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UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: DIGEST OF HYDRAULIC DATA COLLECTED FOR DESIGN OF MADDEN DAM

HYDRAULIC LABORATORY REPORT NO. 2

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by

E. W. LANE

Under direction of

TECHNICAL MEMORANDUM NO. 122

Denver, Colorado

February 19, 1930

(PRICE $0.25)

Denver, Colorado, February 19, 1930

Memorandum to Chief Designing Engineer
(E. W. Lane)

Subject: DIGEST OF HYDRAULIC DATA COLLECTED FOR DESIGN OF MADDEN DAM.

Abstract of Tabulation of Floods in the Chagres River in Excess of 5,000 Sec.-Ft.

The flood records at Panama cover two periods, the French Period, 1882-1904, in which the records of Chagres River flow was taken at Gamboa, and the American Period, 1899-1929, with records taken at Alhajuela. The records at Gamboa are given in feet of stage, the number of floods above 10-foot stage in each month being recorded, and the maximum stage for the month. A 10-foot stage at Gamboa corresponds to a 15-20,000 sec.-ft. discharge at Alhajuela. The peak and 24-hour discharges of all the floods in excess of 5,000 sec.-ft. at Alhajuela are recorded. The following table gives a condensed summary of the data:

SUMMARY OF FLOODS

Data from Alhajuela Records, 1899-1929

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Number of Floods													
Over 5,000 sec.-ft.	21	14	2	38	171	198	220	279	296	335	278	128	1877
" 10,000 " "	9	5	1	19	69	65	78	103	85	95	108	50	653
" 20,000 " "	5	4	0	4	25	11	16	22	14	22	47	23	91
" 30,000 " "	3	3	0	0	6	4	5	3	2	6	19	13	59
" 50,000 " "	2	0	0	0	1	1	0	0	0	2	5	6	14
Years of Record	28	27	27	27	26	26	27	28	28	28	28	29	26
Max. Discharge (1000 sec.-ft.)	52.2	50.2	19.4	29.2	61.0	63.9	36.5	43.3	33.6	108.3	78.9	154.0	154.0
Max. 24-hr. " (" " ")	47.5	28.3	6.3	19.0	30.1	25.9	22.1	17.0	18.9	73.4	67.7	100.1	100.1
Av. Interval between Floods													
Over 5,000 sec.-ft.	1.3	1.9	13.5	0.7	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.014
" 10,000 " "	3.1	5.4	27.0	1.4	0.4	0.5	0.3	0.3	0.3	0.3	0.3	0.6	0.040
" 20,000 " "	5.6	6.8	0	6.8	1.0	2.4	1.7	1.3	2.0	1.3	0.6	1.3	0.136
" 30,000 " "	9.3	9.0	0	0	4.3	6.5	5.4	9.3	14.0	4.7	1.5	2.2	0.441
" 50,000 " "	14.0	0	0	0	26.0	26.0	0	0	0	14.0	5.6	4.7	1.860
					Data from Gamboa Records								
Years of Record	21	21	21	21	18	19	19	18	18	18	20	21	
No. of Stages over 10 ft. (corresponds to Alhajuela discharge 15-20,000 sec.-ft.)	11	0	1	11	36	37	48	60	39	47	66	54	
Average Interval in Years	1.9	0	21.0	1.9	0.5	0.5	0.4	0.3	0.5	0.4	0.3	0.4	
Maximum Stage Reached	17.9	10.0	12.8	17.7	23.0	24.0	18.7	18.0	23.3	17.4	31.5	31.8	

Alhajuela Maximum Flood on Record. November, 1879 Discharge (Peak) 176,600 sec.-ft.

