ASSESSMENT OF PEAK DISCHARGE UNCERTAINTY IN THE AMERICAN RIVER BASIN, CALIFORNIA

By Robert W. Meyer

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Conversion Factors and Vertical Datum

Multiply	By	To obtain
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	259.0	hectare

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Flood-discharge data, current-meter and indirect measurements, and stage-discharge relations, the oldest of which dates to the early 1900's, were used to estimate the uncertainty about annual flood peaks in or near the American River Basin at 20 stream-gaging stations operated by the U.S. Geological Survey. The study estimates that, in the study area, most flood peaks that were determined from current-meter measurements have an uncertainty of about ±3 percent, whereas the peaks that were determined from indirect measurements have an uncertainty ranging from ±10 to ±70 percent. The study also determined that the stage-discharge relations that have been developed for most of the sites in the American River Basin are correct.

INTRODUCTION

The American River, which drains about 2,000 mi^2 on the western slope of the Sierra Nevada, brings water, hydropower, and the threat of flooding to many communities in and downstream from the American River Basin. The river system is highly regulated by many dams, diversions, and powerplants. The most important of these is Folsom Dam, which is the most crucial flood-control structure on the American River. The Bureau of Reclamation, in its ongoing effort to improve flood management, has started a paleohydrologic study of the American River Basin. As a part of that study, an assessment of the accuracy of available streamflow and flood-peak data was needed.

Purpose and Scope

The purpose of this study was to review and assess the uncertainty of streamflow and flood-peak data at 18 stream-gaging stations operated by the U.S. Geological Survey (USGS) in the American River Basin. At the request of the Bureau of Reclamation, two sites on the Yuba River (outside the American River Basin) were included for comparison because their drainage areas are similar in size to that of the American River at Fair Oaks. The length of record for the 20 sites ranged from 20 to 90 years. Data reviewed included observations of stage, recording gage data, current-meter and indirect measurements, station descriptions, station analyses, and stage-discharge relations. This report provides flood-peak information for historical and current conditions (1995) and uncertainty about the peaks in the American River Basin. The study evaluated data from published reports, maps, digital data bases, and other paper records maintained by the USGS. The data were compiled into separate gaging-station files that were used to assess the accuracy of flood peaks and to assign a percentage value of uncertainty for specific peaks and ranges of peaks for each gaging station. Also, uncertainty about current-meter measurements

and indirect measurements of discharge was assessed, and stage-discharge relations (rating curves) for numerous sites were reviewed and verified for shape, slope, and plotting location on the stage-discharge relation.

Study Area

The study area encompasses a large part of El Dorado and Placer Counties and a small part of Sacramento and Yuba Counties (fig. 1). The American River is formed by the union of its three principal forks, the South, North, and Middle Forks. The North and Middle Forks are each about 60 mi long, fall nearly 8,000 ft, and drain areas of 349 and 640 mi^2, respectively. The South Fork, also about 60 mi long, falls nearly 9,000 ft and drains an area of about 860 mi^2. The study area includes high, mountainous terrain as well as low-elevation foothills. Most of the area is forested, ranging from pine-fir forests to oak woodlands. Most tributaries and main channels were hydraulically mined prior to 1910, which mobilized large amounts of sediments and caused changes in flow conditions at various sites. Many of the streams are currently regulated by dams and diversions. Data collection and river-management activities in the study area provide information for water use, flood control, and energy production.

METHODS

The determination of peak discharge uncertainty was based on a review of gage-height records, direct and indirect discharge measurements, stage-discharge relations (ratings), and supporting information. Most peaks are determined from the application of an observed or recorded gage height to the station stage-discharge relation (rating). The discharge measurements and gage heights are the data from which rating tables, peak, daily, monthly, and annual discharge data are computed. Discharge measurements of various kinds are required to develop a rating.

The accuracy of streamflow data depends primarily on natural conditions at the gaging station and on methods and care with which the data are collected. Uncertainty about the peak discharge due to natural conditions depends on the degree of permanency of the channel and the relation between stage and discharge. Methods and care with which data are collected can cause errors in observation of stage and measurement or computation of discharge. If inadequate or inappropriate data are collected, stage, discharge, or measurement data may be misinterpreted.

Plots of peak discharge and drainage area for gages in the central Sierra Nevada were made for several regionwide storms; an example is shown in figure 2. The plots include an envelope curve of maximum flood experience (Q_{me}) (Meyer, 1993); any peak that exceeded the Q_{me} and any that plotted near the curve were graphically compared to a similar, nearby gaging station; an example is shown in figure 3. If a large departure from the trend was identified, then the methods used to determine the peak discharge, the documentation of the computation, and the original calculation of such peaks were reviewed.

Gage Height

The stage of a stream is the height of the water surface above an arbitrary datum. The water-surface elevation referenced to some datum (for example, elevation of datum plus the stage) is called the gage height. Gage height is usually expressed in feet and hundredths of a foot.

In stream gaging, gage height is the independent variable used in a stage-discharge relation to derive discharge. Accuracy of the daily mean discharge record is, therefore, dependent on the accuracy of the gage-height record as well as the stage-discharge relation.

Gage-height records may be obtained by a water-stage recorder, by periodic observation of a nonrecording gage, by noting only peak gage heights with a crest-stage gage, or by surveys of water-surface profiles. A continuous record of discharge at a gaging station is computed from a continuous record of stage and the stage-discharge relation (rating). For this purpose, stage records to an accuracy of 0.01 ft generally are needed. The stage-recording instruments used by the USGS provide the required degree of accuracy.

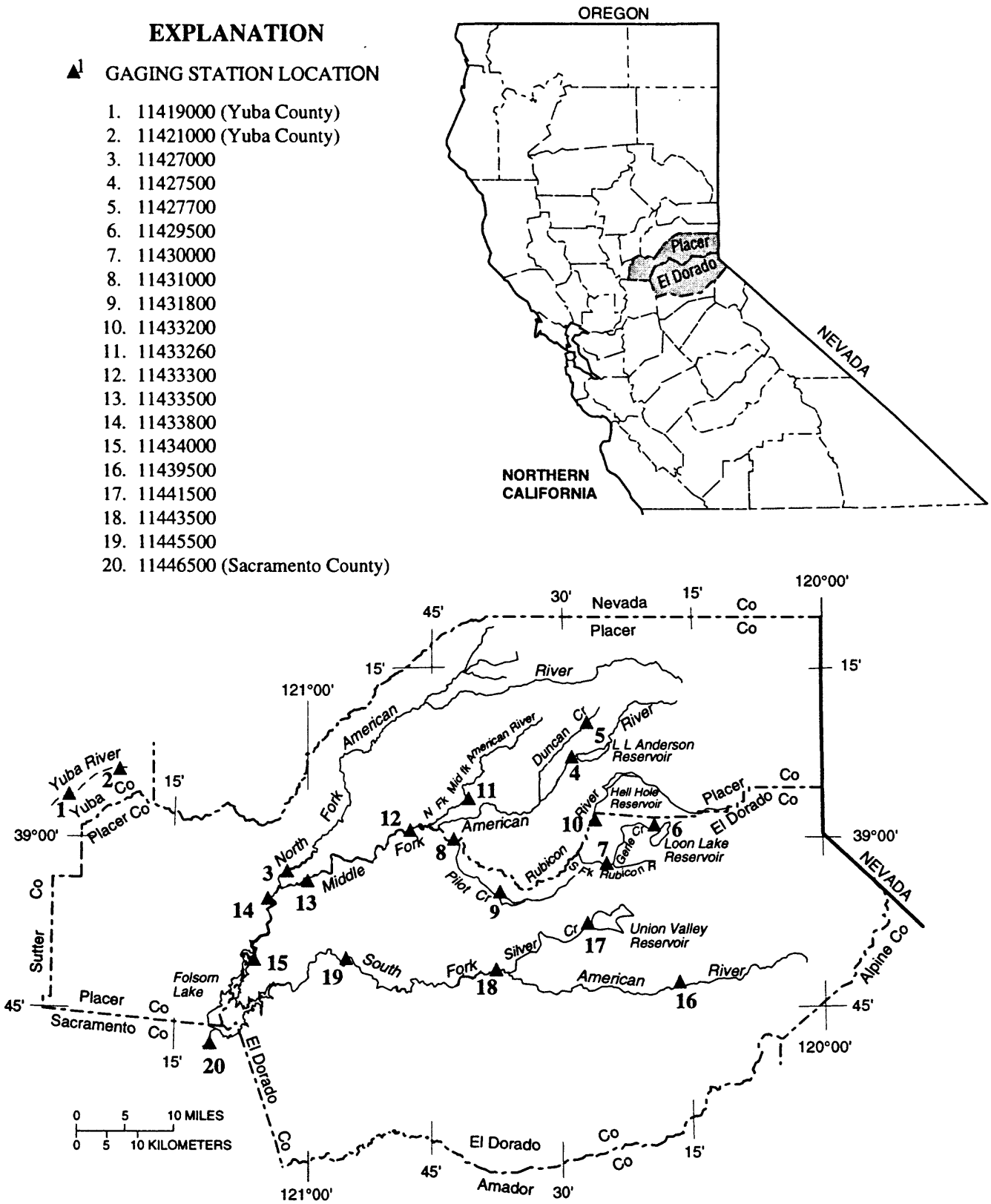

Figure 1. Northern California and study area boundary.

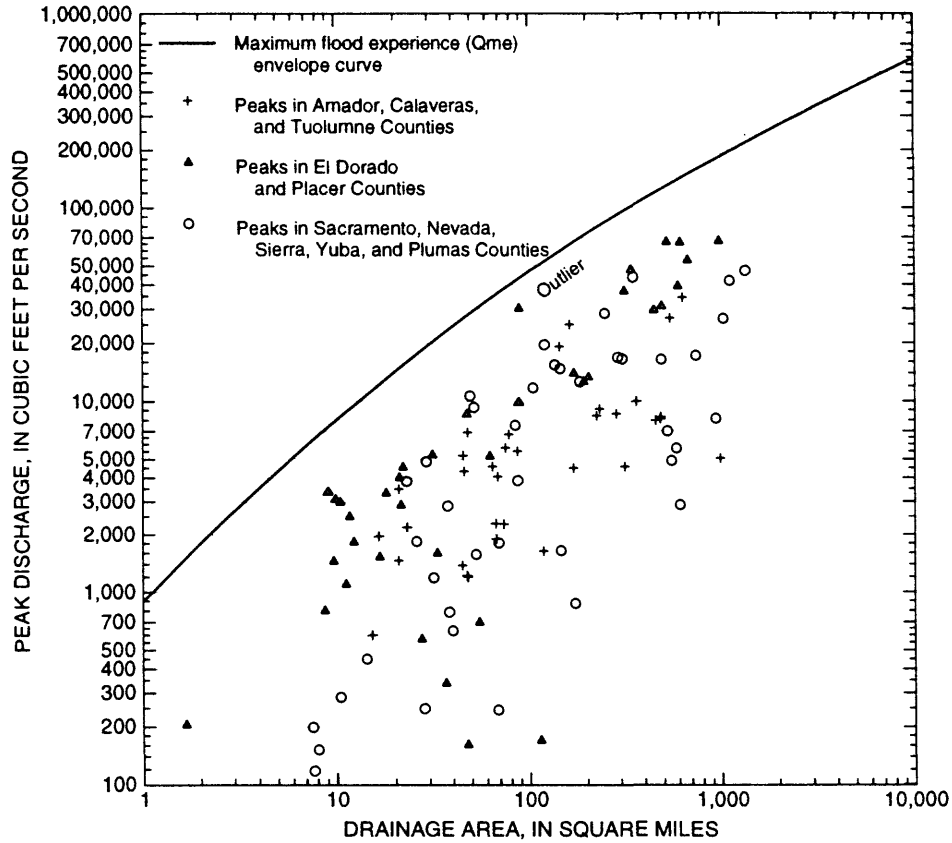

Figure 2. Flood peaks within the American River Basin, California, and surrounding counties, 1980.

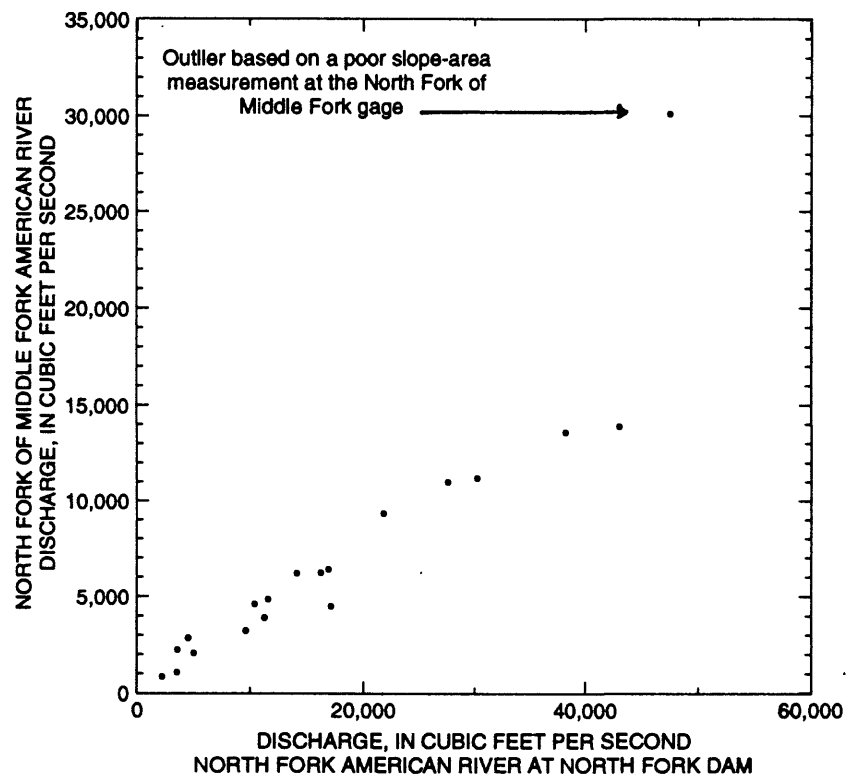

Figure 3. Example of relation between annual peak discharges at two gaging stations.

Many natural changes that occur in a river may increase uncertainty in stage records. Sensing equipment may be buried by sediment or damaged by debris, or the shape and dimensions of the channel near the gage may change significantly. Malfunction or poor maintenance of sensing and recording equipment may result in lost or faulty records. Observers may not observe, or may observe inaccurately, the true peak stage.

Uncertainty in gage height may significantly increase uncertainty in discharges that are obtained directly from ratings. When gage height is unavailable, water-surface profiles near the gage often are surveyed to determine the flood stage. Those surveys may or may not represent the true stage of the river, and it is difficult to assess the loss of accuracy of discharge estimates when gage-height record is unavailable. If the error in stage is large (more than 1 ft, for example), the uncertainty in the discharge would be large. Unless there is a history of the relation between recorded gage height and outside high-water marks, it is not possible to make a good estimate of error due to missing stage records. However, on the basis of an extensive number of northern California gaging-station records, a qualitative guide (see table 1) was developed to assess the impact of various gage-height recording conditions on the uncertainty of peak discharges.

Current-Meter Measurements

The assessment of current-meter measurement uncertainty was made using the method and program *Measerr* described by Sauer and Meyer (1992). In that method, the uncertainty, or standard error, for individual measurements of stream discharge is computed on the basis of a root-mean-square error analysis of the individual component errors. The component errors include errors in the measurement of width, depth, and velocity, and in computation procedures. This analysis can be used to evaluate the uncertainty of most discharge measurements, which then can be used in further analysis of stage-discharge ratings and computation of daily discharge.

The program *Measerr* was used to compute the percent uncertainty of selected measurements. (For an example of an uncertainty analysis of current-meter measurements, see table 2.) For many sites, current-meter measurement data were available in the USGS National Water Information System ADAPS data base. Additional data were obtained from archive copies of measurement summary forms. For this evaluation, only those current-meter measurements that were used to define the mid to upper range of the stage-discharge relation were evaluated. Most measurements had a calculated uncertainty of about ±3 percent. The range was ±2.2 to ±8 percent. No current-meter measurement determined to be critical for rating development was found to exceed 8 percent uncertainty. The mean and range of current-meter measurement accuracy is given for each station for which measurement data were available.

