AN ANALYSIS OF THE MAGNITUDE AND FREQUENCY OF FLOODS ON OAHU, HAWAII

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS 80-45

Prepared in cooperation with the
CITY AND COUNTY OF HONOLULU
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16. Abstracts An analysis of available peak-flow data for the island of Oahu was made by using multiple regression techniques which related flood-frequency data to basin and climatic characteristics for 74 gaging stations on Oahu. In the analysis, several different groupings of stations were investigated, including divisions by geographic location and size of drainage area. The grouping consisting of two leeward divisions and one windward division produced the best results. Drainage basins ranged in area from 0.03 to 45.7 square miles.

Equations relating flood magnitudes of selected frequencies to basin characteristics were developed for the three divisions of Oahu. These equations can be used to estimate the magnitude and frequency of floods for any site gaged or ungaged for any desired recurrence interval from 2 to 100 years. Data on basin characteristics, flood magnitudes for various recurrence intervals from individual station-frequency curves, and computed flood magnitudes by use of the regression equation are tabulated to provide the needed data.

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GLOSSARY

1. Annual peak discharge - The highest peak discharge in a water year (October 1 to September 30).
2. Cubic foot per second (ft^3/s) - The rate of discharge representing a volume of 1 cubic foot of water passing a given point during 1 second.
3. Dependent variable - The variable that is estimated or predicted from given values of the independent variables.
4. Drainage area - An area from which surface runoff is carried away by a single drainage system.
5. Gaging station - A particular site on a stream where systematic observations of gage heights and discharge are obtained.
6. Independent variable - One from which another variable is to be estimated or predicted.
7. Isohyet (isohyetal line) - A line drawn on a map or chart joining points that receive the same amount of precipitation.
8. Recurrence interval - The average interval of time within which a given flood will be exceeded once.
9. Regression equation - An equation derived by methods of regression. A mathematical relation between a dependent variable and one or more independent variables.
10. Observed values - values of discharge derived from individual station-frequency curves.
11. Computed values - values of discharge derived from the use of the regression equations.
12. Residuals - the difference between the observed and computed values.

CONVERSION TABLE

Inch-pound units have been used throughout this report. The following table converts measurements in the inch-pound system to the International System of Units (SI).

Multiply inch-pound units	By	To obtain SI units
inches (in.) -----------	25.4 --	millimeters (mm)
feet (ft) -------------	0.305 --	meters (m)
miles (mi) ------------	1.61 --	kilometers (km)
feet per mile (ft/mi) --	0.189 --	meters per kilometer (m/km)
square miles (mi^2) ----	2.59 --	square kilometers (km^2)
cubic feet per second (ft^3/s) -------------	0.028 --	cubic meters per second (m^3s)

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By Richard H. Nakahara

ABSTRACT

An analysis of available peak-flow data for the island of Oahu was made by using multiple regression techniques that related flood-frequency data to basin and climatic characteristics for 74 gaging stations on Oahu. In the analysis, several different groupings of stations were investigated, including divisions by geographic location and size of drainage area. The grouping consisting of two leeward divisions and one windward division produced the best results. Drainage basins ranged in area from 0.03 to 45.7 square miles.

Equations relating flood magnitudes of selected frequencies to basin characteristics were developed for the three divisions of Oahu. The significant variables are drainage area or, drainage area in combination with either the 24-hour rainfall intensity having a recurrence interval of 2 years or the percentage of vegetative cover. These equations can be used to estimate the magnitude and frequency of floods on Oahu for any site, gaged or ungaged, for any desired recurrence interval from 2 to 100 years. Data on basin characteristics, flood magnitudes for various recurrence intervals from individual station-frequency curves, and computed flood magnitudes by use of the regression equation are tabulated to provide the needed data.

PURPOSE AND SCOPE

The purpose of this study was to analyze all available peak-flow data on Oahu, including those collected under the cooperative program between the City and County of Honolulu and the U.S. Geological Survey. Results from this study can be used to estimate the frequency and magnitude of floods that may occur. These estimates are useful in the planning, designing, and locating of structures, such as dams, bridges, culverts, highways, and buildings, in order to minimize flood damage.

The program, which was begun in 1959, supplemented data being obtained at regular gaging stations that were funded under other ongoing programs, and it consisted primarily of collecting peak-flow data from a network of crest-stage gages installed at sites where data were not otherwise available.

This report describes the methods used in the analysis, the results of the study, and recommendations for the crest-stage program arising from the evaluation of the results.

MAGNITUDE AND FREQUENCY OF FLOODFLOWS

Annual peak discharge data from 74 gaging stations, all of which are located on natural streams, were used in this report. See figure 1 for location of gaging stations. Length of record for individual stations ranged from 10 to 60 years.

Flood-frequency curves were developed for each station by using the log Pearson Type III distribution (U.S. Water Resources Council, 1977).