Abstract of Report on

Flood Frequency of Chagres River at Alhajuela Gaging Station

The best method of determining the size of flood to consider in selecting the spillway capacity of the Madden dam is by means of frequency curves of floods based on the available discharge records. The records at Alhajuela from 1879 to 1899 are approximate, being largely estimates based on records of discharge observed at other points, but good records are available at Alhajuela since 1899. Frequency curves have been plotted for the entire period (51 years) and for the period of good records (31 years). The period of good records indicates higher discharges. For the 1,000-year flood it indicates a peak of 280,000 sec.-ft. (655 sec.-ft. per sq. in.) while the longer period gives 240,000 sec.-ft. (563 sec.-ft. per sq. in.). Since the former is the more conservative value, and is based on the most reliable records, it should be used. Since comparatively little increase in discharge results from considering floods of much greater periods, it is believed that the 1,000-year flood should be used as the basis of design. Since the construction and storage of water in the reservoir eliminates storage capacity which the flood in the unreservoired condition would actually occupy, and since the 280,000 sec.-ft. flood is derived from data with unreservoired conditions, it is recommended that the storage capacity in the reservoir above elevation 240 be considered as offsetting the storage available in

the unreservoired condition and that capacity at the dam be provided to pass 280,000 sec.-ft.

ABSTRACT OF DATA ON CHAGRES RIVER RUN-OFF

Sources of Chagres River Records

The records of the Chagres River discharge of the French period cover the years 1879-1904, and the American period covers from the latter date to the present time. The records of the French period are summarized in Gen. Abbot's "Problems of the Panama Canal".

The Alhajuela station was established April 15, 1899. Since January, 1908, the discharge measurements were made at Calle Larga, 1¼ miles above Alhajuela. Float and current meter gagings were made in 1899 and 1900. Previous to 1907, discharges were measured by the float method. In 1907 both floats and current meters were used, and since then current meters were used, unless conditions rendered it impossible. Automatic gages were used at both Alhajuela and Vigia, and automatic gages were recently installed at Salamanca and Indio.

The period covered by the records at the various stations is as follows:

Station	Period	Missing Years	Incomplete Years
Alhajuela	1899 to date	None	1899 & 1904.
Boqueron (headwaters)	1921-1924	None	All
Boqueron (mouth)	1919 to date	None	None
Camgandi (San Blas)	1920 to date	None	1920, 23 & 26
Chilibrillo	1912 to date	None	1912
Colon	1862 to date	1875, 76, 77, 78, 79, 80 & 89	1862, 67, 81 & 88
Culebra (Pequeni)	1912 to date	None	1912
Gamboa	1881 to date	None	1881, 82, 83 & 95 & 96
Juan Mina	1910 to date	None	1910
Las Minas (Pequeni)	1900	None	None
Nombre de Dios	1905-1911	1906, 07 & 08	1905, 10 & 11
Porto Bello	1905 to date	1907, 15, 16, 17, 18	1905, 06, 08 & 14
Rio Fea (Chagres)	1899-1900	None	1899 & 1900
Rio Indio (Chagres)	1912 to date	None	1912
Rio Puente	1899-1900	None	1899 & 1900
Salamanca (Pequeni)	1899-1900	None	1899
Santa Barbara (Chagres)	1899-1900	None	1899-1900
Vigia	1908 to date	None	1908

Total Run-off at Alhajuela

The actual records extend from 1900 to date, but in routine work the period of 1902 to date is used. By interpolation from Gamboa, Gen. Abbott furnished records beginning in 1890. A table of annual runoffs is given showing the following principal data for annual runoff:

	Million Cu. Ft.	Sec. Ft.	Sec. Ft. per Sq. Mi.	Inches Depth	Period
Maximum year	158,379	5,022	11.76	159.68	
Minimum year	47,859	1,518	3.56	48.22	
Av. 1890-1928	79,585	2,522	5.91	80.23	
Av. 1902-1928	80,856	2,562	6.00	81.50	
Max. 12 months	177,797	5,638			Nov., 1909 to Oct., '10
Min. 12 months	45,105	1,430			Apr. 1905 to Mar., '06

The average rainfall above Alhajuela, 1908-1928, was 122.88 inches, and the average runoff for the same period was 84 inches, or a ratio of runoff to rainfall of 68.4%.