Table 1. Gage-height record quality and assumed peak discharge uncertainty

Conditions at gaging station	Assumed range of impacts of gage height and conditions on uncertainty about peak discharge
Complete gage-height record, stable control conditions, observed high-water marks	± 1 percent
Complete gage-height record, shifting control conditions, observed high-water marks	± 1-5 percent
Incomplete or no gage-height record, stable control conditions, observed high-water marks	± 2-8 percent
Incomplete or no gage-height record, shifting control conditions, observed high-water marks	± 5-15 percent
No gage-height record nor observed high-water marks	Much more than ± 15 percent

Table 2. Example of uncertainty analysis of current-meter measurements at the American River at Fair Oaks, California (11446500)

[Period of record, 1910-95; two observations in each vertical segment; ft/s, foot per second; ft, foot. Overall discharge measurement uncertainty: minimum, 1.9 percent; maximum, 4.5 percent; mean, 2.6 percent; standard deviation 0.6]

Measurement number	No. of vertical observations in measurement section	Mean velocity (ft/s)	Mean depth (ft)	Measurement uncertainty (percent)
749	29	3.26	11.56	2.4
764	32	3.31	12.00	2.3
769	24	3.84	12.71	2.7
770	34	3.17	11.31	2.2
784	24	4.90	14.69	2.7
786	24	3.99	12.69	2.7
787	23	3.12	10.86	2.7
793	25	6.66	15.21	2.6
794	25	2.98	11.72	2.6
795	19	4.38	14.05	3.1
798	30	2.72	11.97	2.4
829	30	3.08	12.37	2.4
854	41	6.57	14.35	2.0
859	29	3.52	11.67	2.4
869	27	3.68	11.83	2.5
873	29	3.64	11.59	2.4
887	28	4.55	12.97	2.4
904	31	3.43	10.94	2.3
915	31	3.21	10.67	2.3
918	31	3.14	10.18	2.3
929	35	3.70	11.42	2.2
938	46	8.46	15.09	1.9
939	39	9.14	18.18	2.1
940	29	5.92	14.96	2.4
942	34	7.51	16.89	2.2
943	33	2.99	12.40	2.2
944	35	3.94	14.07	2.2
945	32	7.15	17.12	2.3
956	36	2.73	11.82	2.1
957	30	3.37	13.10	2.3
961	35	2.86	12.06	2.2
962	28	3.97	13.76	2.4
963	34	3.94	13.79	2.2
986	32	4.12	13.76	2.3
987	31	2.87	11.18	2.3

Indirect Measurements

The discharge of streams usually is measured using the current-meter method (Rantz and others, 1982). During floods, it is frequently impossible or impractical to measure the streamflow by this method. If the peak greatly exceeds the rating, after the passage of the flood, indirect methods are used to estimate peak discharge. The indirect methods generally used are slope area, slope conveyance, contracted opening, flow over dam, and flow through culvert. Results of selected indirect measurements for large discharges in the study area are shown in table 3.

The method most commonly used for indirectly determining peak discharge in the American River Basin has been the slope-area method. Channel geometry, channel roughness, and water-surface profiles are used in a uniform-flow equation when determining peak flow by the slope-area method (Dalrymple and Benson, 1967). This method is subject to many possible errors and problems, such as:

- poor physical conditions in the selected reach or in the entire channel,
- poor or ill-defined high-water marks,
- poorly defined water-surface profiles,
- excessive channel slope or roughness,
- poor selection of the roughness coefficient,
- poor site selection, or no better site is found, and
- insufficient data.

For a detailed evaluation of possible error sources, see Jarrett (1987) and Kirby (1987).

Table 3. Selected indirect measurements in the American River Basin, California

[Type of measurement: FOD, flow over dam; SA, slope area; SC, slope conveyance. Accuracy: G, good; F, fair; P, poor. ft^3/s, cubic foot per second]

Station No.	Station name	Type of measurement	Accuracy	Peak date	Peak discharge (ft^3/s)	Estimated uncertainty (percent)
11427000	North Fork American River at North Fork Dam	FOD	F	12-22-64	65,400	±10
11427500	Middle Fork American River at French Meadows	SA	F	12-23-64	16,300	±25
11429500	Gerle Creek below Loon Lake Dam	SA	F	2-1-63	3,240	+5 to -50
11430000	South Fork Rubicon River below Gerle Creek	SA	P	2-1-63	11,500	+10 to -30
11431000	Rubicon River near Georgetown	SA	P	2-1-63	58,000	±40
11431800	Pilot Creek above Stumpy Meadows	SA	F	1-13-80	2,500	±20
		SA	G	12-22-64	2,380	± 20
		SA	P	2-1-63	2,070	±40
11433200	Rubicon River near Foresthill	SA	F	2-8-60	16,500	+0 to -35
		SC	P	12-23-64	[1]456,000	
11433260	North Fork of Middle Fork American River near Foresthill	SA	P	1-13-80	30,100	+0 to -70
11433300	Middle Fork American River near Foresthill	SC	P	12-23-64	310,000	±50
		SA	P	2-1-63	112,700	+10 to -50
		SA	P	2-8-60	[2]28,000	
11433500	Middle Fork American River near Auburn	SA	P	12-23-64	253,000	+0 to -40
11433800	Middle Fork American River below Auburn Damsite	SA	F	1-14-80	66,700	±20

[1]Measurement determined to be invalid.

[2]Peak discharge for this measurement was revised from 39,000 ft^3/s.

The quality standards used for evaluation of slope-conveyance and slope-area estimates of peak discharge were:

- •Banks and bed were reasonably stable,
- •Reach fairly straight and uniform in shape and slope,
- •Reach free of major obstructions or disturbances, such as large eddies or tributary inflow,
- •Water-surface fall through the reach was at least ten times the expected error in measurement of fall. For example, expected error is about 0.05 ft; therefore, about 0.5 ft of fall or more in the reach is needed for good results,
- •Fall in the reach was equal to or greater than the velocity head,
- •No extreme expansion or contraction in the reach,
- •Little possibility of significant stream-bed scour after the peak and before the measurement,
- •Assigned roughness coefficient reasonable for conditions,
- •Measurement result compared well with an extension of the rating, and any significant deviations are explainable,
- •Measurement result compared well with peak discharges at other gages in the basin, and
- •Reach was free of hydraulic jumps as indicated by water-surface profile.

Summaries of indirect measurements include an estimate of the uncertainty about the calculated discharge. In the evaluation of the original computation, a measurement that was considered "good" would be expected to be within 10 percent of the true discharge; this would represent a case where the physical conditions were favorable and the field data adequate, well defined, and well documented. A "fair" measurement would represent about 15 percent uncertainty, with unfavorable conditions. A "poor" measurement might have a 25 percent or greater uncertainty. However, the assignment of uncertainty is subjective, based largely on the judgment of the hydrologist.

The basic review assumption was that the computed discharge was the true discharge, with no uncertainty. The original data and computations for each measurement were reviewed. If the drawings, photos, and notes, and computations indicated significant departure from quality standards, or the discharge did not compare well with nearby gaging stations, the uncertainty about the computed discharge was increased. Most departures were small for most measurements and cumulatively resulted in uncertainty values of ±5 to ±15 percent.

Two sources of error that may greatly increase uncertainty about the true discharge are cross sectional area and channel roughness. No indirect measurement reviewed had discernible errors in cross sectional area. Most measurement reaches had channel beds composed of cobbles, boulders, and bedrock, making the channel resistant to change. The available documentation (notes and photos) gave no indication of significant scour or fill.

Ongoing research has provided more and better understanding of channel roughness coefficients, especially in rougher, mountainous channels. The original notes, sketches, and stereo photos were used to obtain independent estimates of the Manning roughness coefficient "n." If the originally assigned roughness coefficients differed by more than 0.005 from that selected by the reviewing hydrologist, a second reviewing hydrologist was consulted, consensus reached, and a percentage difference determined between the original and new roughness coefficient. An example would be (0.037 - 0.050)/0.050 = -0.26 or -26 percent. This difference between the two roughness coefficients is assumed to be an indication of the uncertainty about the true peak discharge that is due solely to difficulty in correctly and consistently selecting "n." The re-evaluated roughness coefficients were based on information provided by Jarrett (1987), which was not available when most of the measurements were made.

Different methods of estimating peak discharges may be compared in order to evaluate the results of an indirect measurement. Unit runoff determined from nearby gages often provides a good estimate of peak discharge, especially for winter, region-wide floods. In addition, ratings may be linearized and extended beyond the highest current-meter measurements. A rating extension to twice the discharge of the highest current-meter measurement may be used if the rating is linear on log paper. Such extensions provide reasonable estimates if overbank flow is ruled out. The actual stage-discharge relation may vary from linear to a leftward-bending curve in a channel with a simple geometric shape, such as a rectangle or parabola.

At many of the gages reviewed, the channels were constrained by steep, narrow canyons so there was little opportunity for overbank flow; such channel constraints limit the probability of rightward curvature of the stage-discharge relation. Many sites have moderate to steep slopes, which reduce the possibility of significant backwater impacting the rating. This condition limits the amount the rating could reasonably be expected to bend leftward.

In most indirect measurements, site selection, field data-collection, and survey methods were adequate to good. For a few measurements, the best possible procedures were not used, or the physical conditions were so unfavorable that good results could not be obtained.

Rating Curves

A rating analysis is a process in which the gage height and the discharge from a series of measurements are plotted on graph paper, a curve defined by the measurements drawn, and a relation table prepared from the curve. The USGS utilizes the methods described by Kennedy (1984). The quality of each rating is a function of the quality of the available data; ratings based on too few measurements or those generated from measurements that scatter widely on the plot increase uncertainty about the rating.

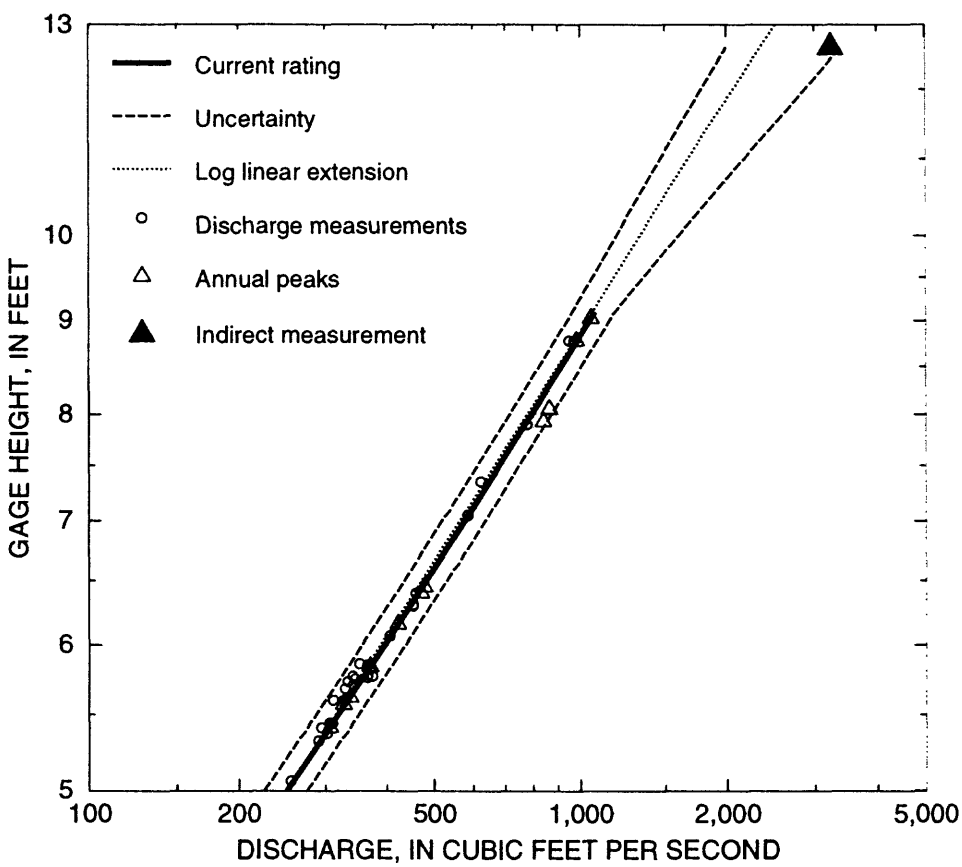

Figure 4. Examples of uncertainty bounds, rating curves, measurements, and peak discharges

All ratings reviewed as part of this study were "simple" stage-discharge relations and used discharge measurements as the primary data for analysis. To evaluate the rating for each gage, peak discharge, current-meter, and indirect measurements were plotted against stage. An example is shown in figure 4. Series of peaks that plot as a smooth curve represent the rating in use at the time of the peaks. The scatter of measurements and the number of rating curves are indicators of control stability. Measurement scatter may indicate a shifting control, or at a stable site, may indicate poor measuring conditions. Uncertainty estimates were sketched in for several ratings, measurements, and peaks at each site. The discharge uncertainty was based on review of measurement scatter about the ratings, the calculated uncertainty of available current-meter discharge measurements, and the estimated uncertainty of indirect measurements and measuring conditions. For those measurements plotting to either side of a rating, the uncertainty estimate was smoothed through the left- or right-most error limit of the measurements; see figure 5. In the United States, a statistical approach to rating analysis is not favored (Rantz and others, 1982); therefore, statistically based confidence limits were not computed.

At most sites the mid-range of the ratings was well defined. Upper ends of most ratings were not as well defined by measurements. As the number of measurements declines, the uncertainty about the rating curve increases. The high-flow terminus of a rating is often defined by a single indirect measurement. The uncertainty about the rating at that discharge is assumed to be the same as the uncertainty of the indirect measurement, and may be greater if the gage-height record is poor or missing.

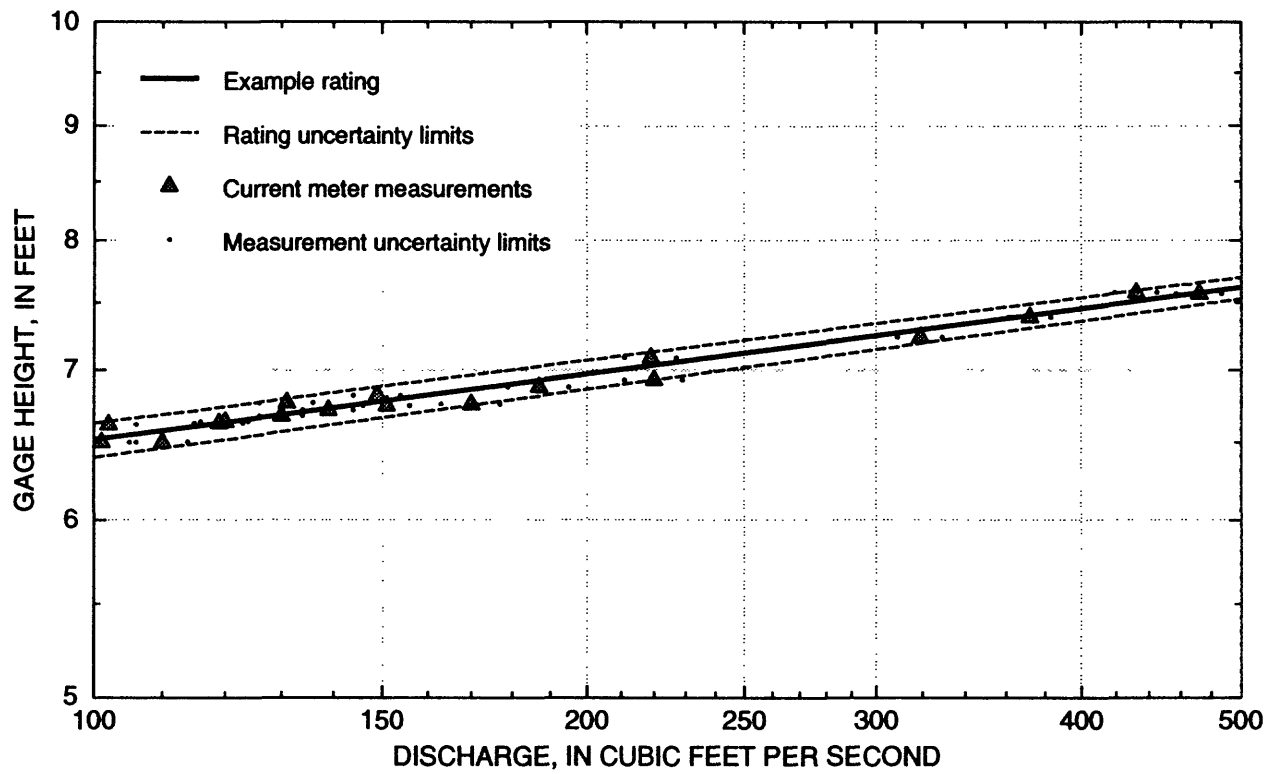

Figure 5. Example of stage-discharge relation with uncertainty bounds.

Selection of Peaks for Review

The initial determination of peaks to be reviewed was made graphically. A plot of the peaks of record for a region including the nine counties surrounding the study area is shown in figure 6. Peak discharge at selected gaging stations was compared with the computed 100-year flood for each site and the maximum flood experience (Q_{me}) in table 4. For comparative purposes, peaks of record at various sites in the northwestern Sierra Nevada are shown in table 5. Comparison of the peaks where data are concentrated in relation to the Q_{me} curve allows visual identification of peaks that require further investigation. Two peaks that appear as outliers to the Q_{me} curve were identified on the Rubicon River and Middle Fork of the American River. These two peaks occurred during a major storm in December 1964, when the Hell Hole Dam failed, causing a flood far greater than any natural peak in the historical record.