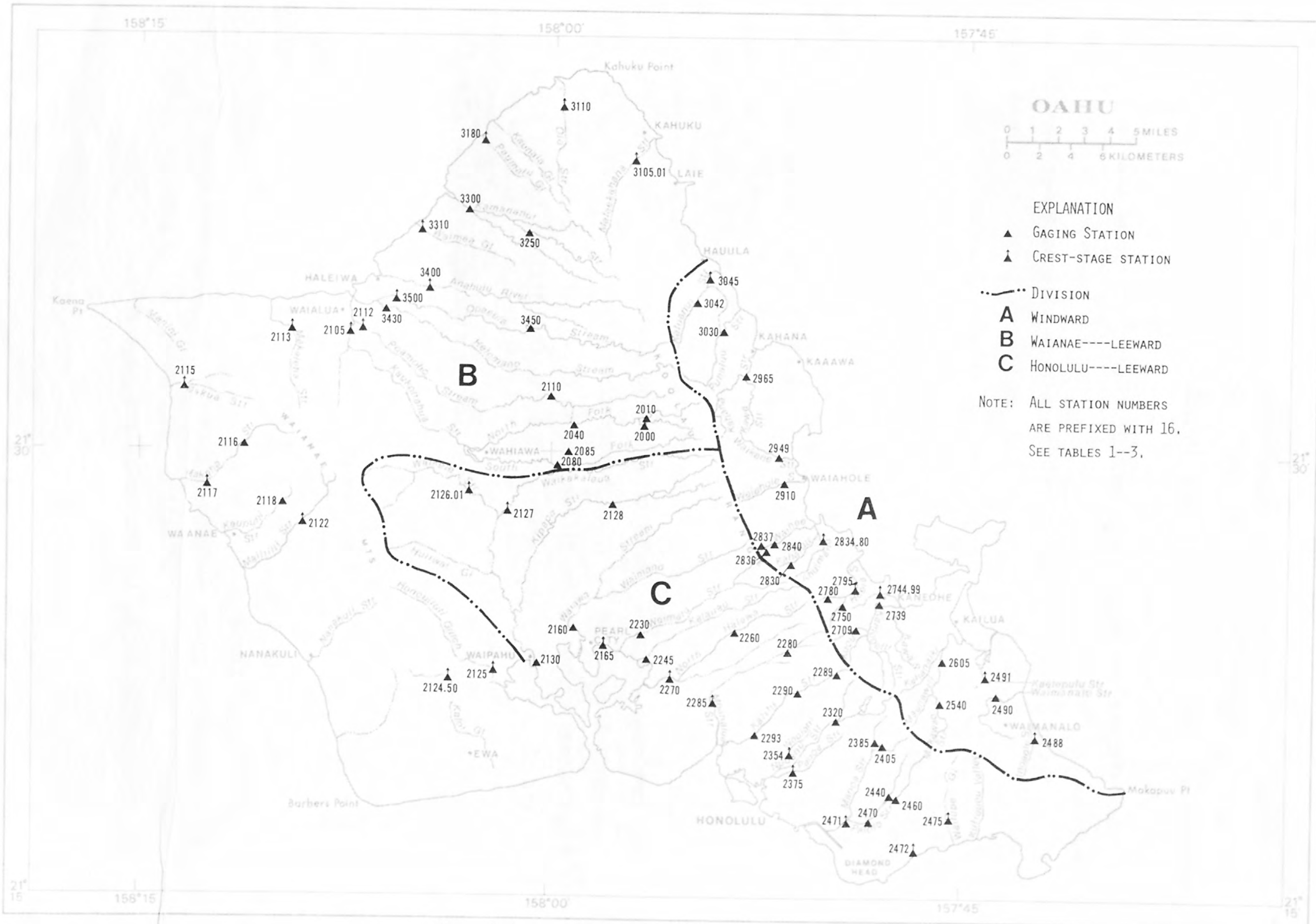

Figure 1. Location and grouping (A,B,C) of stations on Oahu.

From the frequency curves, values of flood discharges were obtained at the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. The values are listed in tables 1-3 as the first row for each station. For example:

At station 16284000, Q_{50} and Q_{100} obtained from the frequency curve are:

Q_{50} = 2,520 ft^3/s; a flood of this magnitude will be exceeded once in 50 years (on the average), or the probability of a flood this size to occur in any 1 year is 1/50 or 2 percent.

Q_{100} = 3,200 ft^3/s; a flood of this size will be exceeded once in 100 years (on the average), or the probability of a flood of this magnitude to occur in any 1 year is 1/100 or 1 percent.

BASIN AND CLIMATIC CHARACTERISTICS

Topographic and climatic characteristics of the drainage basins, listed in tables 4, 5, and 6, were derived as follows:

DA, Drainage area -- Area of drainage basin, in square miles, as planimetered from 1:24,000 topographic maps.

CS, Channel slope -- The difference in elevation at points 10 percent and 85 percent of the channel length (CL) divided by the distance between the two points.

CL, Channel length -- Distance along a stream, in miles, from the gaging station to the basin divide.

P, Mean annual precipitation -- Rainfall, in inches, determined by placing a grid over an isohyetal map of Oahu (Board of Water Supply, City and County of Honolulu) and locating 20-25 random points within the basin boundary and computing the arithmetic average of these points.

FC, Vegetative cover -- The ratio of the drainage area covered by the forests and/or vegetation, as shown in green on 1:24,000 topographic maps, to the total drainage area.

Table 1. Peak discharges, in cubic feet per second, for selected recurrence intervals at gaging stations in Group A

The upper row of Q_t values are from individual frequency curves, where t = 2, 5, 10, 25, 50, 100

The lower row of Q_t values were computed by using regression equations.