Dry Season Flow

A table is given showing the data on dry season flow, of which the following is a summary:

Dry season length (days), maximum 212; minimum 41 - Average 124
(Jan. 2 to May 5)

Dry season runoff volume, maximum 17,621 million cu. ft.
minimum 5,852 " " "

Dry season runoff rate, maximum 1,652 sec. ft.
minimum 642 " "
average 987 " "

The duration of the dry season, however, is the most important factor in the water supply of the canal. The runoff rate for the (1906) dry season, which had the greatest length (212 days), averaged 883 sec. ft., as compared with 642 sec. ft. for the season (1912) having the lowest rate of runoff. The average runoff for 212 days in 1912, however, was 994 sec. ft., or 111 sec. ft. greater than in 1906, and the year 1906 is therefore the critical year.

Wet Season Runoff

The following is a summary of the data on wet season runoff:

Wet season length (days), maximum 292; minimum 184 - Mean 241
May 6 - Jan. 1

Dry season runoff volume, maximum 152,054 million cu. ft.
minimum 36,099 " " "

Dry season runoff rate, maximum 6,027 sec. ft.
minimum 1,952 " "
average 3,491 " "

Monthly Runoff

The following is a summary of the monthly runoff. Gen. Abbot's values for the early period is included, but for routine hydrographic work the period 1902 to 1929 is used.

Period 1902-1929 Discharge in Second-Feet

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum	5050	3315	1625	3140	5220	4870	6197	4724	5022	8126	11300	17300
Minimum	682	516	382	281	491	1363	1248	1579	1722	2031	2267	1265
Average	1970	1237	735	987	2088	2540	2804	3038	3215	3579	4586	3792

The maximum and minimum values for the period 1890 to 1929 are the same as for 1902-1929 except that in September the maximum for the 1890-1929 period is 5191 sec. ft.

Floods of 30,000 Sec.-Ft. and Over

As no flood damage is reported on the Panama Railroad from 1850 to 1879 it is probable that no flood of over 84,000 sec.-ft. at Alhajuela occurred in that interval. Records of approximate discharge are available for 1879-1899 and good records since 1899. The records for the 47 years from 1882 to 1928 show the following total duration in hours of discharges of 30,000 sec.-ft. and over:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
66	17	0	35	77	83	76	55	56	92	336	524	1417

This shows conclusively that the critical period as regards floods is November and December.

The floods of 1879 and 1888 appear to be the maximum in 80 years. The records for 1879 are too meager to permit an estimate to be made of the volume (A peak rate of 176,600 sec.-ft. and a 24-hour maximum of 141,300 sec.-ft. is given elsewhere). In 1888 the probable maximum 24-hour discharge was 10 billion sec.-ft. and for 48 hours and 7 days was 18 billion and 32 billion sec.-ft. respectively. In December, 1888, there were about 205 hours when the discharge at Alhajuela exceeded 30,000 sec.-ft.

Data on Ten Largest Floods

The hydrographs of the ten largest floods were drawn up to the same scale, as far as the data available would permit, and mass curves of volume constructed. The data on the earlier floods is very rough and estimates of peak rate and volume made by various persons differ widely. The estimates of Gen. Abbot are recognized as being very low.

Flood of November 20-25, 1879. The data available indicate that this was the largest flood on record. According to newspaper reports it began on the night of November 19 and the rain probably ceased about 1 P.M. on November 25. The crest reached Mamei at 8 P.M., November 24. Gen. Abbot calculated a peak discharge of 78,000

sec.-ft. A. P. Davis thought it about 100,000 (Estimates elsewhere in data, indicate 176,000 as accepted discharge for this flood).

Flood of November 25-28, 1885. This flood on November 25, rose to a peak in 36 hours, subsided to a 10-foot stage for about 5 days and was then followed by a secondary smaller flood. Gen. Abbot gives the discharge of this flood as 64,488 sec.-ft. (The plotted graphs indicate that the present accepted value is 124,000).

