CACHE CREEK STREAMWAY STUDY

3.3 HYDROLOGY, HYDRAULICS, AND SEDIMENT YIELDS

3.3 *HYDROLOGY, HYDRAULICS, AND SEDIMENT YIELD*

Basin Characteristics

Location

Cache Creek Basin is located about 110 miles northeast of San Francisco in the coastal mountain ranges. Figure 3.3-1 shows the location of the Cache Creek Basin and the primary study area for the Streamway Investigations reported herein. Predominant features include the following: (1) Clear Lake, the largest natural body of fresh water entirely within the State of California, (2) the main stem of Cache Creek from Clear Lake to the Yolo Bypass, (3) the principal tributaries to Cache Creek, including North Fork Cache Creek and Bear Creek, (4) Capay Valley and the alluvial floodplain areas west of Capay through Woodland to the Yolo Bypass. Cache Creek and its principal tributaries drain approximately 1,140 square miles of area. The topography of the basin varies from steep, rugged, densely vegetated hillslopes of the Coast Ranges to the gentle slopes of the valley floor near Capay, located on the western margin of a large alluvial floodplain. Elevations range from 6,120 feet at Goat Mountain on edge of the northern basin to approximately 25 feet at the Corps of Engineers' sediment retention basin, east of Woodland. The geology of the basin is extremely complex and varied as are the soils and geomorphic characteristics. Details regarding the geology and geomorphology of the basin are summarized in Chapters 2 and 5 in this report.

Stream Discharge

Stream discharge on Cache Creek is measured at several gages in or near the study area. Figure 3.3-1 shows the gage locations, Table 3.3-1 presents selected hydrologic data for the gages, and Table 3.3-2 presents the approximate peak flows for various frequencies at the Rumsey, Capay and Yolo gage locations. Mean annual runoff from available gage data is approximately 577,000 acre-feet at Capay and 374,000 acre-feet at Yolo. Cache Creek emanates from Clear Lake in Lake County and flows through a narrow and steep 30-mile long canyon (Cache Creek Canyon) to Capay Valley in Yolo County. Figure 3.3-1 shows the location and path of Cache Creek in the Coastal Range and where it flows out onto the broad alluvial floodplain valley floor downstream from the community of Capay.

Water Diversions

Significant water diversions have occurred within the Cache Creek basin since the mid- to late-1800s. Today, Cache Creek flows are partially controlled by the dam at the Indian Valley Reservoir on the North Fork Cache Creek (see Figure 3.3-1). Two diversions supply irrigation water to Capay Valley and the large farm areas northwest and southwest of Woodland. The small