(Abbreviations: Discharge, Disch; Stream, Str; near, nr; altitude, alt; feet, ft)

Station No. (16-)	Station name	Length of record	Drainage area (mi^2)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Maximum flood Year	Maximum flood Disch ft^3/s
248800	Inoaole Str at Waimanalo			473	798	1,050	1,390	1,670	1,970		
	....	19	1.21	715	1,510	2,230	3,360	4,360	5,520	1967	1,420
249000	Waimanalo Str at Waimanalo			1,400	3,160	4,810	7,510	10,000	12,900		
	....	12	2.16	1,110	2,330	3,410	5,110	6,610	8,340	1963	4,560
249100	Kaelepulu Str tributary at			133	304	467	735	983	1,270		
	Kailua	15	0.16	154	331	505	776	1,020	1,310	1970	418
254000	Makawao Str nr Kailua			790	2,060	3,380	5,710	7,990	10,800		
	....	20	2.04	1,060	2,230	3,270	4,900	6,350	8,010	1965	6,000
260500	Maunawili Str at Highway 61,			1,650	3,220	4,540	6,540	8,260	10,200		
	nr Kailua	20	5.34	2,210	4,560	6,630	9,830	12,700	15,900	1965	9,690
270900	Luluku Str at alt 220 ft,			149	426	733	1,300	1,880	2,610		
	nr Kaneohe	11	0.44	332	714	1,060	1,610	2,110	2,690	1970	651
273900	Kamooalii at Kaneohe			2,000	4,610	7,090	11,200	15,000	19,500		
	....	20	4.38	1,900	3,930	5,730	8,520	11,000	13,800	1969	12,000
274499	Keaahala Str at Kamehameha			448	1,250	2,130	3,730	5,360	7,400		
	Highway, at Kaneohe	19	0.62	430	921	1,370	2,070	2,700	3,430	1965	2,750
275000	Haiku Str nr Heeia			737	1,780	2,760	4,330	5,760	7,400		
	....	43	0.97	605	1,280	1,900	2,860	3,720	4,720	1965	5,740
278000	Iolekaa Str mauka nr Heeia			45	116	189	316	441	594		
	....	26	0.29	241	523	782	1,190	1,570	2,000	1965	797
279500	Heeia Str at Kaneohe			1,380	3,880	6,630	11,700	16,800	23,200		
	....	11	1.80	967	2,030	2,980	4,480	5,800	7,320	1965	5,600
283000	Kahaluu Str nr Heeia			139	268	381	556	710	887		
	....	34	0.28	235	510	762	1,160	1,530	1,950	1965	1,730
283480	Ahuimanu Str nr Kahaluu			1,530	3,830	6,150	10,200	14,000	18,700		
	....	15	2.31	1,170	2,450	3,580	5,360	6,940	8,750	1969	7,300
283600	South Fork Waihee Str nr			92	177	249	356	447	550		
	Heeia	15	0.03	43	97	148	231	308	398	1965	279
283700	North Fork Waihee Str nr			89	186	271	405	524	660		
	Heeia	15	0.03	43	97	148	231	308	398	1965	376
284000	Waihee Str nr Heeia			421	876	1,290	1,940	2,520	3,200		
	....	39	0.93	586	1,240	1,840	2,770	3,610	4,580	1965	5,110
291000	Waiahole Str at alt 250 ft,			615	1,170	1,630	2,310	2,890	3,540		
	nr Waiahole	13	0.99	614	1,300	1,920	2,900	3,780	4,790	1963	2,230
294900	Waikane Str at alt 75 ft,			1,890	4,060	6,040	9,200	12,000	15,300		
	at Waikane	18	2.22	1,130	2,370	3,480	5,210	6,740	8,500	1965	8,800
296500	Kahana Str at alt 30 ft,			3,040	4,310	5,170	6,260	7,080	7,900		
	nr Kahana	18	3.74	1,690	3,500	5,100	7,600	9,800	12,300	1963	5,430
303000	Punaluu Str nr Punaluu			1,700	2,840	3,710	4,910	5,880	6,910		
	....	24	2.78	1,350	2,810	4,100	6,130	7,920	9,980	1974	5,700
304200	Kaluanui Str nr Punaluu			867	1,480	1,960	2,630	3,170	3,760		
	....	10	1.11	670	1,420	2,090	3,150	4,100	5,190	1969	2,010
304500	Kaluanui Str at Hauula			1,420	2,410	3,180	4,250	5,130	6,060		
	....	20	2.12	1,100	2,290	3,360	5,040	6,520	8,230	1974	3,350

Table 2. Peak discharges, in cubic feet per second, for selected recurrence intervals at gaging stations in Group B

The upper row of Q_t values are from individual frequency curves, where t = 2, 5, 10, 25, 50, 100

The lower row of Q_t values were computed by using regression equations

(Abbreviations: Discharge, Disch; Stream, Str; near, nr; Road, Rd; altitude, alt; feet, ft)