Flood of December 11-17, 1888. This flood came from the upper river. The rise at Gamboa started on December 11, it reached a peak of 22 feet, subsided slightly and then rose to 31.4 feet at 9, P.M. on the 13th, subsiding gradually. Gen. Abbot gives the peak discharge as 58,132 sec.-ft. (but the graphs use 149,000 sec.-ft.).

Flood of December 21-25, 1888. This flood follows closely on the December 11-17 one. The records show 424 hours above the 10-foot stage at Gamboa for the month, more than double any in the first 20 years of records. (The peaks on the graph indicate 105,000 sec.-ft. discharge).

Flood of December 1-2, 1890. The flood began to rise on December 1, peaked on December 2 and fell rapidly the next day. Gen. Abbot gives a peak discharge of 65,371 sec.-ft. (The graph shows 123,000).

Flood of December 19-22, 1893. This flood was in the lower river. It consisted of three waves. Gen. Abbot estimated the discharge as 43,086 sec.-ft. (The graphs give 80,000).

Flood of December 3-4, 1906. The rise at Alhajuela began 2 P.M., December 2, reaching a peak in 20 hours of 26.89 feet. The discharge from Gen. Abbot's rating table was 92,100 sec.-ft. (The graphs use 140,000).

Flood of November 16-20, 1909. This was a small flood with a peak discharge of 78,000 sec.-ft.

Flood of December 10-13, 1909. Another small flood, peak discharge 73,000 sec.-ft.

Flood of December 26-31, 1909. This is the greatest flood at Alhajuela of which there is an accurate record, but it was probably exceeded in rate and volume by the 1879 flood and in volume by the 1888 flood. No gagings were made but the discharge was estimated at 170,000, but this was questioned and a value of 154,000 (a mean of the results of eight flow formulas) is now used. Gen. Abbot's formula gives 111,200 sec.-ft.

Flood of October 22-25, 1923. This flood was greater in the lower part of the valley. It reached a stage of 24.4 feet on October 22. There was a second smaller rise on the 24th. A current meter gaging of this flood taken under difficult ties indicated a crest discharge of 108,300 sec.-ft., which is believed to be too low (but is used on the hydrographs).

Source and Disposal of Water Supplied to Gatun Lake for Fiscal Year 1929.

The total yield of the Gatun Lake watershed for the fiscal year 1929 amounted to 209.39 billion cubic feet, accounted for as follows:

		Billion Cubic Feet
Runoff above Alhajuela	38.3%	80.28
Yield from land area below Alhajuela	41.6%	87.05
Direct rainfall on lake surface	20.1%	42.06
Total -	100.0%	209.39
Evaporation from lake surface	10.3%	21.60
Gatun Lake lockages	20.2%	42.26
Hydro-electric power	21.0%	43.87
Spillway waste	50.6%	106.04
Leakage, municipal and other minor uses	.8%	1.73
Decrease in storage	-2.9%	-6.11
Total	100.0%	209.39

Volume of Flood Flows

The volume of flood flows were given from 1906 to date, those prior to 1906 being too approximate. The volumes given are for flows of over 30,000 sec.-ft., the floods being assumed to begin when the river discharge rose to 30,000 sec.-ft. and to end when they dropped to that amount. The volumes ranged from 256 million cu. ft. to 9,365 million cu. ft. (Dec. 26-27, 1909). In several cases, however, the floods were so close together that for some purposes two or more floods might have to be considered as one flood.

Denver, Colorado, February 15, 1930

Memorandum to Chief Designing Engineer
(D. C. McConaughy)

Subject: Hydrographic Studies.

In order to prepare graphs of the action of a reservoir during a flood, it is necessary to know, or to assume, all details concerning the given flood. The peak discharge as assumed by the engineers of the Canal Zone, 280,000 second feet, has been accepted. This is computed by them to be the rate of discharge reached once in a thousand years. In order to arrive at an estimate of the volume of this flood, it has been assumed that the volume will be, also, that which occurs once in a thousand years.