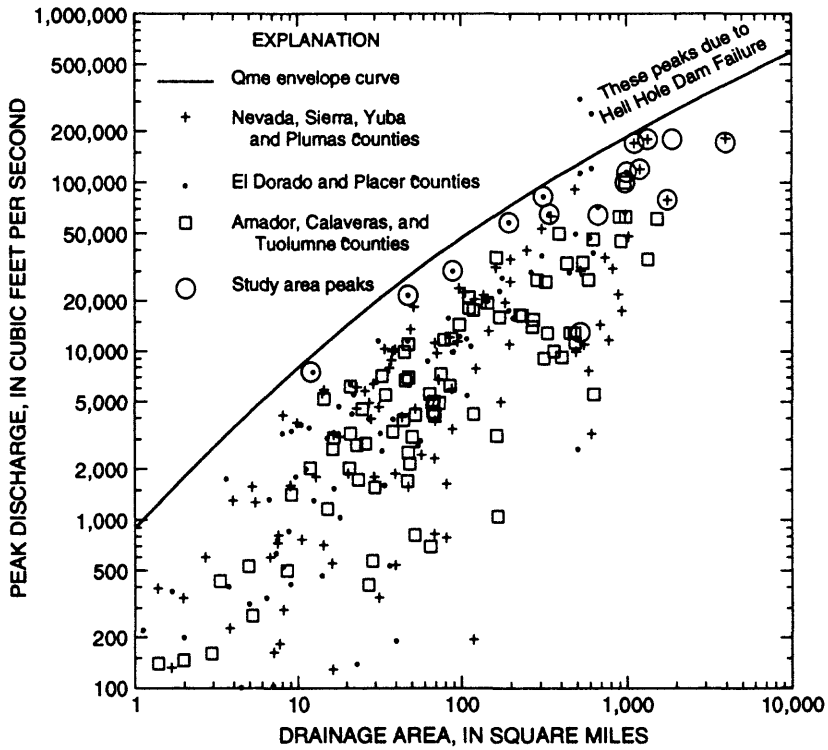

Figure 6. Maximum observed peak discharges in nine counties surrounding the American River Basin, California.

Table 4. Comparison of peak discharges, computed 100-year flood, and maximum observed flood, American River Basin, California

[mi^2, square mile; ft^3/s, cubic foot per second; $(ft^3/s)/mi^2$, cubic foot per second per square mile; Q_{me}, maximum experienced flood for a given drainage area (Meyer, 1993); water year, October through September]

Station number and name	Drainage area (mi^2)	Computed 100-year flood (ft^3/s)	100-year flood per mi^2 [$(ft^3/s)/mi^2$]	Q_{me} (ft^3/s)	Q_{me} per mi^2 [$(ft^3/s)/mi^2$]	Unregulated peak of record (ft^3/s)	Water year
11419000 Yuba River at Smartville	1,195	179,900	150	205,000	171	120,000	1928
11421000 Yuba River near Marysville	1,339	regulated		218,000	163	180,000	1965
11427000 North Fork American River at North Fork Dam	342	103,600	302	102,000	300	65,400	1965
11427500 Middle Fork American River at French Meadows	47.9	regulated		27,900	580	21,500	1963
11427700 Duncan Creek near French Meadows	9.94	6,700	674	7,980	802	3,650	1965
11429500 Gerle Creek below Loon Lake Dam	8.01	regulated		6,570	820	3,240	1963
11430000 South Fork Rubicon River below Gerle Creek	47.6	regulated		27,800	580	11,500	1963
11431000 Rubicon River near Georgetown	195	[1]88,900	455	72,100	369	58,000	1963
11431800 Pilot Creek above Stumpy Meadows	11.7	7,510	642	9,130	780	3,510	1986
11433200 Rubicon River near Foresthill	315	regulated		96,700	307	83,000	1963
11433260 North Fork of Middle Fork American River near Foresthill	88.9	40,100	451	43,200	485	30,100	1980
11433300 Middle Fork American River near Foresthill	524	regulated		130,000	248	113,000	1963
11433500 Middle Fork American River near Auburn	614	regulated		142,000	231	121,000	1963
11433800 North Fork American River below Auburn Damsite	973	regulated		183,000	188	66,700	1980
11434000 North Fork American River at Rattlesnake Bridge	999	[1]177,500	178	186,000	186	115,000	1950
11439500 South Fork American River near Kyburz	193	20,000	104	71,700	371	17,400	1965
11441500 South Fork Silver Creek near Ice House	27.5	[1]3,130	114	18,300	665	3,940	1956
11443500 South Fork American River near Camino	493	regulated		126,000	256	49,800	1956
11445500 South Fork American River near Lotus	673	regulated		150,000	223	71,800	1956
11446500 American River at Fair Oaks	1,888	regulated		260,000	137	180,000	1950

[1]Partial regulation.

Table 5. Selected floods of the northwestern Sierra Nevada, California

[mi^2, square mile; ft^3/s, cubic foot per second; water year, October through September. Accuracy: Good = ±10 percent; fair = ± 15 percent; poor = more than ± 25 percent]

Station number	Station name	Drainage area (mi^2)	Discharge (ft^3/s)	Cubic feet per second per square mile	Water year	Accuracy (percent)
11407000	Feather River at Oroville	3,624	230,000	63	1907	±25
11407700	Feather River at Yuba City	3,974	172,000	43	1965	±15
11446500	American River at Fair Oaks	1,888	180,000	95	1951	±15
11403200	North Fork Feather River below Rock Creek Diversion	1,773	79,400	45	1986	±15
11421000	Yuba River near Marysville	1,339	108,000	134	1965	±20
11419000	Yuba River at Smartville	1,200	120,000	100	1928	±25
11418000	Yuba River below Englebright Dam	1,108	171,000	154	1965	±10
11434000	North Fork American River at Rattlesnake Bridge	996	115,000	115	1951	±25
11300000	Stanislaus River at Knights Ferry	980	100,000	102	1862	±50
			64,500	66	1907	±50
11445500	South Fork American River near Lotus	673	64,500	96	1951	±15
11433500	Middle Fork American River near Foresthill	524	113,000	216	1963	±50
11427000	North Fork American River at North Fork Dam	342	65,400	191	1965	±10
11433200	Rubicon River near Foresthill	315	83,000	263	1963	±25
11431000	Rubicon River near Georgetown	195	58,000	297	1963	±35
11433260	North Fork of Middle Fork American River near Foresthill	88.9	30,100	339	1980	±50
11427500	Middle Fork American River at French Meadows	47.9	21,500	449	1963	+0 to -40
11431800	Pilot Creek above Stumpy Meadows	11.7	3,510	300	1986	±15
11427700	Duncan Creek near French Meadows	9.94	3,650	367	1965	±10
11429500	Gerle Creek below Loon Lake Dam	8.01	3,240	404	1963	+0 to-50

GAGE RECORDS

Twenty gage records were selected for review. Several gaging stations with less than 10 mi^2 of drainage area or with less than 10 years of record were not considered. The discussions of each of the 20 gage records that follow include a station description, location, information about peaks, remarks regarding regulation, and an assessment of percent uncertainty of peaks. Each gage record is followed by a plot of annual peak discharge by water year (a water year is the 12-month period from October 1 to September 30, designated by the calendar year in which it ends and which includes 9 of the 12 months) (figs. 7-26). The two Yuba River sites are at the end.

11427000 NORTH FORK AMERICAN RIVER AT NORTH FORK DAM

LOCATION.--Lat 38°56'10", long 121°01'22", in SW 1/4 NW 1/4 sec.31, T.13 N., R.9 E., Placer County, Hydrologic Unit 18020128, on left bank 50 ft upstream from crest of North Fork Dam, 2 mi upstream from Middle Fork, and 4 mi northeast of Auburn.

DRAINAGE AREA.--342 mi^2.

PERIOD OF RECORD.--October 1941 to current year (1995).

GAGE.--Water-stage recorder and concrete debris dam. Elevation of gage is 715.0 ft above sea level (levels by U.S. Army Corps of Engineers).

REMARKS.--Minor regulation by Lake Clementine, usable capacity, 12,800 acre-ft, formed by North Fork Dam. Storage in Big Reservoir and Lake Valley Reservoir (station 11426170), combined capacity, 10,300 acre-ft upstream from station. Combined storage and diversion have small effect on natural flow.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 65,400 ft^3/s, Dec. 23, 1964, gage height, 11.87 ft, from rating curve extended above 24,000 ft^3/s on basis of computed flow over crest of dam at gage height 10.22 ft.

ASSESSMENT.--The gage control is the crest of a debris dam about 50 ft downstream from the gage. The crest has four suppressed spillway sections at 715.00 ft and eight at 718 ft. All except the end sections are 46 ft wide. For flows over 10,000 ft^3/s the stage-discharge relation is based on five current- meter measurements and a flow-over-dam (FOD) computation.

Two of the high-flow measurements were rated poor; another was noted as having significant inflow between the cable section and the control. Two "good" measurements, made in different years by different hydrographers, define the rating-curve location at about 24,000 ft^3/s. The FOD computation fits a smooth, slightly sloping curve through the two "good" current-meter measurements. Current-meter measurements had an average uncertainty of 2.9 percent, ranging from ±2.4 to ±4.5 percent. The cableway was discontinued because of significant (and variable) tributary inflow.

The reliability of the computed discharge over a dam depends primarily on selection of the proper discharge coefficient. Because the rating developed theoretically for this site is verified by two good measurements, the peak of record is assumed to have an uncertainty no greater than 10 percent. Overall, based on measurements and the stability of the control and rating, the uncertainty about all peaks ranges from ±3 to ±10 percent.

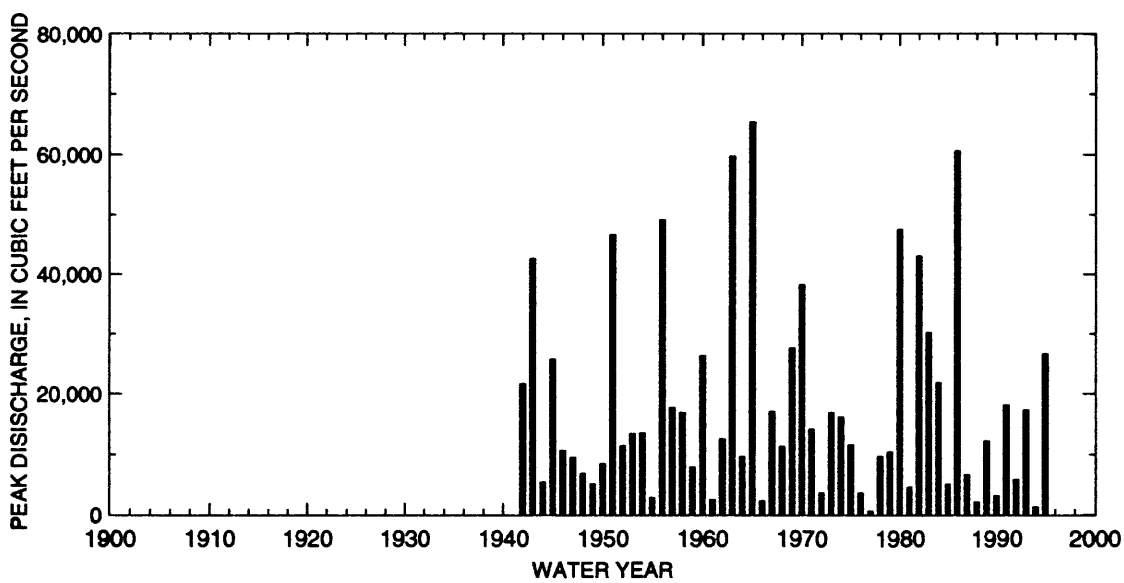

Figure 7. Annual peak discharge at North Fork American River near North Fork Dam.

11427500 MIDDLE FORK AMERICAN RIVER AT FRENCH MEADOWS

LOCATION.--Lat 39°06'35", long 120°28'49", in SW 1/4 NW 1/4 sec.36, T.15 N., R.13 E., Placer County, Hydrologic Unit 18020128, Tahoe National Forest, on left bank 0.6 mi downstream from French Meadows Dam, 4.1 mi upstream from Chipmunk Creek, and 14 mi south of Cisco.

DRAINAGE AREA.--47.9 mi^2.

PERIOD OF RECORD.--October 1951 to current year (1995).

GAGE.--Water-stage recorder. Elevation of gage is 4,920 ft above sea level, from topographic map. Prior to Oct. 1, 1962, at site 0.8 mi upstream at different datum.

REMARKS.--Considerable regulation by French Meadows Reservoir (station 11427400) 0.6 mi upstream beginning December 1964. Water diverted into basin from Duncan Creek to French Meadows Reservoir since December 1964. Water diverted out of basin from French Meadows Reservoir through French Meadows Powerplant (station 11427200) to Hell Hole Reservoir (station 11428700) since December 1965.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 21,500 ft^3/s, Jan. 31, 1963, gage height, 14.20 ft, from rating curve extended above 1,100 ft^3/s on basis of peak flow at former site. Maximum discharge since construction of French Meadows Dam in 1964, 2,870 ft^3/s, Mar. 8, 1986, gage height, 10.4 ft, from floodmarks, from flow over spillway of French Meadows Reservoir.

ASSESSMENT.--A total of 380 current-meter measurements have been made (including 86 at the upstream site). The average uncertainty was about 3.25 percent, ranging from ±2.4 to ±6 percent. At the former site, on Dec. 23, 1955, a three-cross-section slope-area computation was made; only two sections were used. The original evaluation said "Poor, use with caution." It was ten times the largest current-meter measurement. In addition, the gage height for the peak was questionable, the recorded gage height was 14.95 ft and the outside gage height was 17.2 ft, and the discharge computed was 16,500 ft^3/s. The station was moved 0.8 mi downstream in October 1962. A large peak occurred Jan. 31, 1963. The rating developed for the upstream site was extended to the January peak, and the discharge determined was transferred to the downstream site. The 1963 discharge of 21,500 ft^3/s should be considered a maximum likely discharge for the gage height recorded at the current site (14.20 ft). A log-linear extension to the gage height of 14.2 ft, using only measurements made at the current site, indicates a discharge of 15,000 ft^3/s, with a unit runoff of 300 $(ft^3/s)/mi^2$. The peak discharge based on the log-linear extension appears to be a reasonable estimate of peak discharge; the peak could have been lower. The 1955 peak has an uncertainty of +0 to -25, and the 1963 peak +0 to -40, based on rating shape and slope, and the quality of the indirect measurement. On the basis of photographs, there was no or little overbank flow area at the site that would result in a rightward bend in the stage-discharge relation. There is a significant decrease in annual peak magnitude due to French Meadows Reservoir operations.

Overall, on the basis of measurements, control stability, and rating shape and slope, the uncertainty about all peaks ranges from ±5 to ±25 percent, with the Jan. 31, 1963, peak an exception.

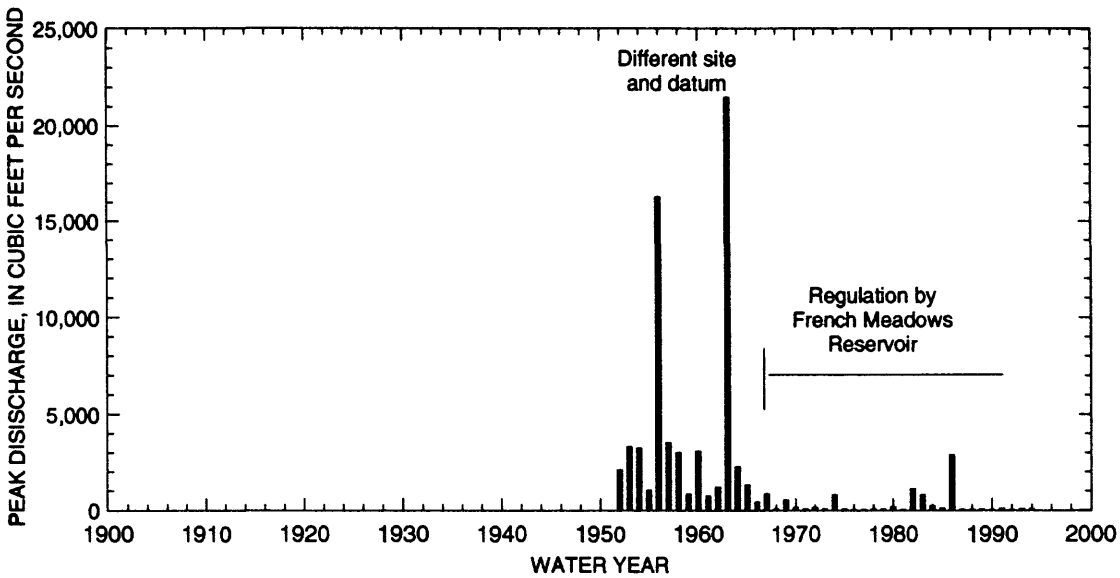

Figure 8. Annual peak discharge at Middle Fork American River at French Meadows, California.