Station No. (16-)	Station name	Length of record	Drainage area (mi^2)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Maximum flood Year	Maximum flood Disch ft^3/s
200000	North Fork Kaukonahua Str above			2,550	3,790	4,600	5,590	6,290	6,980		
	Right Branch, nr Wahiawa	54	1.38	1,380	2,220	2,840	3,680	4,330	5,020	1933	5,490
201000	Poamoho Str nr Wahiawa			1,050	1,500	1,810	2,210	2,500	2,800		
	....	28	1.20	1,270	2,030	2,580	3,330	3,920	4,520	1940	2,320
204000	North Fork Kaukonahua Str nr			2,520	3,180	3,580	4,060	4,410	4,740		
	Wahiawa	22	4.86	1,920	3,590	4,960	6,980	8,680	10,500	1963	4,660
208000	South Fork Kaukonahua Str at			1,840	3,110	4,080	5,440	6,540	7,710		
	East Pump Reservoir, nr Wahiawa	20	4.04	1,540	2,920	4,070	5,770	7,220	8,810	1963	5,460
208500	Right Branch of South Fork			510	1,470	2,550	4,550	6,600	9,210		
	Kaukonahua Str nr Wahiawa	15	0.86	652	1,140	1,510	2,050	2,480	2,950	1968	3,160
210500	Kaukonahua Str at Waialua			2,160	7,090	13,100	25,100	38,100	55,300		
	....	11	38.70	3,260	7,830	12,300	19,900	27,100	35,700	1963	15,600
211000	Poamoho Str nr Wahiawa			1,770	2,960	3,850	5,100	6,100	7,170		
	....	16	1.79	1,580	2,580	3,330	4,350	5,150	6,000	1968	3,630
211200	Poamoho Str at Waialua			1,790	4,340	6,850	11,100	15,200	20,000		
	....	11	10.90	1,760	3,860	5,800	8,910	11,800	15,100	1974	7,340
211300	Makaleha Str nr Waialua			507	1,120	1,700	2,620	3,470	4,460		
	....	20	4.15	430	1,080	1,750	2,900	4,010	5,370	1964	2,580
211500	Makua Str at Makua			232	841	1,640	3,320	5,220	7,820		
	....	19	4.13	358	936	1,540	2,600	3,650	4,940	1976	3,220
211600	Makaha Str nr Makaha			375	746	1,060	1,550	1,970	2,450		
	....	18	2.31	280	697	1,120	1,840	2,530	3,380	1962	1,170
211700	Makaha Str at Makaha			710	1,530	2,280	3,470	4,550	5,790		
	....	12	5.25	305	859	1,470	2,600	3,750	5,200	1976	4,310
211800	Kaupuni Str at alt 374 ft,			281	883	1,600	2,980	4,460	6,390		
	nr Waianae	17	3.58	368	932	1,510	2,510	3,480	4,660	1976	1,730
212200	Mailiilii Str nr Waianae			497	981	1,390	2,020	2,570	3,180		
	....	20	1.51	240	574	901	1,450	1,970	2,580	1966	2,200
212450	Kaloi Gulch tributary nr			252	540	800	1,210	1,580	2,010		
	Honouliuli	10	1.70	141	386	650	1,130	1,610	2,210	1969	645
212500	Honouliuli Str nr Waipahu			716	1,570	2,360	3,620	4,770	6,100		
	....	18	11.00	621	1,710	2,890	5,040	7,210	9,930	1969	2,470
310501	Malaekahana Str at alt 30 ft,			1,050	2,870	4,840	8,400	12,000	16,400		
	nr Kahuku	19	4.05	1,540	2,920	4,070	5,780	7,230	8,830	1963	4,640
311000	Oio Str nr Kahuku			366	844	1,300	2,060	2,760	3,590		
	....	20	2.13	470	1,030	1,550	2,380	3,130	4,000	1965	1,390
318000	Paumalu Gulch at Sunset Beach			159	556	1,070	2,120	3,290	4,880		
	....	10	2.59	369	882	1,390	2,230	3,030	3,990	1974	982
325000	Kamananui Str at Pupukea			1,340	1,850	2,180	2,600	2,910	3,220		
	Military Rd, nr Maunawai	14	3.13	1,020	2,020	2,880	4,190	5,320	6,590	1975	3,390
330000	Kamananui Str at Maunawai			2,530	4,060	5,170	6,690	7,890	9,150		
	....	20	9.79	2,040	4,260	6,240	9,320	12,100	15,200	1974	5,610
331000	Waimea Gulch nr Kawailoa Camp			66	235	451	901	1,400	2,090		
	....	10	2.23	386	891	1,370	2,170	2,910	3,780	1974	621
340000	Anahulu River nr Haleiwa			3,040	5,550	7,560	10,500	13,000	15,700		
	....	20	13.50	3,380	6,690	9,520	13,800	17,600	21,700	1974	15,900
343000	Helemano Str at Haleiwa			3,680	9,850	16,400	28,100	39,600	54,000		
	....	10	14.20	2,480	5,290	7,830	11,900	15,500	19,700	1974	18,200
345000	Opaeula Str nr Wahiawa			2,050	2,960	3,580	4,370	4,970	5,570		
	....	18	2.98	1,790	3,120	4,160	5,620	6,320	8,090	1974	5,540
350000	Opaeula Str nr Haleiwa			1,660	3,160	4,410	6,290	7,890	9,670		
	....	22	5.96	1,820	3,570	5,050	7,290	9,230	11,400	1974	7,600

Table 3. Peak discharges, in cubic feet per second, for selected recurrence intervals at gaging stations in Group C

The upper row of Q_t values are from individual frequency curves, where t = 2, 5, 10, 25, 50, 100