There are available eleven hydrographs (drawings 5058-20 to 5058-29 and 5058-22A) showing the largest floods; two of these, November 20, 1879 and December 19-22, 1893, show only the peak and a few notes of other stages.

There is also a list of floods for which the rate of discharge exceeded 30,000 sec. ft. with peak discharge, and duration, contained in a memorandum of George E. Matthew, Principal Hydrographer, to the Chief of Surveys, dated October 22, 1929, with a supplemental list giving volume of discharge, contained in radiogram of February 6, 1930. In the present study, some of the floods shown separately on the above mentioned lists have been combined; notably in the case of the flood of December 10-12, 1909 and October 22-25, 1923. From the appearance of the hydrographs it seems probable that the floods as assumed herein were produced by a single storm.

The suppemental list of flood discharges, previously mentioned, gives discharges for 56 "floods" over the period 1906 to 1927; it is stated that "data prior to 1906 is approximate and therefore not furnished". With the exception of the years 1909 and 1923, there were no floods of any considerable volume during that period. An idea of the order of magnitude of floods of unknown volume prior to 1906 may be obtained from the peak discharge and duration of discharges of 30,000 sec. ft., contained in Mr. Matthew's memorandum, by assuming the hydrographs of these floods to be represented by a triangle superimposed on a rectangle; the larger floods, as arrived at by this rough method, are as follows:

Table I.--Estimated Magnitude of Large Floods of Unknown Volume 1882 to 1906.

Date	Max. Q. Sec. ft.	Duration (hours)	Volume (million cu.ft.)
1882, Nov. 4-7	45,400	16.33	2100
1885, Dec. 3-5	75,200	39.16	7400
1887, June 14-15	75,200	16.16	3000
" Sep. 6-7	70,200	16.67	3000
" Nov. 1-3	46,800	21.50	3000
1888, Dec. 7-8	54,500	21.00	3200
1889, Nov. 22-23	55,400	19.83	3000
1891, Nov. 19-20	51,600	26.00	3800
1892, Nov. 12-13	66,300	17.50	3000
1894, Dec. 26-27	47,900	30.00	4200
1897, May 16-19	68,900	19.50	3200
1902, Jan. 1-3	52,200	44.50	6600

These are additional to the 12 largest floods shown by the hydrographs; so that in the 49-year period from 1879 to 1927 it is probable that there occurred at least 24 floods with a run-off exceeding two billion cu.ft.

In the 22-year period from 1906 to 1927 there were only 6 floods with a run-off exceeding two billion cu. ft., and only 13 exceeding one billion cu. ft. Of the twelve largest floods of known volume, only 6 occurred in the period 1906 to 1927, and four of these were among the five smallest floods of the twelve. It is therefore concluded that, even though the record prior to 1906 may be open to some question, it is not desirable to confine the present study to the years 1906 to 1927.

This study has therefore been based on the twelve floods shown by the available hydrographs. The hydrograph for the flood of November 20-25, 1879, shows only the peak discharge of 176,600 occurring at noon November 24, with a notation that "the big rise probably began during early morning of November 23" and "evening of November 25 probably 30,000 sec. ft. discharge". It is assumed that the rising stage reached 30,000 sec. ft. at 3 A.M., November 23, and that the discharge had fallen to 30,000 sec. ft. at 8 P.M., November 25. From these assumptions the run-off is estimated at 22.2 billion cu. ft. The hydrograph for the flood of December 18-22, 1893, shows a crest of "probably about 40,000 sec. ft." at 1 P.M., December 19; a second crest of 80,500 at 4 A.M., December 21, and a note "probably discharging about 30,000 sec. ft." at 1 P.M., December 22. From these notes the run-off is estimated at 11.5 billion cu. ft., of which 8 billion was produced by a discharge of 30,000 sec. ft. Other volumes have been taken from the curves of cumulative run-off shown on the hydrographs. The duration of the "flood"

has not been determined by a fixed rule, except that it begins and ends with discharges of 30,000 sec. ft.; in the case of the flood of October 22-25, 1923, the discharge after the first peak dropped to 17,000 sec. ft. and was below 30,000 sec. ft. for 17 hours, so that there may be some question as to whether this should be considered one flood or two. It has been classed as a single flood. This is the only case which seems doubtful. The following table shows the floods used as a basis for the probability study.