11427700 DUNCAN CREEK NEAR FRENCH MEADOWS

LOCATION.--Lat 39°08'09", long 120°28'39", in NE 1/4 NW 1/4 sec.24, T.15 N., R.13 E., Placer County, Hydrologic Unit 18020128, Tahoe National Forest, on left bank 0.2 mi upstream from diversion dam, 0.5 mi downstream from Little Duncan Creek, 2 mi northwest of French Meadows, and 20 mi northeast of Foresthill.

DRAINAGE AREA.--9.94 mi^2.

PERIOD OF RECORD.--August 1960 to current year (1995).

GAGE.--Water-stage recorder. Elevation of gage is 5,270 ft above sea level, from topographic map. Prior to Sept. 3, 1965, at site 150 ft upstream at datum 9.56 ft higher.

REMARKS.--No regulation or diversion upstream from station.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 3,650 ft^3/s, Dec. 22, 1964, gage height, 10.6 ft, from floodmarks, from rating curve extended above 400 ft^3/s on basis of computation of flow over diversion dam.

ASSESSMENT.--Current-meter measurements at this site have an average uncertainty of 6 percent, ranging from ±3 to ±12 percent. Measuring conditions are fair to poor. For a peak on Feb. 1, 1963, a two-section slope-area computation was made about 2 mi downstream of the gage. The results of the slope-area computation (4,640 ft^3/s) were used to extend the rating to the Dec. 23, 1964, peak. Both results were revised (in 1965) on the basis of a flow-over-dam (FOD) computation that indicated the slope-area computation over-estimated the peak by 70 percent. The FOD results were good, which should give an uncertainty of 5 to 10 percent. The records for 1963-65 are somewhat confusing; the rating analysis, measurements, and peaks for those years are questionable. Overall, on the basis of current-meter measurements, control and rating stability, and FOD measurement, the uncertainty about all peaks at this site is about 10 percent.

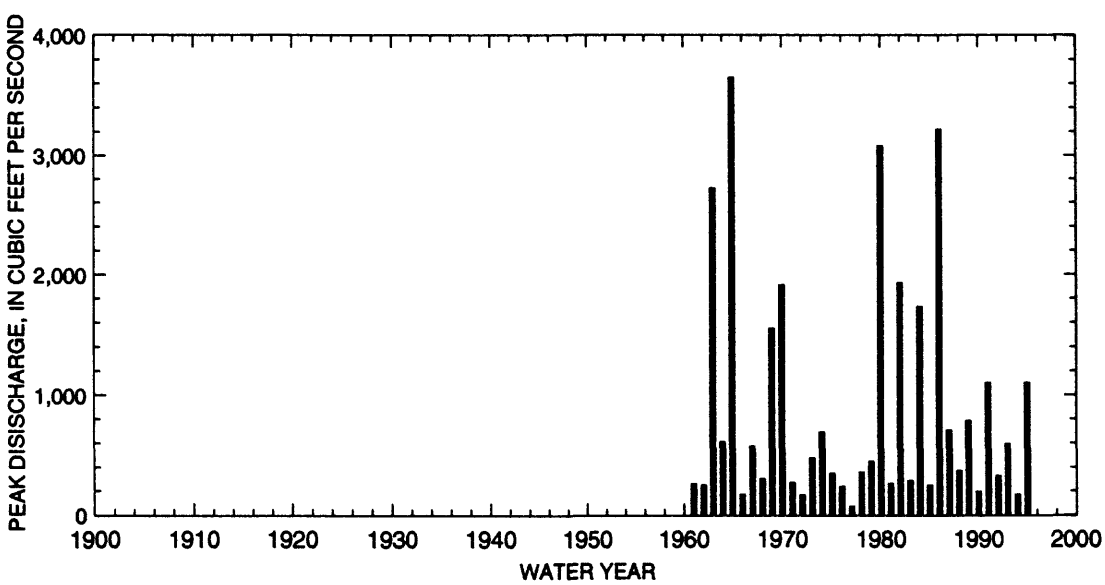

Figure 9. Annual peak discharge at Duncan Creek at French Meadows, California.

11429500 GERLE CREEK BELOW LOON LAKE DAM

LOCATION.--Lat 39°00'20", long 120°18'52", in NE 1/4 NE 1/4 sec.5, T.13 N., R.15 E., El Dorado County, Hydrologic Unit 18020128, Eldorado National Forest, on right bank 0.3 mi downstream from Loon Lake Dam, and 11 mi southwest of Meeks Bay.

DRAINAGE AREA.--8.01 mi^2.

PERIOD OF RECORD.--July 1910 to April 1914 (fragmentary), August 1962 to current year (1995). Prior to August 1962, published as "near Rubicon Springs."

GAGE.--Water-stage recorder and V-notch sharp-crested weir. Elevation of gage is 6,250 ft above sea level, from topographic map. Prior to August 1962, nonrecording gage at site 1,400 ft upstream at different datum.

REMARKS.--Record good including estimated daily discharges. Beginning in 1884, flow regulated by Loon Lake (station 11429350). Original dam was dismantled during September and October 1962 to permit construction of a new earthfill dam, which was completed Dec. 27, 1963.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 3,240 ft^3/s, unregulated, Feb. 1, 1963, gage height, 12.65 ft, from rating curve extended above 970 ft^3/s on basis of slope-area measurement of peak flow; no flow Oct. 15, 1913. Maximum discharge since construction of Loon Lake Dam in 1963, 1,050 ft^3/s, June 5, 1969, gage height, 9.03 ft.

ASSESSMENT--This gage is in a steep, narrow channel with little likelihood of overbank flow. The average discharge measurement uncertainty was about 3 percent, ranging from ±2.3 to ±5 percent. Measurements define the stage-discharge relation very well from 100 ft^3/s to 1,500 ft^3/s. The peak discharge of Feb. 1, 1963, was determined by a slope-area measurement. The slope-area computation of 3,240 ft^3/s was rated fair and had two cross sections, questionable gage height, and at least a 15-percent difference between the field-selected roughness coefficient and the coefficient selected during this review. The measurement does not plot well on a log-linear stage-discharge relation. The log-linear extension to the 1963 peak gage height of 12.65 ft indicates 2,200 ft^3/s compared to the computed discharge of 3,240 ft^3/s. Another rating extension taking into account channel roughness and contraction indicates a peak discharge of 2,000 ft^3/s was possible. The peak of record has an uncertainty ranging from -50 to +5 percent. All peaks, except for the peak of record, have an uncertainty of less than 10 percent. Powerplant diversion began in 1972. Diversions have significantly affected annual peak discharges at this site.

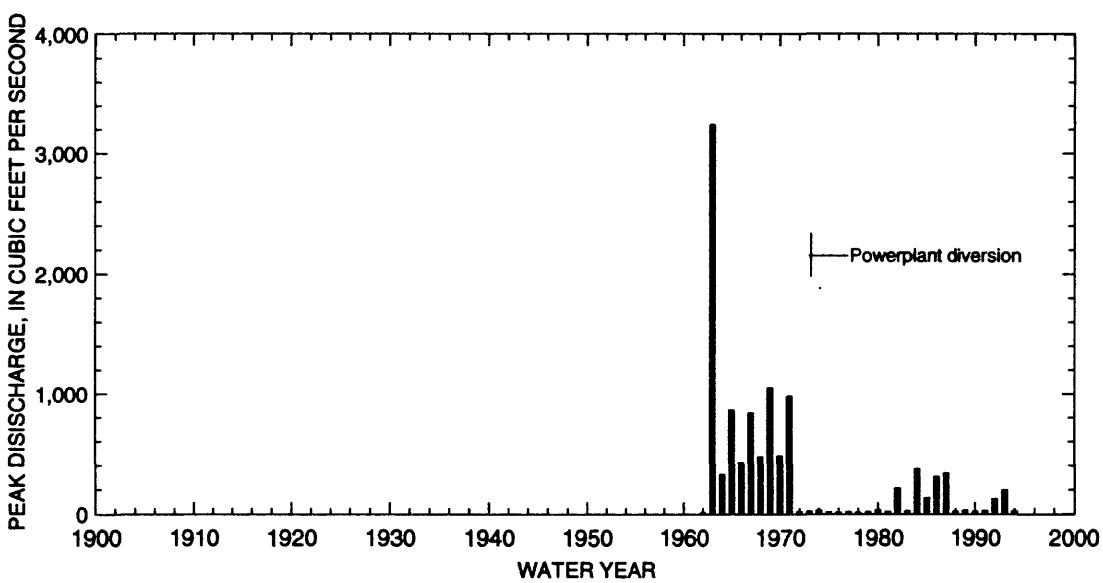

Figure 10. Annual peak discharge at Gerle Creek below Loon Lake Dam, California.

11430000 SOUTH FORK RUBICON RIVER BELOW GERLE CREEK

LOCATION.--Lat 38°57'17", long 120°24'02", in SW 1/4 SW 1/4 sec.22, T.13 N., R.14 E., El Dorado County, Hydrologic Unit 18020128, Eldorado National Forest, on left bank 600 ft downstream from Gerle Creek, 1.2 mi downstream from South Fork Rubicon River Diversion Dam, and 18 mi east of Georgetown.

DRAINAGE AREA.--47.6 mi^2.

PERIOD OF RECORD.--February 1910 to June 1914 (published as Little South Fork Rubicon River below Gerle Creek near Quintette), August 1961 to current year (1995).

REVISED RECORDS.--USGS Water-Supply Paper 1931: Drainage area.

GAGE.--Water-stage recorder. Elevation of gage is 4,970 ft above sea level, from topographic map. Feb. 1, 1910, to June 21, 1914, nonrecording gage at site about 700 ft downstream at different datum.

REMARKS.--Beginning in 1884, flow regulated by Loon Lake (station 11429350). Original dam was dismantled during September and October 1962 to permit construction of a new earthfill dam completed Dec. 27, 1963. Water is diverted 1.2 mi upstream at South Fork Rubicon River Diversion Dam to Robbs Peak Powerplant (station 11429300). Diversion of up to 1,440 ft^3/s to Silver Creek basin began in October 1962.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 11,500 ft^3/s, Jan. 31, 1963, gage height, 12.32 ft, from rating curve extended above 2,500 ft^3/s on basis of slope-area measurement of peak flow.

ASSESSMENT.--The stage-discharge relation at this gage is very stable. The well-defined rating, with a log-linear extension, aligns well with the single slope-area measurement. The maximum discharge of 11,500 ft^3/s on Jan. 31, 1963, was based on the slope-area measurement. The measurement had two cross sections and was rated poor. Because the rating based on current-meter measurements is well defined and aligns well with the slope area, most peaks may be assumed to have an uncertainty of ±15 percent. The slope-area-based peak has an uncertainty of ±25 percent.

All current-meter measurements with more than 500 ft^3/s were evaluated. The average uncertainty was 2.9 percent, and ranged from ±2.6 to ±4.2 percent. No measurements greater than 500 ft^3/s have been made since 1967; the site is now regulated by Loon Lake.

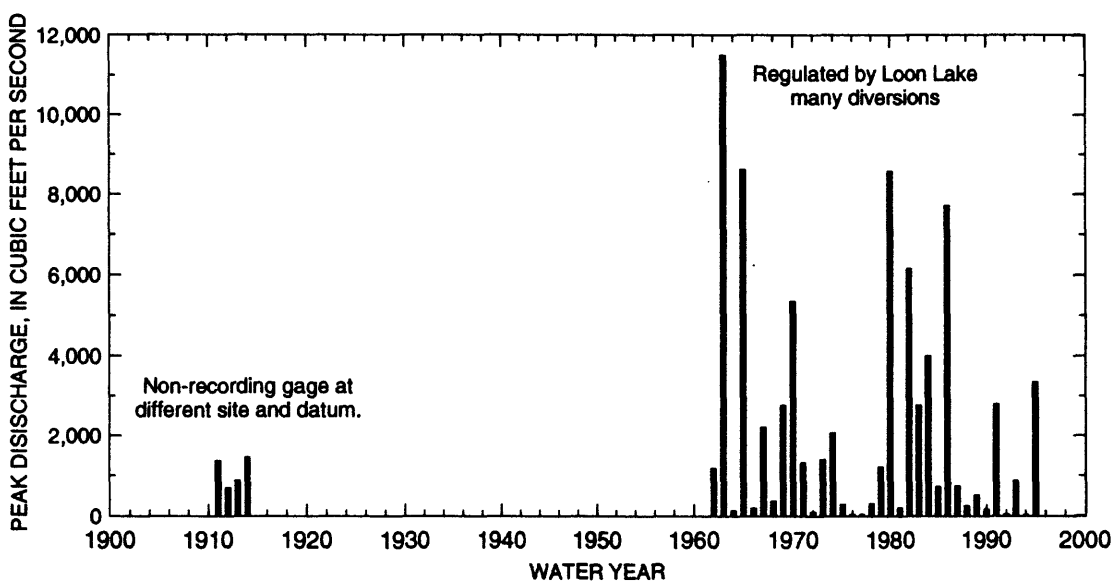

Figure 11. Annual peak discharge at South Fork Rubicon River below Gerle Creek, California.

11431000 RUBICON RIVER NEAR GEORGETOWN

LOCATION.--Lat 38°57'30", long 120°29'05", in SE 1/4, sec. 23, T.13 N., R.13 E., on right bank 1.3 mi downstream from South Fork and 20 miles east of Georgetown.

DRAINAGE AREA.--195 mi^2.

PERIOD OF RECORD.--November 1909 to June 1914, May 1943 to December 1964.

GAGE.--Water stage recorder. Elevation of gage 3,350 ft above sea level. From 1909 to 1914 at site 0.4 mi upstream at different datum. Prior to Mar. 11, 1963, at site across stream at same datum.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, unknown, Dec. 23, 1964, gage height, 71 ft from floodmarks, caused by overtopping of the partly constructed Hell Hole Dam; next highest peak discharge, Feb. 1, 1963, 58,000 ft^3/s, gage height 25.8 ft, rating extended above 11,000 ft^3/s on basis of slope-area measurements at 44,600 and 58,000 ft^3/s.

ASSESSMENT.--Peak discharges from 500 to 5,000 ft^3/s were based on a well-defined rating, with an uncertainty in the range of ±4 to ±7 percent. The peaks between 5,000 and 58,000 ft^3/s were based on a poorly defined rating. One current-meter measurement at 11,500 ft^3/s defines the rating from about 5,000 to 13,000 ft^3/s. That measurement had questionable depth and cross sectional area. The velocity was determined by a 0.2-ft depth observation. The uncertainty of that measurement is ±15 percent. The peaks in the range 5,000 to 13,000 ft^3/s have an uncertainty of +10 to -25 percent.

Two indirect measurements defined the highest peaks, one in 1951, the other in 1963. Both were poor, with large uncertainty in the assigned roughness coefficients, water-surface profiles, and cross sectional area. On the basis of various possible interpretations of the data, the uncertainty for peaks in the range 13,000 to 58,000 ft^3/s is from ±15 to ±40 percent. The 1950 peak had a large difference (4.5 ft) between the recorded and floodmark-based stage. The 1943 and 1945 peak discharges were revised based on the 1951 slope-area measurement.

A slope-conveyance computation was attempted to determine the peak flow due to the Hell Hole Dam failure. All original notes, drawings, and computations are missing; written statements indicate the measurement was invalid.

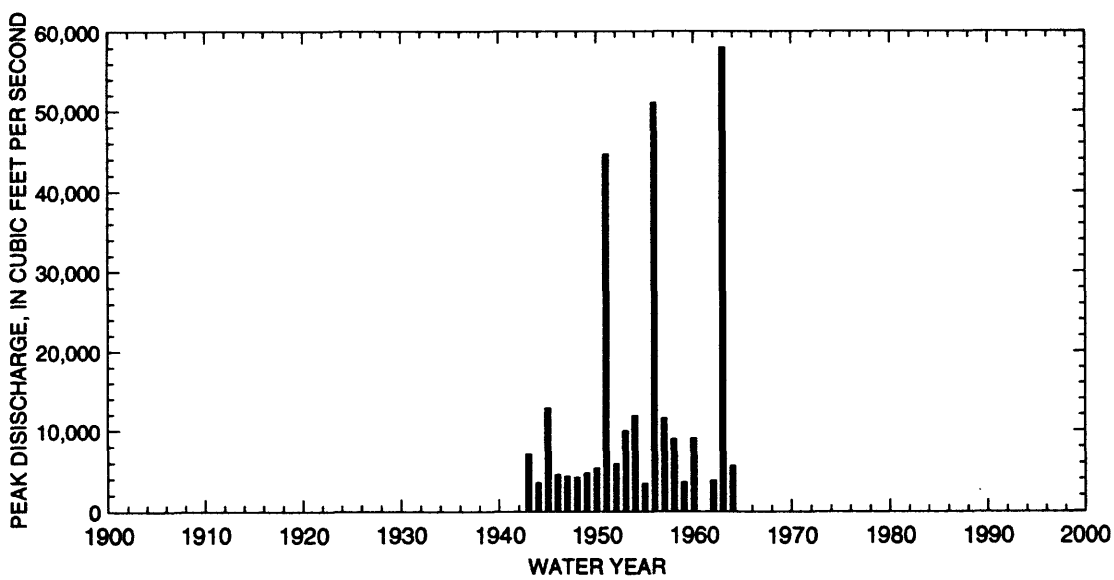

Figure 12. Annual peak discharge at Rubicon River near Georgetown, California.