The lower row of Q_t values were computed by using regression equations

(Abbreviations: Discharge, Disch; Stream, Str; near, nr; Road, Rd; altitude, alt; feet, ft)

Station No. (16-)	Station name	Length of record	Drainage area (mi^2)	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Maximum flood Year	Maximum flood Disch ft^3/s
212601	Waikele Str at Wheeler Field			610	1,100	1,490	2,050	2,520	3,030		
	....	19	6.35	771	1,560	2,250	3,210	4,250	5,310	1958	1,810
212700	Waikakalaua Str nr Wahiawa			765	1,730	2,650	4,140	5,520	7,140		
	....	20	6.96	620	1,280	1,870	2,790	3,610	4,550	1963	4,820
212800	Kipapa Str nr Wahiawa			1,910	2,880	3,560	4,460	5,150	5,860		
	....	21	4.29	1,770	3,290	4,520	6,330	7,840	9,490	1963	5,680
213000	Waikele Str at Waipahu			3,230	6,950	10,300	15,700	20,600	26,200		
	....	26	45.70	4,040	7,830	11,000	15,800	19,900	24,500	1954	13,600
216000	Waiawa Str nr Pearl City			7,770	14,900	20,800	29,700	37,400	45,800		
	....	25	26.40	6,190	11,300	15,400	21,300	26,300	31,600	1968	23,400
216500	Waimano flood channel at			267	578	863	1,320	1,730	2,210		
	Pearl City	15	2.63	351	726	1,060	1,580	2,050	2,580	1954	2,810
223000	Waimalu Str nr Aiea			2,120	4,220	6,030	8,800	11,200	13,900		
	....	22	6.07	2,180	4,050	5,560	7,780	9,640	11,700	1968	8,020
224500	Kalauao Str at Moanalua Rd,			779	1,420	1,950	2,710	3,350	4,050		
	at Aiea	24	2.59	1,030	1,960	2,730	3,870	4,830	5,890	1963	2,580
226000	North Halawa Str nr Aiea			1,520	2,990	4,250	6,140	7,780	9,610		
	....	28	3.45	1,550	2,890	3,970	5,560	6,890	8,340	1932	6,650
227000	Halawa Str at Aiea			2,020	3,510	4,670	6,320	7,670	9,130		
	....	18	8.78	2,670	4,970	6,830	9,560	11,800	14,300	1966	6,570
228000	Moanalua Str nr Honolulu			1,130	2,080	2,800	3,790	4,560	5,350		
	....	51	2.73	1,250	2,350	3,240	4,550	5,660	6,870	1931	4,580
228500	Moanalua Str at alt 100 ft,			1,880	3,530	4,900	6,930	8,650	10,600		
	nr Honolulu	13	4.16	1,790	3,330	4,580	6,390	7,910	9,570	1967	3,790
228900	Kalihi Str nr Kaneohe			466	1,120	1,760	2,850	3,880	5,120		
	....	10	0.60	323	631	891	1,280	1,620	1,990	1969	1,510
229000	Kalihi Str nr Honolulu			1,550	3,310	4,830	7,120	9,080	11,200		
	....	61	2.61	1,190	2,230	3,090	4,340	5,400	6,560	1930	12,400
229300	Kalihi Str at Kalihi			3,490	5,420	6,810	8,670	10,100	11,600		
	....	17	5.18	1,590	3,010	4,180	5,910	7,370	8,980	1974	7,110
232000	Nuuanu Str below reservoir 2			697	1,650	2,540	3,990	5,310	6,830		
	wasteway, nr Honolulu	60	3.35	1,430	2,680	3,690	5,190	6,440	7,810	1921	6,990
235400	Waolani Str at Honolulu			799	1,350	1,770	2,360	2,840	3,340		
	....	19	1.28	472	924	1,310	1,890	2,390	2,940	1963	2,500
237500	Pauoa Str at Honolulu			422	761	1,030	1,430	1,750	2,110		
	....	20	1.43	439	869	1,240	1,800	2,280	2,830	1963	2,200
238500	Waihi Str at Honolulu			668	1,320	1,880	2,720	3,450	4,270		
	....	57	1.14	576	1,100	1,550	2,200	2,760	3,380	1921	3,250
240500	Waiakeakua Str at Honolulu			525	948	1,310	1,860	2,350	2,920		
	....	59	1.06	557	1,070	1,490	2,120	2,660	3,260	1921	3,090
244000	Pukele Str nr Honolulu			423	841	1,200	1,740	2,220	2,750		
	....	51	1.18	503	977	1,380	1,970	2,490	3,060	1930	2,600
246000	Waiomao Str nr Honolulu			377	737	1,030	1,460	1,820	2,210		
	....	45	1.04	510	984	1,380	1,970	2,480	3,040	1930	1,550
247000	Palolo Str nr Honolulu			1,280	2,130	2,780	3,670	4,400	5,160		
	....	25	3.63	1,190	2,270	3,170	4,500	5,630	6,880	1967	4,270
247100	Manoa-Palolo Drainage Canal			3,220	6,040	8,360	11,800	14,700	17,900		
	at Moiliili	10	9.35	2,060	3,920	5,470	7,760	9,710	11,900	1967	10,100
247200	Waialaenui Gulch at Honolulu			814	1,530	2,130	3,010	3,760	4,590		
	....	11	1.75	739	1,420	1,980	2,820	3,530	4,330	1958	2,010
247500	Wailupe Gulch at Aina Haina			636	1,270	1,820	2,670	3,400	4,230		
	....	20	2.35	1,090	2,040	2,830	3,990	4,960	6,040	1967	3,600