Table II.--Calculations for Probability Plotting

Date	Duration (hours)	Run-off (million cu.ft.)	No. times equalled	Per cent Time 1882-1929	Per cent Time 1879-1929	Per cent Time 1850-1929
Dec. 30, 1909	12	2,700	*25	51.0	48.0	30.6
Dec. 3, 1906	22	6,800	11	21.9	20.6	13.1
Dec. 1-2, 1890	24	6,900	10	19.8	18.6	11.8
Dec. 26-27,1909	21	8,400	9	17.7	16.6	10.6
Dec. 10-12,1909	58	9,600	8	15.6	14.7	9.35
Nov. 25-27,1885	40	10,600	7	13.6	12.7	8.12
Nov. 17-20,1909	62	11,500	6	11.2	10.5	6.68
Dec. 19-22,1893	76	11,600	5	9.37	8.82	5.62
Oct. 22-25,1923	63	12,100	4	7.30	6.87	4.38
Dec. 22-24,1888	68	14,100	3	5.21	4.89	3.12
Nov. 23-25,1879	65	22,200	2	3.12	2.95	1.88
Dec. 12-16,1888	97	29,000	1	1.03	0.98	0.62

*Estimated

The last three columns are computed from the formula $P = \frac{100\ (N-0.5)}{Y}$

where P is percent of years.
N is number of times the flood was equalled or exceeded in the time period.
Y is number of years in time period.

Probability has been computed on the bases of three time periods as follows:

First, for the period 1882-1929, 48 years, since the floods actually occurred during that period with the exception of that of 1879.

Second, for the period 1879-1929, 51 years, during which time the floods actually occurred.

Third, for the period 1850-1929, 80 years, on the assumption made in Mr. Matthew's memorandum of October 22, 1929, that there were no large floods from 1850 to 1879.

The resulting curves are shown on drawing 213-D-2 from which it is seen that the volume occurring once in one thousand years is about 56 billion cu. ft.

Three different hydrographs have been assumed for the flood, all based on the assumption that the peak discharge is 280,000 sec. ft., the total volume 56 billion cu. ft. and the peak time 3 hours. These hydrographs with the resulting reservoir action are shown on drawing 213-D-1, which is believed self-explanatory. The rate of rise for floods 1 and 2 on the drawing is 10,000 sec. ft. per hour, assumed from a study of the hydrographs of known floods; this rate has varied from 20 minutes to 3½ hours. In computing the action of the reservoir, it has been assumed that the approach of a flood of this magnitude will be known in advance and that the drum gates will be completely lowered and the gates and valves opened when the discharge reaches 30,000 sec. ft.

The volume corresponds to a run-off about 56 inches over the watershed. The average annual run-off for the years 1908-1928, as shown by tabulation in memorandum of George E. Matthew, Principal Hydrographer, to Chief of Surveys, dated September 7, 1929, is 84 inches, or

68.4% of the average annual rainfall (122.88 inches) for the same period. If, for such a large flood, a run-off of 80 percent be assumed, the rainfall would be 70 inches in five and one-half days. Considering that this storm is supposed to occur only once in 1,000 years, this rate is believed not at all unreasonable for the tropics.

For determining the depth of water below the dam there are available data contained in memorandum of Mr. George E. Matthew, Principal Hydrographer, to Chief of Surveys dated September 7, 1929, and October 22, 1929, and the following drawings.

S-5058-18 Chagres River Discharge - Madden Damsite #1.

S-5058-19 Chagres River Area Curve (Calle Larga Values) Madden Damsite #1.