11431800 PILOT CREEK ABOVE STUMPY MEADOWS

LOCATION.--Lat 38°53'41", long 120°34'02", in NE 1/4 NW 1/4 sec.18, T.12 N., R.13 E., El Dorado County, Hydrologic Unit 18020128, on right bank 2.1 mi upstream from Stumpy Meadows Dam and 12.5 mi east of Georgetown.

DRAINAGE AREA.--11.7 mi^2.

PERIOD OF RECORD.--October 1960 to current year (1995). Prior to October 1971, published as "above Stumpy Meadows Reservoir."

GAGE.--Water-stage recorder. Elevation of gage is 4,280 ft above sea level, from topographic map.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 3,510 ft^3/s, Feb. 17, 1986, gage height, 7.15 ft, from rating curve extended above 540 ft^3/s on basis of slope-area measurement at gage height 6.31 ft; maximum gage height, 8.05 ft, Jan. 31, 1963.

ASSESSMENT.--Three indirect measurements were made for this gage. The first (1963) was considered an estimate and quite poor (uncertainty estimated ±40 percent). The others (1964 and 1980) were rated "fair." Both have an uncertainty of ±20 percent. All other peaks between 500 and 1,500 ft^3/s are considered to have an uncertainty of less than ±15 percent.

The current-meter measurements for this gage had an average uncertainty of 3.4 percent, ranging from ±2.4 to ±5 percent.

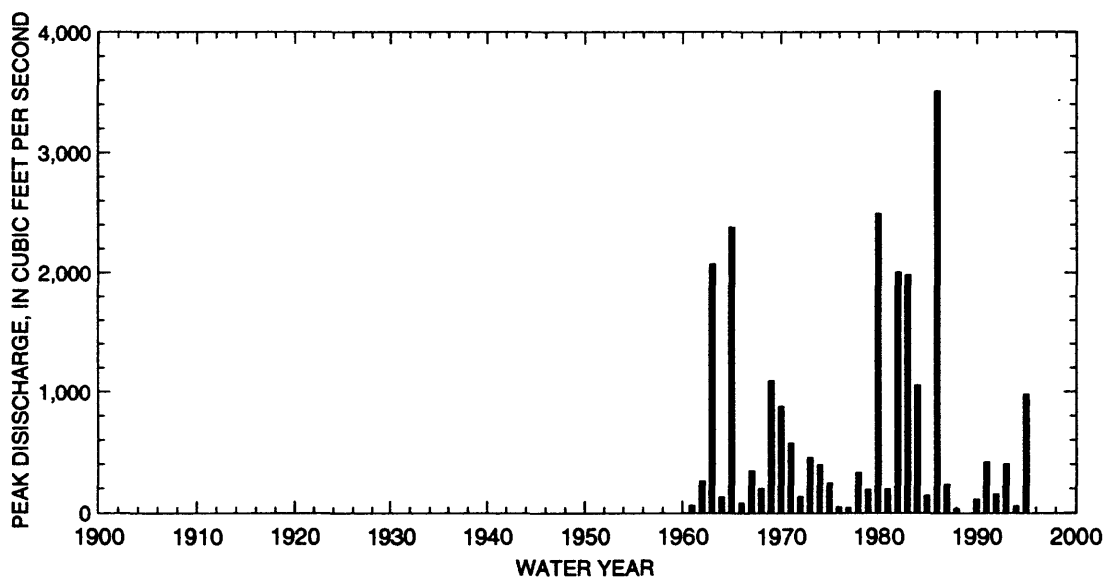

Figure 13. Annual peak discharge at Pilot Creek above Stumpy Meadows, California.

11433200 RUBICON RIVER NEAR FORESTHILL

LOCATION.--Lat 38°59'33", long 120°43'14", in SE 1/4 NW 1/4, T.13 N., R.11 E., Placer County, Eldorado National Forest, on right bank 0.6 mi upstream from Ralston powerhouse, 1.2 mi upstream from confluence of Rubicon River and Middle Fork American River, and 5.6 mi southeast of Foresthill.

DRAINAGE AREA.--315 mi^2.

PERIOD OF RECORD.--October 1958 to September 1984.

GAGE.--Elevation of gage is 1,200 ft above sea level, from topographic map. October 1958 to May 17, 1963, at site 2.0 mi upstream, 150 ft downstream from Ralston Bridge, and May 17, 1963, to Mar. 30, 1965, at site 2.1 mi upstream, 100 ft upstream from Ralston Bridge at datum 1,362.2 ft above sea level.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, unknown, Dec. 23, 1964, gage height, 55.4 ft from high-water marks, caused by overtopping of the partly constructed Hell Hole Dam; next highest peak discharge, 83,000 ft^3/s, Feb. 1, 1963, gage height, 35.0 ft, former site and datum.

EXTREMES OUTSIDE PERIOD OF RECORD.--Floods of December 1937, November 1950, and December 1955 had approximate discharges of 44,000 ft^3/s, 56,000 ft^3/s, and 76,000 ft^3/s, respectively, based on 1958-64 stage-discharge relation(s) and U.S. Forest Service high-water marks.

ASSESSMENT.--The 1937, 1950, and 1955 peak discharges are considered estimates, with unknown uncertainty. The high-water marks were from painted marks on the Ralston Bridge. Those marks were allegedly marked by U.S. Forest Service personnel, then the peaks estimated from the USGS-developed stage-discharge relation at a site upstream of the bridge. The uncertainty about those peaks is no less than 25 percent.

The annual peak of 1960, 16,500 ft^3/s at gage height 15.55 ft, was based on a slope-area computation. The computation plots far to the right on rating curve(s) 3 and 4. Based on this plot, an uncertainty of +0 percent to -35 percent was assigned.

The 1963 peak (peak of record--not including Hell Hole Dam failure) of 83,000 ft^3/s was estimated on the basis of unit discharge at gages upstream and downstream from this gage. The uncertainty for this peak is ±40 percent. The peak determination at the upstream and downstream sites was poor.

Peaks in the period 1966-83 appear to be based on a single, log-linear rating curve, with little scatter. Uncertainty for the peaks in this period is ±10 percent.

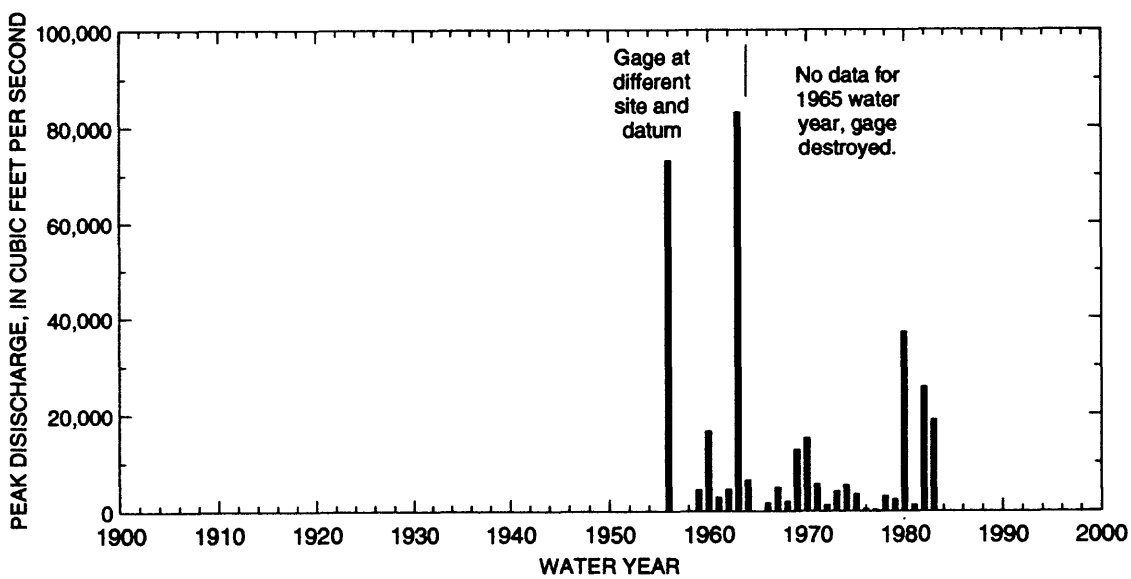

Figure 14. Annual peak discharge at Rubicon River near Foresthill, California.

11433260 NORTH FORK OF MIDDLE FORK AMERICAN RIVER NEAR FORESTHILL

LOCATION.--Lat 39°01'27", long 120°43'03", in NE 1/4 NW 1/4, sec. 35, T.14 N., R.11 E., Placer County, Tahoe National Forest, on right bank 1.0 mi downstream from El Dorado Canyon and 4.8 mi east of Foresthill.

DRAINAGE AREA.--88.9 mi^2.

PERIOD OF RECORD.--July 1965 to September 1985.

GAGE.--Water-stage recorder. Elevation of gage is 1,300 ft above sea level.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 30,100 ft^3/s, Jan. 13, 1980, gage height, 17.00 ft from high-water marks from rating curve extended above 5,500 ft^3/s on basis of slope-area measurement of peak flow.

ASSESSMENT.--The river channel at this gage is very rough and steep, averaging about 2.5 percent slope. In 1980 a slope-area measurement was made that resulted in 30,100 ft^3/s. According to the chief of party (CP), a good site could not be found; conditions in several reaches investigated were poor. There is no possibility of overbank flow here. The water-surface profiles indicate 0 to 5 ft of super-elevation in parts of the reach. The CP selected the site, ran the survey, selected the roughness coefficients, did the computations, and reviewed the measurement. This is not normal procedure. Comparison to runoff at nearby sites indicates that about 18,000 ft^3/s would be a reasonable estimate. The gage height used for the measurement was based on a poor profile in the gage reach; the recorder was out of operation. In spite of the above, the measurement result (using an outside gage height) plots on a log-linear extension of the rating. The original evaluation of the measurement called it "fair" or from ±15 to ±25 percent uncertainty. For this evaluation, the measurement is considered poor, with an uncertainty of +0 to -70 percent. An unusual flood peak *may* have occurred at this site.

A stage-discharge relation was reconstructed using data from the peak file. A (near) log-linear plot resulted, with all peaks deviating ±10 percent or less from the fitted curve. The uncertainty for all peaks except the peak of record is approximately ±15 percent.

Current-meter measurement data were unavailable for analysis.

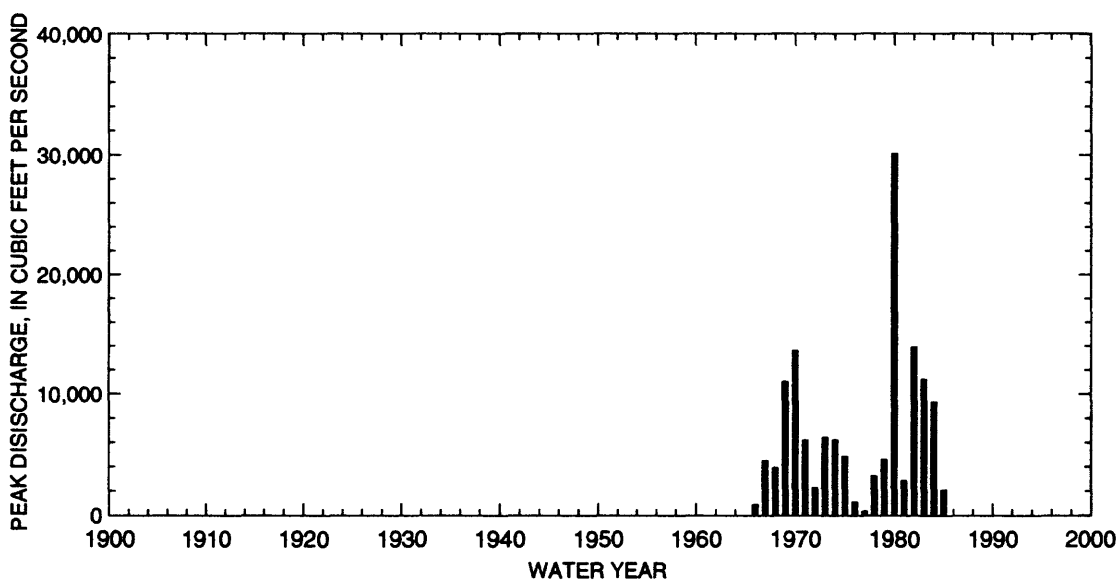

Figure 15. Annual peak discharge at North Fork of Middle Fork American River near Foresthill, California.

11433300 MIDDLE FORK AMERICAN RIVER NEAR FORESTHILL

LOCATION.--Lat 39°00'22", long 120°45'35", in NW 1/4 NW 1/4 sec.4, T.13 N., R.11 E., Placer County, Hydrologic Unit 18020128, Tahoe National Forest, on right bank 1.6 mi downstream from Oxbow Powerplant and 3.3 mi east of Foresthill.

DRAINAGE AREA.--524 mi^2.

PERIOD OF RECORD.--October 1958 to current year (1995).

GAGE.--Water-stage recorder. Elevation of gage is 1,070 ft above sea level, from topographic map. Prior to Oct. 22, 1965, at site 3.2 mi downstream at different datum. Oct. 22, 1965, to Aug. 28, 1985, at site 400 ft downstream at different datum.

REMARKS.--Flow regulated by French Meadows Reservoir, Hell Hole Reservoir, Loon Lake (stations 11427400, 11428700, and 11429350, respectively), Stumpy Meadows Lake, usable capacity, 17,500 acre-ft, and several smaller reservoirs.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 310,000 ft^3/s, Dec. 23, 1964, gage height, 69.0 ft from high-water marks, site and datum then in use, caused by overtopping of the partly constructed Hell Hole Dam on the Rubicon River, from rating curve extended above 28,000 ft^3/s on basis of slope-area measurement at gage height 38.0 ft and slope-conveyance study at gage height 69.0 ft, at site and datum then in use; next highest peak, 113,000 ft^3/s, Feb. 1, 1963, gage height, 38.0 ft, site and datum then in use.

ASSESSMENT.--The slope-area computation for Feb. 8, 1960, indicated that the peak discharge was 39,000 ft^3/s, gage height 20.12 ft, with a unit runoff of 72.4 $(ft^3/s)/mi^2$. The unit runoff does not compare well with results from other gage sites in the basin. All comparisons indicate the 39,000 ft^3/s peak is too high. (E.J. Jones, USGS, written commun., 1960). The peak plots *far right*, especially when compared to the 1963 slope-area results. The measurement had four cross sections, with three used. High-water marks were fair, with a large degree of scatter. Water-surface profile definition was poor. A small tributary is drawn on the plane view; no evaluation of its impact is provided. There is a possibility of unevaluated eddy losses due to curvature upstream of the reach. A sketch of the left bank indicates it is much rougher than the right bank, which would explain the poor water-surface profile there. The cross sections were located about 110 ft apart; the sections were about 240 ft wide. A plot of available measurements made in the period 1960-64, and the 1963 slope area seem to indicate that something has seriously compromised the accuracy of the 1960 peak determination.

The slope-area computation for Feb. 1, 1963, was 113,000 ft^3/s, gage height 39.0 ft, with a unit runoff of 211 $(ft^3/s)/mi^2$. "The unit runoff for the 1960 peak is high compared to other stations. A rating drawn through the 1960 measurement would bend considerably to the right and this doesn't seem logical. I would give the 1963 measurement a little better rating overall" (Loren E. Young, USGS, written commun., 1963).

The water-surface profile for the 1963 measurement was fair to poor. It is superior to that of the 1960 measurement. This was a three-cross-section measurement, but because of large expansion losses, only two were used. A reviewer changed the field-selected roughness coefficient from 0.045 to 0.040. After review of the stereo photographs, the 0.040 was reasonable. There is at least a ±15 percent uncertainty due solely to the Manning's n value. Based on the photos, the 0.040 is probably a minimum value.

Both peaks were fairly large. Given the probable stream power, the gravel, cobble, and small boulder bed material was likely in motion. This *might* cause some uncertainty in cross sectional area at the time of the peak. Both indirect measurements are considered poor.

The attempt to measure peak discharge for the Hell Hole Dam failure was based on a slope-conveyance computation, the weakest of indirect measurements. The original survey notes, drawings, and computations have been missing since 1968. A reconstruction of the measurement, based on a single drawing of the measurement cross section, exists. The original Manning's n values, channel conditions, and water-surface slope were assumed, based on the 1963 slope-area computation. The assumptions are weak. The uncertainty about the 310,000 ft^3/s is large, and may be as much as 50 percent. There is no way to assess those limits.

