution of floods with respect to time that also may be expected in the Waimanalo area.

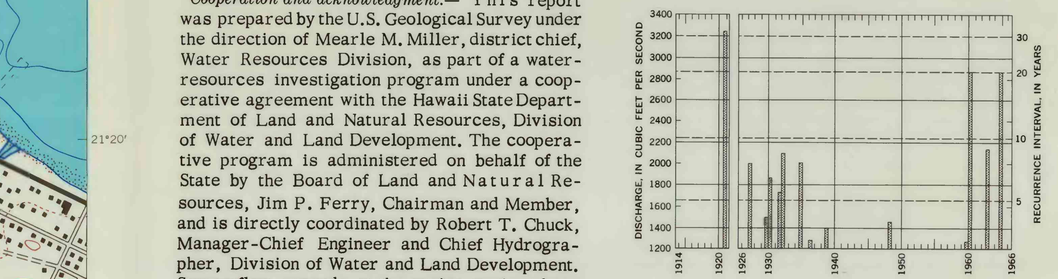


FIGURE 2.—*Floods greater than 1,200 cfs, 1914-21, 1926-66, West Branch Manoa Stream near Honolulu (2400).*

Flood frequency.— Flood-frequency curves based on data from many gaging stations in a region having homogeneous flood characteristics are considered more reliable than curves based on records for individual gaging stations. Streamflow records for Inoaole Stream near Waimanalo (2488) were combined with records from several nearby gaging stations to develop flood-frequency curves for Inoaole Stream (2488) at Hihimanu Street and for Waimanalo Stream (2490) at Kalanianaole Highway. The relations between discharge and frequency are shown in figures 3 and 4. The relations between stage and frequency are shown in figures 5 and 6 and are derived from the discharge-frequency relations and the stage-discharge relations, or rating curves, based on channel conditions existing in 1966. The relation between stage and frequency is affected by changes in the physical conditions of stream channels and constrictions. Longer records and future changes in channel conditions may define somewhat different flood-frequency curves. Extrapolation of the curves beyond the limits shown is not recommended.

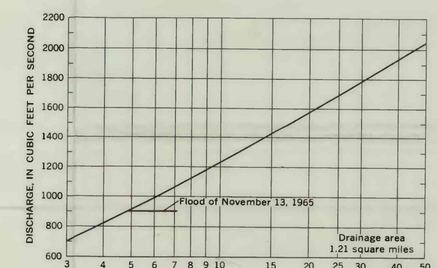


FIGURE 3.—*Frequency of flood discharges on Inoaole Stream near Waimanalo.*

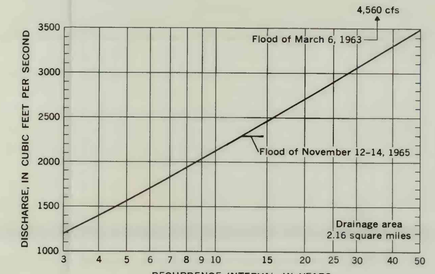


FIGURE 4.—*Frequency of flood discharges on Waimanalo Stream near Waimanalo.*

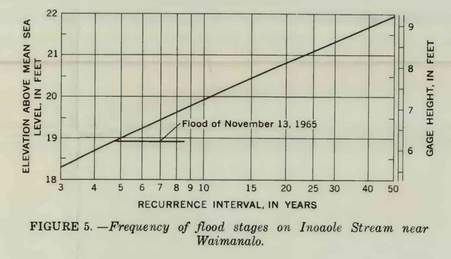


FIGURE 5.—*Frequency of flood stages on Inoaole Stream near Waimanalo.*

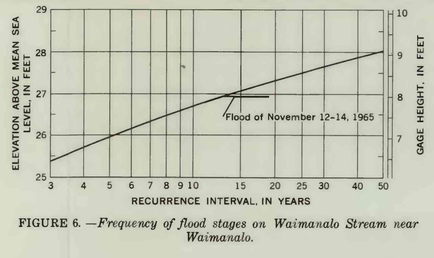


FIGURE 6.—*Frequency of flood stages on Waimanalo Stream near Waimanalo.*

Recurrence intervals.— As applied to flood events, recurrence interval is the average number of years within which a flood of a given magnitude will be exceeded once. For floods greater than the 10-year flood, recurrence interval is inversely related to the probability, or chance, of a given flood being exceeded in any one year. For example, a 10-year flood would have 1 chance in 10 of being equaled or exceeded in any one year and a 100-year flood would have 1 chance in 100 of being equaled or exceeded in any one year.

Recurrence intervals are average figures--the average number of years between occurrences of floods that exceed a given magnitude. The fact that a 20-year flood may occur in any one year does not reduce the probability of another flood of greater magnitude occurring within the same year.

The general relations between recurrence interval and flood height at Inoaole Stream at Hihimanu Street (2488) and Waimanalo Stream at Kalanianaole Highway (2490) are tabulated below:

Recurrence interval (years)	Elevation above mean sea level (feet)	
	Inoaole Stream near Waimanalo	Waimanalo Stream near Waimanalo
50	21.9	28.0
40	21.7	27.8
25	21.1	27.5
10	19.9	26.7
5	19.0	26.0
3	18.3	25.4

It is emphasized that the recurrence interval of the November 1965, flood is only 13 years on Waimanalo Stream at the gaging station (fig. 4) and only 5 years on Inoaole Stream at the crest-stage gage (fig. 3). Floods greatly exceeding these in magnitude may be expected to occur in the future.

Flood elevations.— High-water marks were flagged shortly after the flood of November 12-14, 1965, and their elevations, in feet above mean sea level, were determined by surveys. Representative elevations of the water surface are shown on the map. Elevations shown are from high-water marks on trees, posts, streambanks, and other surfaces and do not necessarily indicate the actual boundary of inundation. Flood boundaries shown on the map were based on information obtained during the field investigations.

Most of the flooding during November 1965 probably would not have occurred had there been adequate drainage for the ponded areas. There are no drainage facilities for the ponded area paralleling Oluolu Street and the adjacent area to the north. The culverts on Waimanalo Stream in Bellows Air Force Base are adequate to accommodate only about a 2-year flood. Hence, the lowland west of Bellows Air Force Base can be expected to be flooded frequently unless the culverts are enlarged.

Additional data.— Other information pertaining to floods in the Waimanalo area can be obtained at the office of the U.S. Geological Survey, Honolulu, Hawaii, and from the following published reports:

Cox, D. C., and Mink, J. F., 1963, The tsunami of 23 May 1960 in the Hawaiian Islands: Seismol. Soc. America Bull., v. 53, no. 6, p. 1191-1209.

Harland, Bartholomew, and Associates, 1959, A general plan for Waimanalo Valley, Island of Oahu, prepared for the Commissioner of Public Lands, 69 p.

Hoffard, S. H., 1965, Floods of December 1964-February 1965 in Hawaii: Hawaii Div. Water and Land Devel. Rept. R 26, 68 p.

Hoffard, S. H., and Vaudrey, W. C., 1966, An investigation of floods in Hawaii, Progress Report No. 9: U. S. Geol. Survey open-file report, 169 p.

U. S. Weather Bureau, 1965, Climatological data, Hawaii, v. 61, no. 11, p. 129-142.

Vaudrey, W. C., 1963, Floods of March-May 1963 in Hawaii: U. S. Geol. Survey open-file report, 65 p.

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For sale by U. S. Geological Survey, price 75 cents