Table 4. Basin and climatic characteristics and maximum observed floods in Group A

Station No. (16-)	Length of record	DA mi^2	CS ft/mi	CL mi	P in.	FC percent	E ft	P_{2-24} in.	Maximum flood Year	Maximum flood Discharge ft^3/s
248800	19	1.21	462	1.78	42	8	590	6.20	1967	1,420
249000	12	2.16	343	2.41	72	85	760	7.39	1963	4,560
249100	15	0.16	420	0.83	55	100	580	5.10	1970	418
254000	20	2.04	333	2.04	87	75	700	5.80	1965	6,000
260500	20	5.34	209	3.20	95	60	770	6.40	1965	9,690
270900	11	0.44	2,147	0.96	105	93	1,220	7.63	1970	651
273900	20	4.38	212	3.65	86	40	560	6.20	1969	12,000
274499	19	0.62	212	1.95	70	26	270	5.30	1965	2,750
275000	43	0.97	116	1.04	100	96	1,150	6.30	1965	5,740
278000	26	0.29	2,060	0.68	98	100	1,440	6.00	1965	797
279500	11	1.80	386	2.07	98	97	1,110	7.25	1965	5,600
283000	34	0.28	755	0.55	150	100	1,470	7.40	1965	1,730
283480	15	2.31	466	2.42	82	71	560	5.80	1969	7,300
283600	15	0.03	3,200	0.35	150	100	1,400	8.00	1965	279
283700	15	0.03	4,640	0.35	150	100	1,500	8.10	1965	376
284000	39	0.93	1,250	1.04	140	100	1,210	7.20	1965	5,110
291000	13	0.99	2,120	1.02	140	100	1,350	7.80	1963	2,230
294900	18	2.22	1,210	2.70	128	100	1,000	6.00	1965	8,800
296500	18	3.74	180	4.30	187	100	1,030	8.20	1963	5,430
303000	24	2.78	493	3.02	222	100	1,230	7.40	1974	5,700
304200	10	1.11	1,037	3.10	199	97	1,650	7.82	1969	2,010
304500	20	2.12	82	3.73	157	99	1,650	7.00	1974	3,350

Table 5. Basin and climatic characteristics and maximum observed floods in Group B

Station No. (16-)	Length of record	DA mi^2	CS ft/mi	CL mi	P in.	FC percent	E ft	P_{2-24} in.	Maximum flood Year	Maximum flood Discharge ft^3/s
200000	54	1.38	155	4.65	241	100	1,750	10.00	1933	5,490
201000	28	1.20	223	4.50	241	100	1,700	10.00	1940	2,320
204000	22	4.86	92	9.80	198	100	1,550	8.60	1963	4,660
208000	20	4.04	302	5.75	167	95	1,380	8.30	1963	5,460
208500	15	0.86	155	2.45	180	91	1,280	8.60	1968	3,160
210500	11	38.70	59	23.41	87	70	1,250	6.68	1963	15,600
211000	16	1.79	170	6.10	185	100	1,660	9.90	1968	3,630
211200	11	10.90	93	18.70	89	51	1,070	7.07	1974	7,340
211300	20	4.15	570	3.08	70	99	1,570	5.40	1964	2,580
211500	19	4.13	420	2.41	48	95	1,120	5.10	1976	3,220
211600	18	2.31	886	2.45	74	90	2,160	5.30	1962	1,170
211700	12	5.25	845	4.60	57	82	1,630	4.60	1976	4,310
211800	17	3.58	740	1.95	61	66	800	5.30	1976	1,730
212200	20	1.51	540	2.10	42	86	1,010	5.50	1966	2,200
212450	10	1.70	578	3.28	32	74	980	4.50	1969	645
212500	18	11.00	174	7.35	38	46	1,120	5.00	1969	2,470
310501	19	4.05	362	4.96	91	90	480	8.30	1963	4,640
311000	20	2.13	290	3.69	60	75	770	6.40	1965	1,390
318000	10	2.59	271	3.80	69	53	690	5.67	1974	982
325000	14	3.13	292	7.60	151	100	1,380	7.63	1975	3,390
330000	20	9.79	154	11.61	106	98	1,170	7.60	1974	5,610
331000	10	2.23	191	5.39	63	39	770	5.94	1974	621
340000	20	13.50	136	13.50	112	96	1,250	8.40	1974	15,900
343000	10	14.20	93	19.31	116	75	1,170	7.50	1974	18,200
345000	18	2.98	112	11.40	185	100	1,800	9.30	1974	5,540
350000	22	5.96	102	15.00	108	87	1,300	8.10	1974	7,600

Table 6. Basin and climatic characteristics and maximum observed floods in Group C