If one assumes the 1963 indirect measurement is correct, and applies a scale offset to all peaks and measurements, a linear curve from 10,000 ft^3/s to 310,000 ft^3/s is obtained. If the same type of curve is fitted to the 1960 peak, the extension to the dam failure stage of 69 ft results in unbelievable discharges well in excess of 600,000 ft^3/s. This implies that something is wrong with the peak discharge or gage height determined for the 1960 peak. The 1960 peak may have been as low as 28,000 ft^3/s and has an uncertainty of +0 to -40 percent. The 1963 peak of 113,000 ft^3/s has an uncertainty of +10 to -50 percent.

More than 360 current-meter measurements were made for this gage. At both sites, the moderate to high flow measurements selected for evaluation had an average of 2.6 percent error, ranging from ±2 to ±4.3 percent.

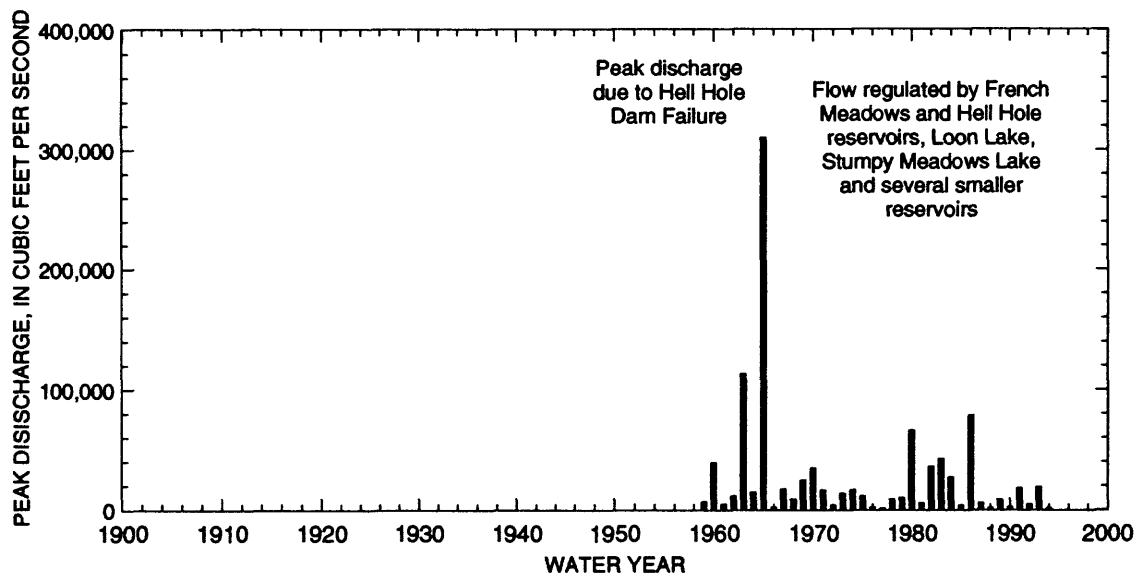

Figure 16. Annual peak discharge at Middle Fork American River near Foresthill, California.

11433500 MIDDLE FORK AMERICAN RIVER NEAR AUBURN

LOCATION.--Lat 38°55'05", long 121°00'51", in NE 1/4 SW 1/4 sec.6, T.12 N., R.9 E., Placer County, on right bank at quarry, 1.4 mi upstream from mouth and 3.3 mi northeast of Auburn.

DRAINAGE AREA.--614 mi^2.

PERIOD OF RECORD.--October 1911 to September 1986.

GAGE.--Water-stage recorder and crest-stage gage. Elevation of gage is 552.35 ft above sea level. Prior to December 1930, nonrecording gage near present site at different datum. December 1930 to Mar. 1, 1963, water-stage recorder at site 0.4 mi upstream at different datum.

REMARKS.--Natural flow of stream affected by many reservoirs and diversions.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge 253,000 ft^3/s, Dec. 23, 1964, gage height, 60.4 ft, from high-water marks, from rating extended above 69,000 ft^3/s on the basis of slope-area measurement of peak flow (caused by overtopping of the partly constructed Hell Hole Dam); next highest peak 121,000 ft^3/s, Feb. 1, 1963, gage height, 43.1 ft, from high-water marks, site and datum then in use.

ASSESSMENT.--The peak of record discharge (Hell Hole Dam failure) was based on a poor slope-area measurement. Several hydrologists involved in reviewing the measurement had serious reservations about using the computed results. Because the flow subsequent to the peak was too high, the survey of cross sections was postponed for 8 months. Significant amounts of aggradation or degradation could have occurred in that time; the uncertainty regarding cross-sectional area may be high, but undetermined. In addition, there was a problem with the water-surface profiles. "I distrust reaches with long negative hydraulic gradients where the upstream end of the reach is well below the elevation of much of the downstream reach" (S.E. Rantz, USGS, written commun., 1966). The original reviewer(s) recommended additional surveying, relocation of a cross section, and recomputing the measurement--that was not done. The measurement plots "off" to the right of a log-linear extension of the rating curve. Peak discharge based on a linear extension would be about 180,000 ft^3/s. The uncertainty for this peak discharge is +0 to -40 percent.

The second largest discharge, 121,000 ft^3/s, on Feb. 1, 1963, gage height 43.1 ft, from high-water marks, was determined from a rating linearly extended from 69,000 ft^3/s (which was directly measured the same day). The uncertainty is approximately ±15 percent.

A peak on Nov. 20, 1950, was based on a poor slope-area computation. There was no gage-height record, and the gage recorder was out of service until August 1951. The uncertainty is approximately ±25 percent.

The peak of Mar. 25, 1928, 62,000 ft^3/s, at a gage height of 35.6 ft (site and datum then in use), is a revised value, based on the 1950 compilation study (USGS Water-Supply Paper 1315-A). It was the largest peak in the period 1911-50. Discharge estimates for this peak range from 62,000 ft^3/s to 100,000 ft^3/s. Gage height was questionable. Various methods of estimation were used. Rating analysis and careful review of prior work resulted in the current value. The uncertainty is estimated as no better than 40 percent.

Peaks from 1912-27 were based on maximum observed gage heights. These peaks may not represent the actual peak of the year. The great majority were based on the gage-height readings and taken directly from the established rating curve(s). Uncertainty for these early peaks is unknown, but probably ranges from ±10 to ±30 percent.

The mid to upper portion of the stage-discharge relation is defined by about 25 current-meter measurements, with 5 measurements greater than 20,000 ft^3/s. Peaks between 5,000 to 35,000 ft^3/s had an uncertainty of ±10 to ±15 percent; between 35,000 to 70,000 ft^3/s, ±15 to ±25 percent; and larger than 70,000 ft^3/s, greater than ±25 percent.

All current-meter measurements evaluated were cable measurements. All but two were rated as good measurements using the traditional evaluation. The two largest measurements, numbers 392 and 423, were made with a 0.2 observation depth only (rated fair). A coefficient of 0.95 was applied to measurement number 423; it is unknown if the same coefficient was applied to measurement number 392. The 0.95 coefficient appears high. It is unknown whether a comparison study of lower measurements to determine the correct coefficient was made. A normal value for a natural river section is about 0.85. There is an uncertainty of at least ±10 percent for these two measurements.

The current-meter measuring conditions were good. The average number of vertical sections was about 25, with 2 observations per vertical the norm. The measurements selected for evaluation covered 1911-83. With the exception of measurements 392 and 423, the average uncertainty was about ±3 percent, ranging from ±2.3 to ±6.8 percent.

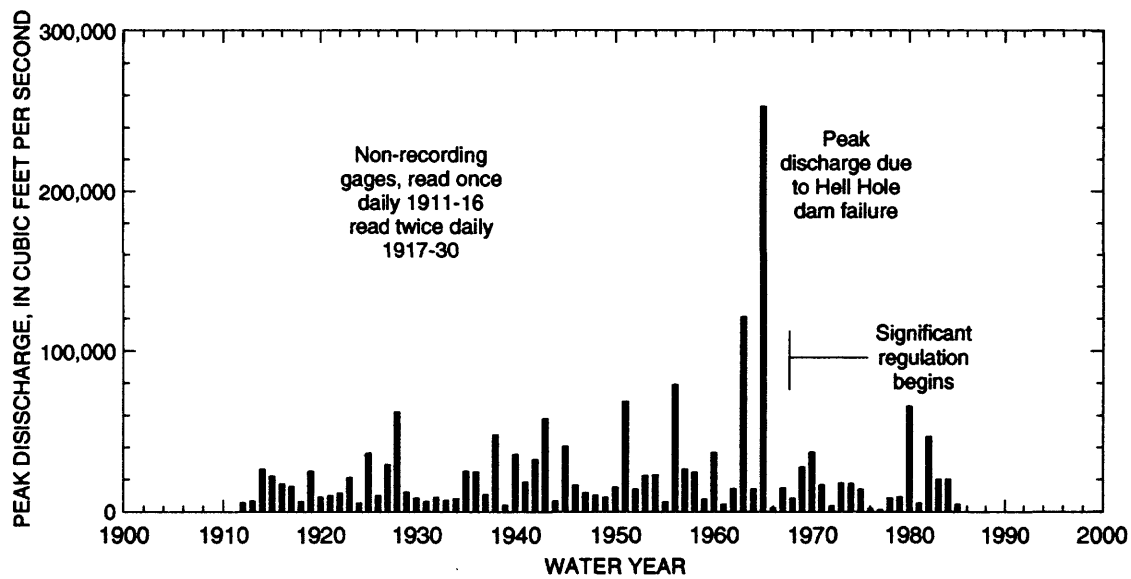

Figure 17. Annual peak discharge at Middle Fork American River near Auburn, California.

11433800 NORTH FORK AMERICAN RIVER BELOW AUBURN DAMSITE

LOCATION.--Lat 38°52'24", long 121°03'13", in SE 1/4 SW 1/4 sec.23, T.12 N., R.8 E., El Dorado County, on left bank 1,300 ft upstream from Knickerbocker Creek, 4,000 ft downstream from Auburn damsite and 2.0 mi southeast of Auburn.

DRAINAGE AREA.--973 mi^2.

PERIOD OF RECORD.--May 1972 to September 1986.

GAGE.--Water-stage recorder. Elevation of gage is 400.00 ft above sea level.

REMARKS.--Natural flow of stream affected by many reservoirs and diversions.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge 66,700 ft^3/s, Jan. 14, 1980, gage height, 87.5 ft from high-water marks, affected by temporary storage at Auburn damsite.

ASSESSMENT.--The peak of record at this site was based on a "fair" slope-area computation. The computation was based on four cross sections, good fall (4.6 ft), and a lengthy reach (1,090 ft) with good high-water marks. The computed discharge and recorded gage height "fit" the stage-discharge relation quite well.

There were 146 current-meter measurements and several ratings available for review. The measurement uncertainty averaged 3 percent and ranged from ±2.4 to ±4 percent. The channel was stable. Current-meter measurements defined the rating(s) from low flow to 20,000 ft^3/s.

Peaks in the range 1,000 to 20,000 ft^3/s have an uncertainty of ±10 percent. For peaks greater than 20,000 ft^3/s, the uncertainty is about ±15 percent.

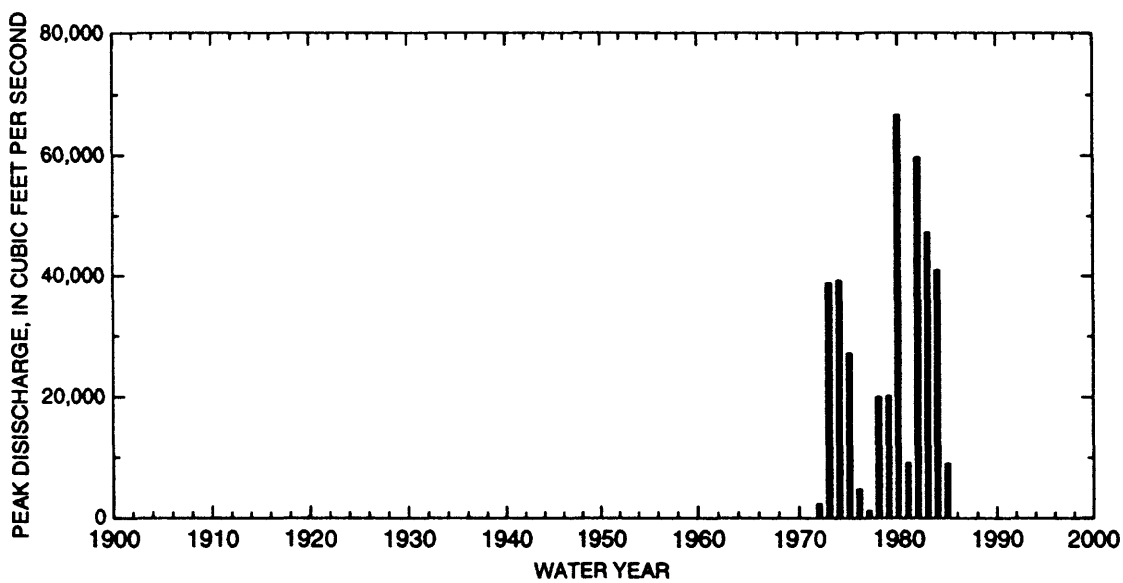

Figure 18. Annual peak discharge at North Fork American River below Auburn Damsite, California.

11434000 NORTH FORK AMERICAN RIVER AT RATTLESNAKE BRIDGE

LOCATION.--Lat 38°48'50", long 121°05'35", in SW 1/4 sec.9, T.11 N., R.8 E., 800 ft downstream from Rattlesnake Bridge, 3.6 mi downstream from Pilot Creek, and 6 mi south of Auburn.

DRAINAGE AREA.--999 mi^2.

PERIOD OF RECORD.--1931-37, 1939-55.

GAGE.--Elevation of gage is 343.65 ft above sea level, river profile survey.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 115,000 ft^3/s, Nov. 21, 1950.

ASSESSMENT.--The peak of record, 115,000 ft^3/s, was estimated on the basis of prior ratings that were defined to 70,000 ft^3/s by current-meter measurements and summation of North Fork and Middle Fork American River discharges. The peak plots as a point on a log-linear extension of a prior rating. Result is considered a good estimate, with an uncertainty of ±25 percent or less. Rating definition was good. Peaks in the range 10,000 ft^3/s to 70,000 ft^3/s have an uncertainty of ±5 to ±10 percent. Larger peaks, up to about 95,000 ft^3/s, should have an uncertainty of about ±15 percent.

About 200 current-meter measurements were evaluated for uncertainty, with the average error about 3 percent, ranging from ±2.3 to ±4.1 percent.

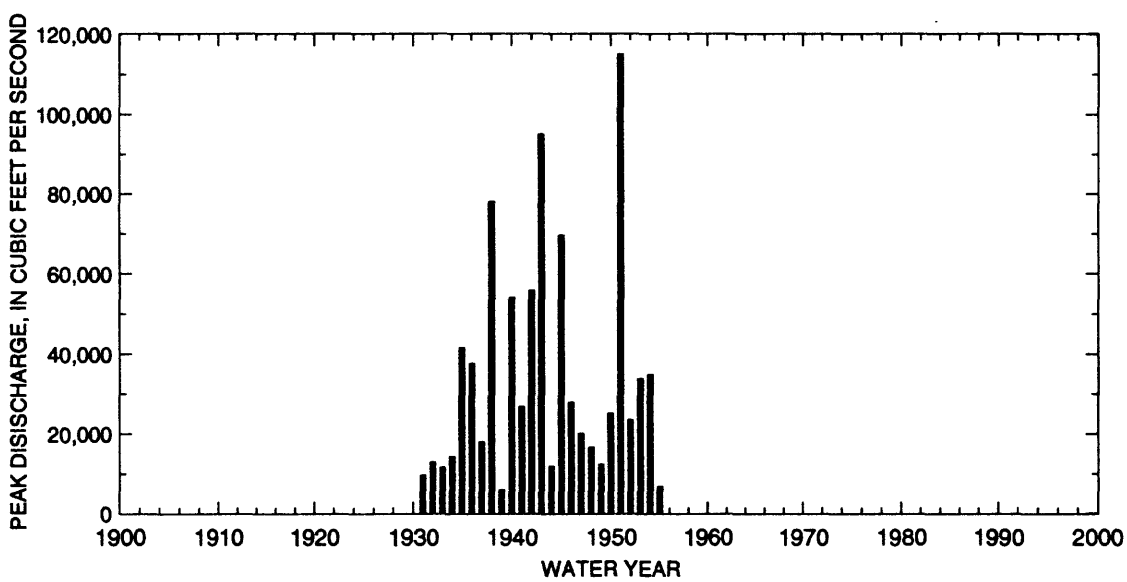

Figure 19. Annual peak discharge at North Fork American River at Rattlesnake Bridge, California.

11439500 SOUTH FORK AMERICAN RIVER NEAR KYBURZ

LOCATION.--Lat 38°45'49", long 120°19'39", in SW 1/4 SW 1/4 sec.29, T.11 N., R.15 E., El Dorado County, Hydrologic Unit 18020129, Eldorado National Forest, on right bank 0.8 mi downstream from Silver Fork American River, and 1.9 mi southwest of Kyburz.

DRAINAGE AREA.--193 mi^2.