5132- 1 High Water Marks and Flood Profiles of the Chagres River and Tributaries.

From the memorandum of September 7 it appears that previous to 1908, gagings were made at Alhajuela, which is shown by drawing 5132-1 as one-half mile below the damsite and subsequent to that date at Calle Larga, shown by the same drawing as one mile above the damsite. These two stations, in the memorandum of September 7, are both referred to as "Alhajuela". The memorandum of October 22 gives crest elevations and maximum rates at "Alhajuela"; if the discharges and elevations are plotted the points prior and subsequent to 1908 lie on the same curve, from which it may be supposed that if the original data were taken at different points a correction has been applied to reduce them to a common basis.

This curve lies four to five feet below that shown on drawing S-5058-18; which corresponds to the difference in elevation between Alhajuela and the damsite as shown by the flood profiles of drawing 5132-1 so that it may be concluded that the data in memorandum of October 22 are for Alhajuela proper (one-half mile below the dam) and that the discharge curve of drawing S-5058-18 is for the damsite, although the note thereon "See drawing S-5058-19 for area curve" which area curve is stated in the title to be for Calle Larga, might indicate that the curve is for Calle Larga.

The discharge curve ends at a discharge of 150,000 sec. ft. so that it has been necessary to extend it; this curve with the extension, is shown on drawing 213-D-18. Areas for the area-velocity method of extension were obtained from a cross-section plotted from the topography at the damsite; mean velocities for discharges were obtained by dividing the discharge as obtained from the curve by the corresponding area from the cross-section. The areas as obtained from the plotted section are about 20% less than those shown on the area curve drawing S-5058-19. While this method is generally considered as the most satisfactory one for extending discharge curves, it is in this case attended by some uncertainty and the results of its application probably should be regarded as no more than a satisfactory check on the other methods. The highest curve is recommended for use.

There is an unaccountable discrepancy between the elevations of the 1000-year flood as shown by drawing 5132-1 and as obtained from the extension of the rating curve. Comparative elevations as taken

from different sources are given in the following table:

Flood Elevations at Various Points

Date	Discharge from memo of Oct. 22	Elevation: Alhajuela: Memo Oct. 22	Elevation: Alhajuela: Drawing 5132-1	Elevation: Dam Site: Discharge Curve	Elevation: Dam Site: Drawing 5132-1
1879	176,000	123.64	123	*129	127.5
1909	154,000	121.00	121.5	127	125.5
1889	149,300	120.41	120	126	124
1923	108,300	117.42	116.5	120.5	121
1903	62,300	108.73	109	113	113
1000 yr.	280,000	—	125	*139	129.5

*As extended by area-velocity curves.

It is seen that while the elevations at Alhajuela, as shown by drawing 5132-1 agree very well with those given in the memo of October 22, the agreement between the elevations at the Dam Site is not so good, the difference in the case of the 1000 year flood amounting to 9.5 feet even though the extension of the rating curve giving the lowest elevations is used. Discharges are not given on drawing 5132-1; but in the letter of transmittal the discharge for the 1000 year flood is said to be 280,000 sec. ft. It seems improbable that the increase of 100,000 sec. ft. from the 1879 flood to the 1000-year flood would result in a rise of only two feet; possibly the rate of discharge has been reduced by taking account of temporary flood storage.

NOTE: Revised drawing 5132-1 showing elevation 139 for the 1000 year flood received March 1, too late for inclusion.

While it is thought ultra-conservative to assume no benefit from the large expenditure contemplated for valves, the reservoir action for the flood giving the most severe conditions has been studied assuming discharge from the reservoir through the spillway only. The results are shown on drawing 213-D-19.

In conclusion, attention should be drawn to the fact that the peak discharge was determined from Alhajuela data and is uncorrected for the effect of the natural flood channel storage in the reservoir basin. Data for determining the magnitude of the correction are not available; it probably is of no great importance, but the subject should be given at least sufficient study to determine whether this is the fact.