Station No. (16-)	Length of record	DA mi^2	CS ft/mi	CL mi	P in.	FC percent	E ft	P_{2-24} in.	Maximum flood Year	Maximum flood Discharge ft^3/s
212600	19	6.35	106	6.50	51	41	1,350	5.70	1958	1,810
212700	20	6.96	96	13.20	93	33	1,030	7.80	1963	4,820
212800	21	4.29	140	8.51	174	96	1,620	8.50	1963	5,680
213000	26	45.70	84	20.40	72	40	920	6.10	1954	13,600
216000	25	26.40	130	10.70	97	77	990	6.50	1968	23,400
216500	15	2.63	152	4.66	61	40	590	4.90	1954	2,810
223000	22	6.07	149	9.57	110	90	1,000	6.70	1968	8,020
224500	24	2.59	226	7.95	95	89	1,020	7.30	1963	2,580
226000	28	3.45	284	4.82	111	100	1,140	7.70	1932	6,650
227000	18	8.78	160	7.80	94	83	1,040	7.30	1966	6,570
228000	51	2.73	264	4.20	121	98	1,160	7.40	1931	4,580
228500	13	4.16	160	6.40	103	99	890	7.20	1967	3,790
228900	10	0.60	853	1.07	110	95	1,510	8.00	1969	1,510
229000	61	2.61	268	2.65	122	98	1,180	7.00	1930	12,400
229300	17	5.18	189	5.37	104	79	980	7.50	1974	7,110
232000	60	3.35	200	2.72	124	96	1,370	7.70	1921	6,990
235400	19	1.28	460	2.14	98	78	770	8.00	1963	2,500
237500	20	1.43	492	3.06	88	69	950	7.60	1963	2,200
238500	57	1.14	1,210	2.05	150	97	1,300	8.00	1921	3,250
240500	59	1.06	1,230	1.61	145	99	1,160	8.00	1921	3,090
244000	51	1.18	364	2.35	120	86	1,170	7.80	1930	2,600
246000	45	1.04	650	2.41	110	86	1,170	7.80	1930	1,550
247000	25	3.63	233	5.00	97	80	930	7.70	1967	4,270
247100	10	9.35	312	5.48	90	66	760	5.66	1967	10,100
247200	11	1.75	394	4.11	63	89	1,040	7.40	1958	2,010
247500	20	2.35	682	2.45	65	98	1,410	6.90	1967	3,600

E, Mean basin elevation -- Elevation, in feet above mean sea level, measured on 1:24,000 topographic maps by laying a grid over the map, determining the elevation at each grid intersection, and averaging these elevations. The grid spacing was selected to give at least 25 intersections within the basin.

P_{2-24}, Rainfall -- 24-hour rainfall intensity, in inches, having a recurrence interval of 2 years, determined by placing a grid over a 2-year 24-hour isohyetal map of Oahu (U.S. Weather Bureau, Technical Paper No. 43, 1962) and calculating the average intensity within the basin boundaries.

REGIONAL ANALYSIS

Although many streams are gaged on Oahu, information for ungaged sites is often requested. Flow characteristics at ungaged sites are estimated by using data or information obtained at gaged sites. One of the methods used in transferring data is to regionalize the data by the use of multiple-regression techniques. In this study a regional analysis was made by using these techniques to relate floodflows to basin and climatic characteristics.

Multiple-Regression Analysis

In the step-backward method used in this study, discharges for a certain recurrence interval (as taken from the frequency curves that were developed for individual stations) are the dependent variables that are related initially to all seven basin and climatic characteristics (CL, CS, DA, P, E, P_{2-24}, FC), which are the independent variables. The least significant variable is then dropped and the regression process is repeated, resulting in a new equation. The above process is repeated until an equation is finally derived that relates discharge to the one most significant independent variable. All the regression equations for this particular recurrence interval are then analyzed and the best equation is selected on the basis of a combination of the least standard error of estimate and the minimum number of independent variables involved. For convenience and practicality, the equation chosen was one with no more than two independent variables.

Standard Error of Estimate

The standard error of estimate, expressed as a percentage, is an approximate measure of the reliability of the regression equation. It is the standard deviation of the difference between observed and computed values (residuals). If the assumptions of the regression analysis are valid, the standard error means that two out of three estimates used to develop the regression equation will be within plus (+) or minus (-) one standard error, and 19 out of 20 estimates will be within plus (+) or minus (-) two standard errors.

The smaller the standard error of estimate, the better the reliability of the regression equation and, conversely, the larger the standard error of estimate, the poorer the regression equation.

The resulting equation has the form,

$$Q_t = aX^bY^c$$

where

Q_t is a flood of t(years) recurrence interval,

X, Y are basin and/or climatic characteristics,

a is the regression constant, and

b, c are the regression coefficients or exponents of the basin and/or climatic characteristics.

Following the selection of the regression equation for a given recurrence interval, the entire computation process is repeated, using the peaks of another recurrence interval with the same set of seven basin and climatic characteristics. For each grouping of stations, regression equations were computed for recurrence intervals of 2, 5, 10, 25, 50, and 100 years.

Correlations between pairs of independent variables are computed in the regression analysis. Because high correlation between two independent variables tends to reduce the statistical significance of each variable involved, only the variable that was considered to be the most significant, as well as the most reliable, was retained.

Grouping of Stations

In the course of this study, many different groupings of stations were tried. The following were some of these.