PERIOD OF RECORD.--August to December 1907, October 1922 to current year (1995). Prior to October 1956, records for river and El Dorado Canal published separately; combined flow only, October 1956 to September 1960.

REVISED RECORDS.--USGS Water-Supply Paper 1445: 1923(M --instantaneous maximum discharge only), 1925(M), 1927(M), 1928 (river only), 1935-37(M). Water-Supply Paper 1515: 1928.

GAGE.--Water-stage recorder. Elevation of gage is 3,840 ft above sea level, from topographic map. Prior to Oct. 1, 1962, at datum 1.00 ft higher.

REMARKS.-- Low and medium flows regulated by Echo Lake, Silver Lake, Caples Lake (stations 10336608, 11435900, and 11436950, respectively), and Lake Aloha, total capacity, 37,100 acre-ft.

EXTREMES FOR PERIOD OF RECORD.--River only: Maximum discharge, 17,400 ft^3/s, Dec. 23, 1964, gage height, 10.92 ft, from rating curve extended above 6,300 ft^3/s on basis of contracted-opening measurement at gage height 10.40 ft.

ASSESSMENT.--Current-meter measurement average uncertainty was ±3.5 percent, ranging from ±2.5 to ±5 percent. Stage-discharge relations are well defined through the range 100 to 6,000 ft^3/s by current-meter measurements. On the basis of rating and control stability, and many good measurements, all peaks between 500 and 6,000 ft^3/s are assumed to have an uncertainty of about ±10 percent or less, and between 6,000 to 8,000 ft^3/s to have an uncertainty of ±15 percent or less.

All peaks greater than 8,000 ft^3/s are based on a 1950 contracted-opening measurement. The contracted-opening measurement was carefully reviewed. The contracted section may be treated as a critical depth section, which allows the computation of water-surface elevation in the approach section. Several interpretations are possible regarding the correct length of reach and roughness coefficient.

Several computations with various assumptions were made, resulting in a wide range of discharge: 10,800 to 17,500 ft^3/s at a gage height of 10.4 ft. The original 1950 computation resulted in a discharge of 14,500 ft^3/s. In 1965, a peak gage height of 10.92 ft was recorded and the rating extended to that gage height, resulting in a discharge of 17,500 ft^3/s.

A current-meter measurement, number 628, on Feb. 18, 1986, and a few lesser measurements made subsequently, indicate that the rating, as based on the contracted-opening measurement, may be in error by +15 to +20 percent. Measurement number 628 was rated "fair" and has a computed uncertainty of ±2.5 percent. Peaks greater than 8,000 ft^3/s have an uncertainty of ±15 percent or more, and the peak of record has an uncertainty of -25 to +12 percent.

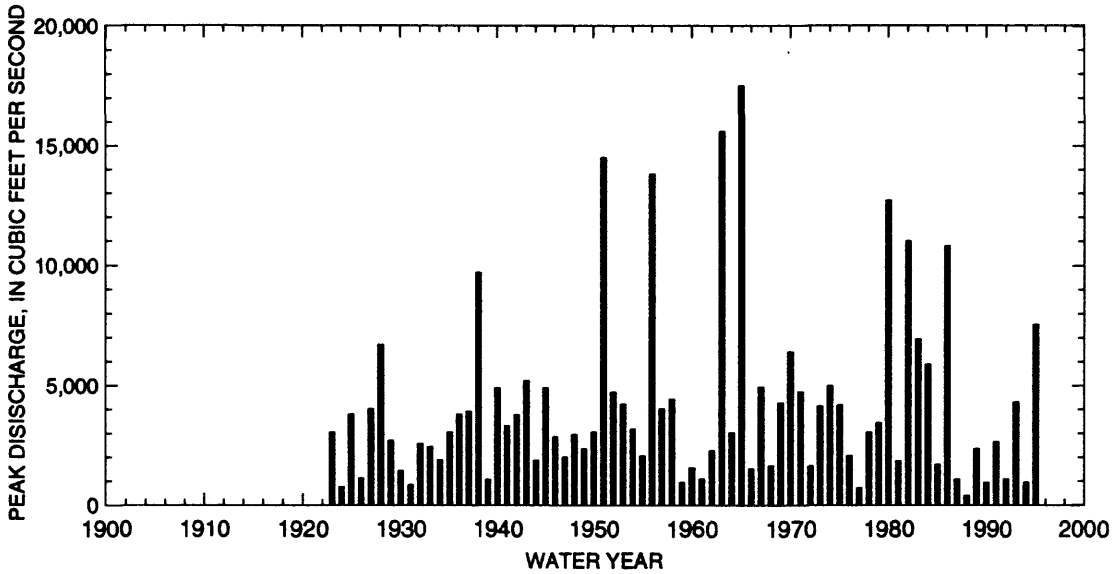

Figure 20. Annual peak discharge at South Fork American River near Kyburz, California.

11441500 SOUTH FORK SILVER CREEK NEAR ICE HOUSE

LOCATION.--Lat 38°49'08", long 120°21'51", in NW 1/4 NW 1/4 sec.12, T.11 N., R.14 E., El Dorado County, Eldorado National Forest, on right bank 300 ft upstream from Peavine Creek, 0.4 mi downstream from Ice House Dam, and 4.8 mi northwest of Kyburz.

DRAINAGE AREA.--27.5 mi^2.
PERIOD OF RECORD.--October 1924 to current year (1995).
REVISED RECORDS.--USGS Water-Supply Paper 1395: 1928, 1938. Water-Supply Paper 1635: Drainage area at former site.

GAGE.--Water-stage recorder and concrete control. Elevation of gage is 5,290 ft above sea level, from topographic map. Prior to Oct. 1, 1959, at site 0.3 mi upstream at different datum.

REMARKS.--Flow regulated by Ice House Reservoir beginning in December 1959.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 3,940 ft^3/s, Dec. 23, 1955, gage height, 6.71 ft, site and datum then in use, from rating curve extended above 540 ft^3/s on basis of slope-area measurement at gage height 6.69 ft. Maximum discharge since construction of Ice House Dam in 1959, 1,930 ft^3/s, May 26, 1982, gage height, 5.74 ft, from rating curve extended above 730 ft^3/s on basis of computation of flow over dam at gage height 5.66 ft.

ASSESSMENT.--The peak of record and one on Nov. 18, 1950, were based on a single slope-area computation. The computation plots on a log-linear rating extension and may be considered fairly accurate (15 percent). All lower peaks prior to 1959 may be considered to have an uncertainty of 10 percent or less. During the regulated period (1959-96), the rating(s) are well defined by current-meter measurements and a good flow-over-dam computation. All peaks in the period may be considered to have an uncertainty of ±10 percent or less.

All current-meter measurements with a discharge greater than 100 ft^3/s averaged 3.5 percent uncertainty, ranging from ±2.5 to ±4.2 percent. About 570 measurements were available; a representative sample with discharge greater than 100 ft^3/s was evaluated.

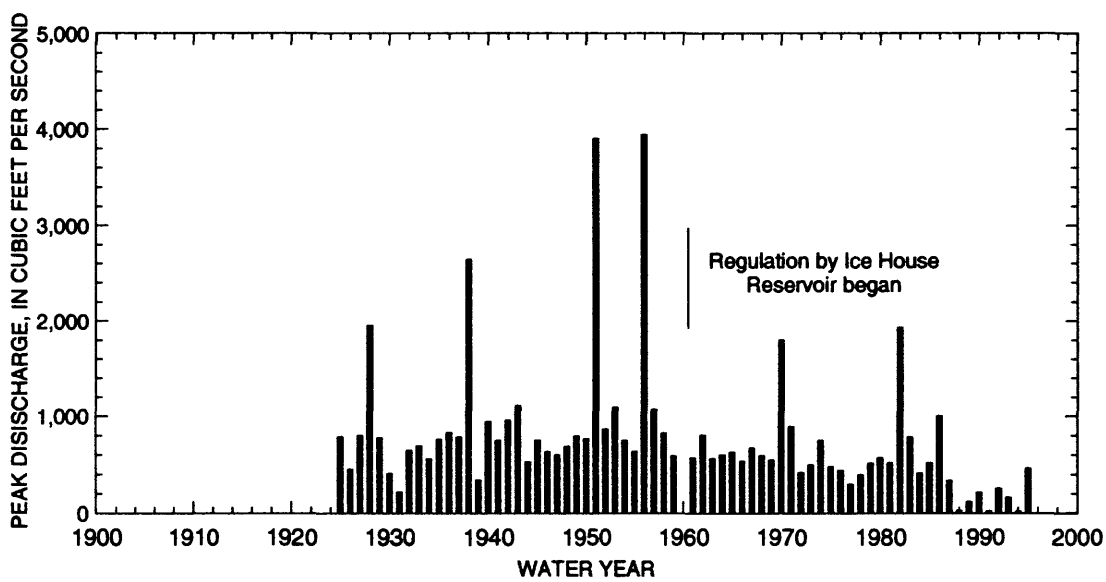

Figure 21. Annual peak discharge at South Fork Silver Creek near Ice House, California.

11443500 SOUTH FORK AMERICAN RIVER NEAR CAMINO

LOCATION.--Lat 38°46'23", long 120°42'02", in SW 1/4 NE 1/4 sec.25, T.11 N., R.11 E., El Dorado County, on right bank 500 ft upstream from Iowa Canyon Creek, and 2.8 mi northwest of Camino.

DRAINAGE AREA.--493 mi^2.

PERIOD OF RECORD.--October 1922 to current year. Monthly discharge only for October 1922, USGS Water-Supply Paper 1315-A. Records for river and American River Flume, published separately October 1922 to September 1956, October 1962 to December 1964 when flume was destroyed. Records of river and flume combined, October 1956 to September 1962.

REVISED RECORDS.--USGS Water-Supply Paper 931: 1928, 1938, 1940 (instantaneous maximum discharge only). Water-Supply Paper 1931: Drainage area at former site.

GAGE.--Elevation of gage is 1,625 ft above sea level, from topographic map. Prior to May 26, 1987, water-stage recorder at different datum at site 1,000 ft downstream. Auxiliary water-stage recorder on Slab Creek Dam records spill discharges, which are combined with release discharges. Between 1951 and 1964, at site 100 ft downstream at different datum. From May 1964 to October 1966, at site 1,000 ft downstream at datum 11.37 ft lower.

REMARKS.--Flow regulated by several reservoirs.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 49,800 ft^3/s, Dec. 23, 1955, gage height, 32.6 ft, from high-water marks, site and datum then in use, from rating curve extended above 24,000 ft^3/s on basis of computation of peak flow over dam.

ASSESSMENT.--Measurements for this site are in the files of the Sacramento Municipal Utility District. Because the measurements were not readily available, a graph of peak gage height and discharge was prepared using peak data available from the USGS peak data base. This type graph is a good surrogate for the rating(s) in use when peak data were determined. There was little variation in the relation, which indicates that the stage-discharge relation was stable. Records for this gaging station are regularly reviewed by USGS personnel. Current-meter measurements are made to USGS standards. Past reviews have indicated that the stage-discharge relations were well defined by current-meter and flow-over-dam measurements. Several peaks were noted as deviating from their expected plotting positions; these peaks would have little impact on flood frequency and magnitude computations. Overall, the peaks have an uncertainty of ±15 or less.

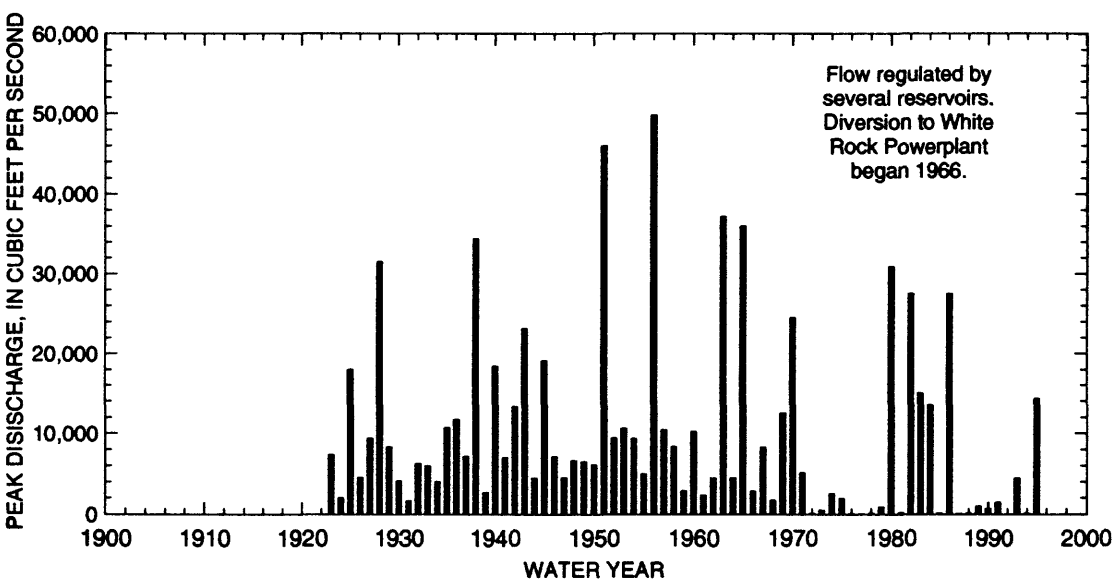

Figure 22. Annual peak discharge at South Fork American River near Camino, California.

11445500 SOUTH FORK AMERICAN RIVER NEAR LOTUS

LOCATION.--Lat 38°49'07", long 120°56'45", in NW 1/4 SW 1/4 sec.11, T.11 N., R.9 E., El Dorado County, Hydrologic Unit 18020129, on left bank 0.4 mi downstream from Greenwood Creek, 2.4 mi northwest of Lotus, and 3.3 mi northwest of Coloma.

DRAINAGE AREA.--673 mi^2.

PERIOD OF RECORD.--May 1951 to September 1995.

REVISED RECORDS.--USGS Water-Supply Paper 1931: Drainage area. USGS Water Data Report CA-75-4: 1964, 1966, 1970.

GAGE.--Water-stage recorder. Elevation of gage is 635 ft above sea level, from topographic map.

REMARKS.--Flow regulated by storage, diversions, and powerplants.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 71,800 ft^3/s, Dec. 23, 1955, gage height, 21.37 ft.

EXTREMES OUTSIDE PERIOD OF RECORD.--Maximum stage known since 1862 and prior to beginning of record, 20.4 ft from high-water marks, Nov. 21, 1950, discharge, 64,500 ft^3/s.

ASSESSMENT.--A total of 377 current-meter measurements were made; the average uncertainty was ±3 percent, ranging from ±2.6 to ±8 percent. The stage-discharge relation(s) were very stable and well defined below 20,000 ft^3/s. Peaks less than 20,000 ft^3/s had an uncertainty of ± 5 percent or less. In the range from 20,000 to 70,000 ft^3/s, the stage-discharge relation was defined by a single current-meter measurement. Given the site stability, but only one measurement, the uncertainty in the range can be assumed to be ±10 percent.

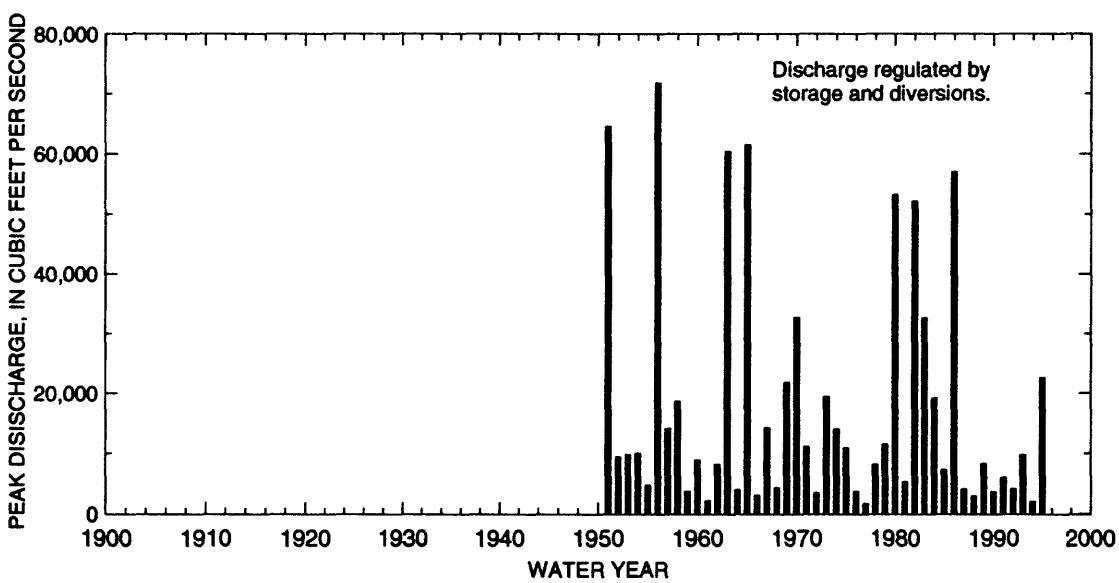

Figure 23. Annual peak discharge at South Fork American River near Lotus, California.

11446500 AMERICAN RIVER AT FAIR OAKS

LOCATION.--Lat 38°38'08", long 121°13'36", in SE 1/4 NE 1/4 sec.17, T.9 N., R.7 E., Sacramento County, Hydrologic Unit 18020111, on right bank 2,100 ft downstream from Nimbus Dam, 2.4 mi east of Fair Oaks, 8.1 mi downstream from South Fork, and at mile 22.2.

DRAINAGE AREA.--1,888 mi^2.

PERIOD OF RECORD.--November 1904 to current year (1995). Monthly discharge only for some periods, published in USGS Water-Supply Paper 1315-A.

REVISED RECORDS.--USGS Water-Supply Paper 1181: 1928(M --instantaneous maximum discharge only). Water-Supply Paper 1515: 1907(M), 1910, 1931(M), 1943(M). Water-Supply Paper 1931: Drainage area.

GAGE.--Water-stage recorder. Elevation of gage is 71.53 ft above sea level. See Water-Supply Paper 2131 for history of changes prior to July 15, 1970.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 180,000 ft^3/s, Nov. 21, 1950, gage height, 31.85 ft, site and datum then in use. Maximum discharge since regulation by Folsom Lake in 1955, 134,000 ft^3/s, Feb. 19, 1986, gage height, 27.96 ft.

ASSESSMENT.--Records from the early years (1904-50) indicate poor to fair channel stability in any one year, but with a trend of degradation over many years. Hydraulic mining prior to 1900, gravel mining operations, and changes in control conditions that occurred naturally resulted in a shifting control condition in most years.

Daily discharges prior to 1930 were based on twice-a-day gage-height readings or Gurly recorders. The gage-height readings could have resulted in large errors in daily discharge during rapidly changing flows. Instantaneous maximum peak discharges were not obtained. The maximum observed daily discharges in the data base likely underestimate the true peak discharge by an unknown amount. Many rating and peak-discharge problems were resolved during the 1950 compilation study (U.S. Geological Survey, 1959). The number of measurements available from 1904-50, including many high (51,000 to 143,000 ft^3/s) discharge measurements, resulted in good stage-discharge definition. Peaks prior to 1930 are assumed to have a ±15 to ±20 percent uncertainty. Peaks subsequent to 1930 may be considered to have an uncertainty of ±10 percent. Peaks for 1907, 1931, and 1943 were revised. The revisions were based on many measurements and well-developed rating curves. Records subsequent to 1950 may be considered to have uncertainties of ±10 percent or less.

About 1,600 current-meter measurements were available for evaluation. Only those that were used in the definition of the mid to high stage-discharge relations were reviewed. Current-meter measurement average uncertainty was 2.7 percent, ranging from ±1.9 to ±4.5 percent.

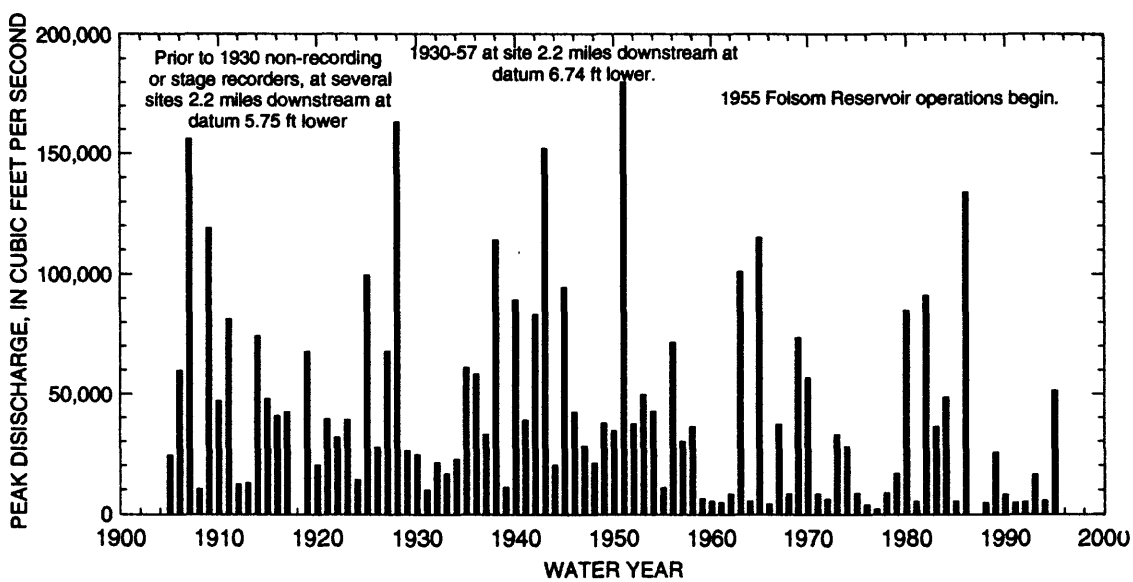

Figure 24. Annual peak discharge at American River at Fair Oaks, California.

11419000 YUBA RIVER AT SMARTVILLE

LOCATION.--Lat 39°13'25", long 121°17'33", in SW 1/4 sec. 22, T. 16N., R. 6 E., at Narrows, 1 mi downstream from Deer Creek and 1 mi north of Smartville.

DRAINAGE AREA.--1,195 mi^2 at site used in 1900; 1,204 mi^2 at final site.

PERIOD OF RECORD.-- June 28, 1900, to March 1941.

GAGE.--Water-stage recorder. Elevation of gage 264.17 ft above sea level (1912). June to October 1900, staff gage at site 4 mi downstream at different datum. June 1903 to July 1906, staff gage at described site, at datum 15.2 ft higher. August 1906 to October 1928, staff gage, and October 1928 to 1930, water-stage recorder at described site at datum 5.2 ft higher than described datum.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, about 120,000 ft^3/s, Mar. 26, 1928, gage height 31.2 ft, described datum, from high-water marks, from rating curve extended above 6,500 ft^3/s on basis of slope-conveyance determination of peak flow.

REMARKS.--Flow regulated by Lake Spaulding beginning in 1912, Bowman Lake and Fordyce Lake beginning in 1926, and many smaller reservoirs. Equivalent records can be obtained for this station since 1941 by adding those for Yuba River at Englebright Dam to those for Deer Creek near Smartville.

ASSESSMENT.--Between 1903-28, once-daily staff readings were made. Discharge measurements in water years 1903-10 averaged 24 and ranged from 15-30 measurements per year; in 1911-27, averaged 7 and ranged from 4 to 10 measurements per year; and in 1928-41, averaged 15 and ranged from 9 to 24 measurements per year. About 540 measurements were made during the operational life of the gage. Measurements prior to 1925 had an estimated uncertainty of about ±5 percent, with a range from ±3 to ±7 percent, and from 1926-41, the average uncertainty was about ±3 percent, with a range from ±2.6 to ±4.7 percent.

In the years prior to 1930, most, if not all, direct high-water measurements were float measurements. Float measurements of discharge that are carefully made under favorable conditions may be accurate to within ±10 percent. If a nonuniform reach is selected and few floats are used in the cross section, measurement results may be in error by as much as ±25 percent (Rantz and others, 1982).

At the measurement site the channel was straight for several hundred feet, and was constrained by steep, rocky banks that were not subject to overflow. The channel was filled to a great depth with gravel and sand tailings from hydraulic mining (1849-80) (Clapp and Martin, 1910). Because of the tailings, the streambed was constantly shifting and degrading. Between 1903 and 1907 the gage datum had to be lowered 10 ft, and another 5 ft in 1930.

Conditions for obtaining accurate discharge data were poor; measurements made with floats in those conditions are assumed to have an uncertainty of about ±20 percent.

Peaks greater than 30,000 ft^3/s, prior to water year 1928, were defined by an area/velocity study. In a channel with rapid degradation, an area/velocity relation would be poor. A measurement for the 1928 peak, indicated "about" 120,000 ft^3/s on Mar. 26, 1928, at a gage height of 31.2 ft (the measurement was not made to current standards). The data collected for the measurement was inadequate and resulted in a very poor estimate. On the basis of all available data, the peak could have been as small as 95,000 ft^3/s or as large as 120,000 ft^3/s, uncertainty of +0 to -25 percent (U.S. Geological Survey, 1959).

The site had a shifting control, large datum changes, fair to poor rating definition, and poor indirect measurements - this leads to the conclusion that the peaks greater than 30,000 ft^3/s are no better than ±20 percent and could be considerably worse. Data are insufficient to assign a specific uncertainty for the largest peaks. For peaks ranging from 10,000 to 30,000 ft^3/s, the uncertainty ranges from ±15 to ±20 percent. For peaks less than 10,000 ft^3/s, the uncertainty is less than 10 percent.

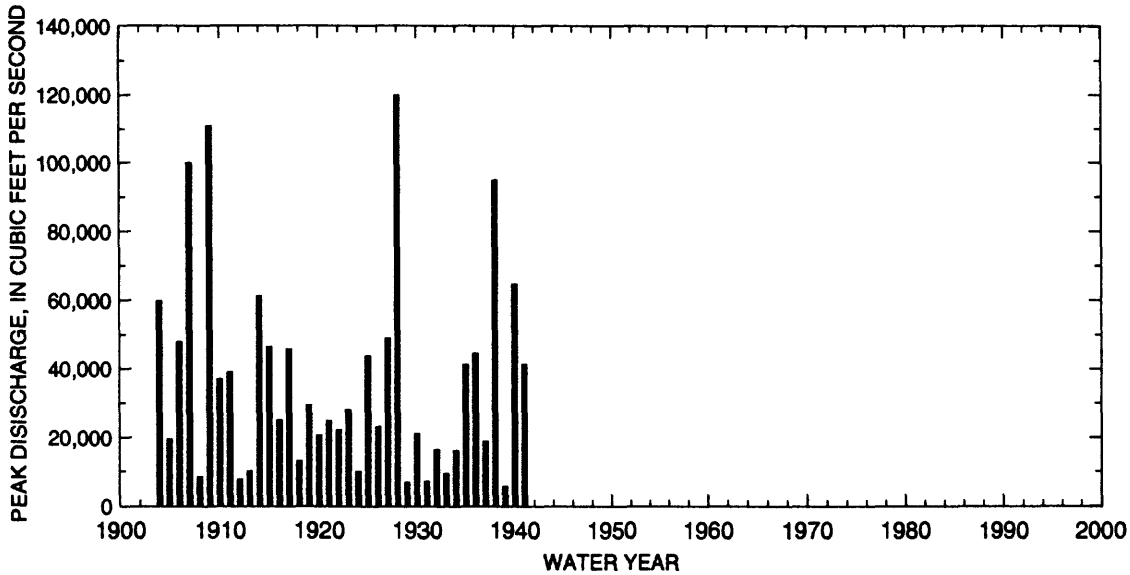

Figure 25. Annual peak discharge at Yuba River at Smartville, California.

11421000 YUBA RIVER NEAR MARYSVILLE

LOCATION.--Lat 39°10'33", long 12°31'26", in New Helvetia Grant, Yuba County, Hydrologic Unit 18020107, on left bank 4.2 mi northeast of Marysville and 5 mi downstream from Dry Creek.

DRAINAGE AREA.--1,339 mi^2.

PERIOD OF RECORD.--October 1940 to current year (1995) (prior to October 1943, low-water periods only). Published as "at Marysville" October 1940 to September 1957. Separate records published for two sites August 1954 to September 1955. Yearly discharge for the 1945 water year published in USGS Water-Supply Paper 1315-A.

REVISED RECORDS.--USGS Water-Supply Paper 1715: 1956 (instantaneous maximum discharge only). Water-Supply Paper 1931: Drainage area.

GAGE.--Water-stage recorder and crest-stage gage. Elevation of gage is 2.95 ft below sea level. Prior to August 1954 and Oct. 1, 1956, to Sept. 30, 1957, at Simpson Lane Bridge in Marysville 4.2 mi downstream at same datum. Sept. 3, 1963, to Sept. 23, 1968, auxiliary water-stage recorder at Simpson Lane Bridge at same datum.

REMARKS.-- Flow regulated by New Bullards Bar Reservoir since January 1969, and several other reservoirs. Many diversions upstream from station for power and for irrigation.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge (water years 1944, 1947-95), 180,000 ft^3/s, Dec. 22, 1964, gage height, 90.15 ft, from high-water marks, from rating curve extended above 91,000 ft^3/s on basis of U.S. Army Corps of Engineers flood-routing study. The 1956 and 1963 peaks were also determined by routing.

ASSESSMENT.--A log-linear plot of all peaks for the 1958-95 water years and many measurements, including all greater than 10,000 ft^3/s, indicate that significant and variable backwater effects from the Feather River have serious impact on the stage-discharge relation at this gage. Prior to 1970, fall to the gage on the Feather River was noted for each measurement. If backwater was noted and accounted for when determining peaks, then the uncertainty is on the order of ±15 percent. Given the scatter of peaks and measurements for the period 1970-95, when backwater was not noted, a reasonable assumption of overall uncertainty would be -20 percent to +10 percent.

The three highest peaks were based on flood routing done by the U.S. Army Corps of Engineers. These peaks indicate a large, abrupt overbank flow that would have begun at about 87.5 ft gage height. For the 1956, 1963, and 1965 peaks provided by the U.S. Army Corps of Engineers, there appears to be no way, given available data, to evaluate the uncertainty. If no overbank flow occurs, then the peaks are overestimated by at least 15 percent.

Prior to 1945, the gage was located closer to the Feather River. This location resulted in serious backwater problems at the gage. Assume peaks in that time period to have an uncertainty no better than ±30 percent. (See McGlashan and Briggs, 1939, for data on stage and discharges for 1862 and other large floods.)

During the period of record, more than 550 current-meter measurements were made; they had an average uncertainty of ±2.6 percent, ranging from ±2.2 to ±4 percent.

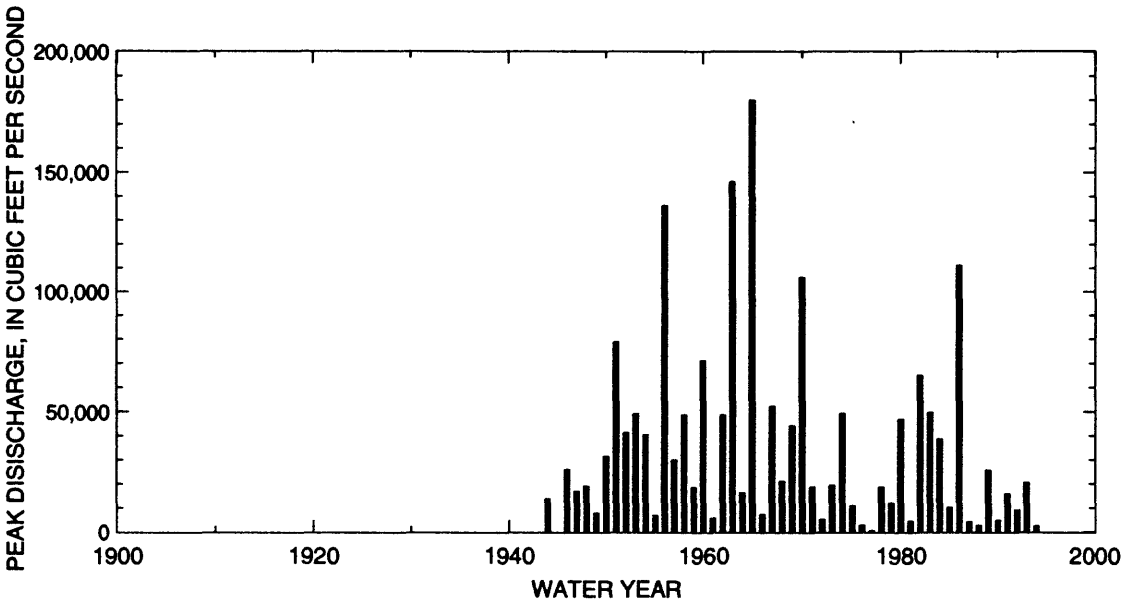

Figure 26. Annual peak discharge at Yuba River near Marysville, California.

SUMMARY

Flood-discharge data, current-meter and indirect measurements, and stage-discharge relations, the oldest of which dates to the early 1900's, were used to estimate the uncertainty of annual flood peaks in or near the American River Basin at 20 stream-gaging stations operated by the U.S. Geological Survey. Graphical and statistical analyses were used to estimate peak discharge uncertainty. Current-meter measurements were analyzed using *Measerr*, a computer program for determining measurement uncertainty. Individual indirect measurements were reviewed and some were recomputed. Uncertainty estimates were drawn on plots of stage-discharge relations, along with peak discharges and measurements. Within the study area, most flood peaks determined from current-meter measurements have an uncertainty of about ±3 to ±5 percent, whereas the peaks determined from indirect measurements have an uncertainty ranging from ±10 to ±70 percent. Also, the stage-discharge relations that were developed for most sites in the American River Basin are correct.

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