1. The whole island was taken as a region.
2. The island was divided into leeward and windward areas.
3. The island was divided, as in No. 2 above, but the leeward area was further subdivided on the basis of drainage area.
4. The island was divided into three areas: the windward (Waimanalo to Kaluanui), the Waianae-leeward (Waianae to Hauula), and the Honolulu-leeward (Waipahu to Kalama Valley).
5. The stations were divided into three groups by drainage-area size.
6. The stations were divided into five groups by drainage-area size.
7. The island was divided into two groups by drainage-area size. Various combinations of drainage-area sizes were tried.

The fourth alternative gave the best regression equations with two or less variables in combination with the smallest standard error of estimate. See figure 1 and tabulation below.

Group	No. of Stations
A	22
B	26
C	26

Regression Equations

The regression constants and coefficients for the three groupings are given in tables 7, 8, and 9.

Table 7. Regression constants and coefficients for Group A, Windward (Waimanalo to Kaluanui)

Equation: $Q_t = a(DA)^b$

t-years (recurrence interval)	Regression constant a	Regression coefficient b	Standard error of estimate (percent)
2	620	0.76	59.5
5	1,310	0.74	53.7
10	1,940	0.73	56.8
25	2,920	0.72	60.3
50	3,800	0.72	63.5
100	4,820	0.71	67.0

Table 8. Regression constants and coefficients for Group B, Waianae-leeward (Waianae to Hauula)

Equation: $Q_t = a(DA)^b(P_{2-24})^c$

t-years (recurrence interval)	Regression constant a	Regression coefficients b	c	Standard error of estimate (percent)
2	1.08	0.62	3.02	58.1
5	7.73	0.66	2.37	41.3
10	21.5	0.68	2.02	39.1
25	63.2	0.71	1.66	42.8
50	127	0.72	1.43	48.1
100	238	0.74	1.22	54.1

Table 9. Regression constants and coefficients for Group C, Honolulu-leeward (Waipahu to Kalama Valley)

Equation: $Q_t = a(DA)^b(FC)^c$

t-years (recurrence interval)	Regression constant a	Regression coefficients b	c	Standard error of estimate (percent)
2	0.98	0.86	1.37	35.0
5	3.11	0.83	1.26	32.8
10	5.75	0.82	1.20	33.5
25	11.1	0.81	1.13	35.2
50	17.1	0.80	1.09	36.9
100	25.4	0.79	1.05	38.6

EXAMPLES

Example 1.

It is desired to estimate the 50-year flood of Kalihi Stream near Kaneohe (station 16228900).

First, determine which group (A, B, or C) the station belongs. Next, select basin and climatic characteristics as needed from table 4, 5, or 6 depending on the group. See below.

Group	Basin and climatic characteristics (Required)
A	DA
B	DA, P_{224}
C	DA, FC.

In this example, the station belongs in Group C.

Basin and climatic characteristics are tabulated in table 6.

The regression equation for Q_{50} is

$$Q_{50} = a(DA)^b(FC)^c$$

where, from table 9,

a = 17.1,

b = 0.80,

c = 1.09.

From table 6,

DA = 0.60,

FC = 95.

Substituting the respective values in the regression equation

$$Q_{50} = 17.1\ (0.60)^{0.80}(95)^{1.09},$$

$$Q_{50} = 17.1\ (0.6645)(143),$$

$$Q_{50} = 1{,}625 = 1{,}620.$$

Example 2.

Estimate the 100-year flood for Nanakuli Stream at Nanakuli.

First, determine which group the station is in. It belongs to Group B.

Next, find the basin and climatic characteristics that are required.

For Group B, the regression equation for Q_{100} is

$$Q_{100} = a(DA)^{b}(P_{2-24})^{c}$$

where

$a = 238,$

$b = 0.74,$

$c = 1.22.$

The basin and climatic characteristics were found to be

$DA = 3.98,$

$P_{2-24} = 4.50.$

Substituting the respective values in the regression equation

$$Q_{100} = 238(3.98)^{0.74}(4.50)^{1.22},$$

$$= 238(2.779)(6.265),$$

$$Q_{100} = 4{,}143 = 4{,}140.$$

RECOMMENDATIONS

On the basis of the results of this study, the relatively small sample of gaging stations in each group, and the short length of record at about 20 percent of the sites, the following recommendations are made for the future of the program.

1. Continue the crest-stage gage program and reanalyze the flood data every 5 years as the basis for a regional analysis of flood frequencies.
2. Convert continuous-record stations on natural, unregulated streams to crest-stage gages when they are discontinued if additional peak-flow data would be of significant value.
3. Determine a regionalized skew coefficient for Oahu and compare the results with the regionalized skew coefficient for Hawaii determined by the U.S. Water Resources Council (1977).
4. Incorporate rain gages in the data collection program to obtain rainfall-runoff relations for Oahu streams for use in the design of drainage facilities. (City and County of Honolulu, 1969.)
5. Study the effects of urbanization on floodflow by installing rainfall-runoff gages upstream and downstream from urbanized areas.

SUMMARY

Regression equations provide a means for estimating peak flows at selected recurrence intervals. The equations were derived by relating peak flows to basin and climatic characterisitics. The characteristics used in this study are not the only ones that affect peak flows; however, within a reasonable standard error of estimate, they represent an effective combination to estimate floodflows.

The relations derived should not be applied to streams affected by regulation and urbanization.

Continued collection of peak-flow data is desirable in order to obtain better estimates of floodflows.

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