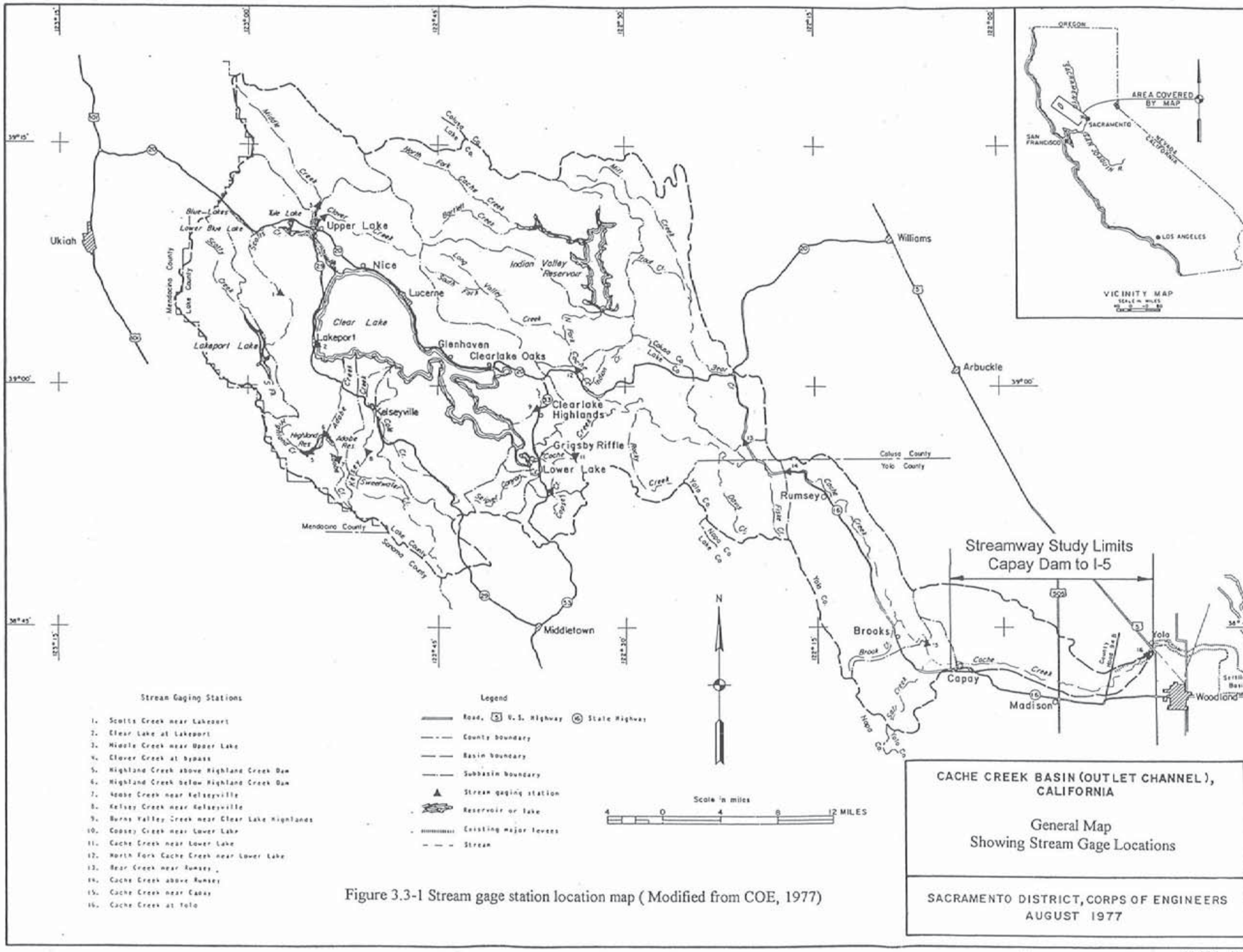

Figure 3.3-1 Stream gage station location map (Modified from COE, 1977)

TABLE 3.3-1

CACHE CREEK BASIN STREAM GAGING STATIONS

Location	Drainage Area (mi^2)	Period of Record Used	Length of Record Used (year)	Average Annual Runoff (acre-ft)	Average Annual Yield (Acre-ft/mi^2)	Average Annual Discharge (cfs)	Station Operator
Cache Creek near Lower Lake	528.0	1944-1991	47	256,000	484.8	350	USGS
North Fork Cache Creek at Hough Springs near Lower Lake	60.2	1971-1991	20	67,900	1127.9	95	USGS
North Fork Cache Creek near Lower Lake[1]	197.0	1930-1981	52	136,500	692.9	185	USGS
Bear Creek near Rumsey[1]	100.0	1958-1980	23	35,760	357.6	50	DWR, CA
Cache Creek above Rumsey[1]	955.0	1965-1986	19	541,200	566.7	755	DWR, CA
Cache Creek near Capay[1]	1044.0	1942-1976	35	556,900	533.4	770	USGS
Cache Creek at Yolo	1139.0	1903-1993	91	378,900	332.7	520	USGS

[1] Stream gage recorder discontinued.

SOURCE: COE, Aug. 1994 Westside Tributaries Study

TABLE 3.3-2

CACHE CREEK BASIN STREAM FLOW FREQUENCIES

Location	Peak Discharge (cfs)				
	2 Year	5 Year	10 Year	50 Year	100 Year
Cache Creek above Rumsey [1]	15,000	27,000	35,000	52,000	60,000
Cache Creek near Capay [1] Cache Creek at Capay[1]	15,000 (14,500)[2]	27,000 (28,000)[2]	34,000 (37,000)[2]	50,000 (57,000)[2]	58,000 (63,500)[2]
Cache Creek at Yolo	13,500	23,500	29,000	41,500	46,000

[1] Stream gage recorder discontinued.
[2] Values in parentheses from COE, Aug 1994 Westside Tributaries Study, Cache Creek at Capay Peak Flow Frequency Curve.

SOURCE: Flood frequency data for Rumsey, Capay, and Yolo from COE, 1990, General Design Memorandum for Cache Creek Basin Outlet channel.

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earthen dam upstream from Rumsey diverts less than three percent of the low flows, but the dam near Capay diverts nearly all the flow reaching that point during the dry season. The low-head diversion dams have very little effect on high flows in the creek. Irrigation water is used for a large variety of crops along the western portion of the Sacramento Valley. Riparian communities occur only where sufficient water is available in or adjacent to the creek to sustain its growth.

Vegetation

Today, open stands of oak trees and chaparral grow on the hills surrounding Capay Valley. Oak, pine, cottonwood, sycamore, willow, and black walnut grow near the creek and its tributaries in Capay Valley. Tamarisk, willow and giant cane are dominant plants found on the sand bars in the channel of Cache Creek. Annual grasses and forbs dominate the uncultivated grasslands (savannah) in the area.

The original appearance of the western portion of the Sacramento Valley, including the drainages from Cache Creek as viewed 150 years ago was vastly different from today.[1] Bands of dense riparian forests 10 to 20 miles wide flanked the rivers and creeks throughout the main valley floor. Narrower riparian bands were also believed to occur along the banks of Cache Creek.[2] Marshy areas, supporting dense communities of tule (Scirpus spp.) were also very prominent in low areas along the valley floor. Yolo County was named after the local Indian name *Yoloy*, or "a place abounding in tules." Large stands of oak were found in the better drained areas between the creek and river systems. Basin geology and soils conditions are described in Section 3.2.

Climate

The climate in the study area is characterized by cool, moist winters and warm, dry summers. Mean annual precipitation in the Cache Creek basin ranges from about 17 inches at the lower end of the basin near Woodland to approximately 50 inches in the upper basin. According to Lustig and Busch,[3] the mean annual precipitation near Capay is approximately 23 inches. Most of the precipitation falls as rain from Pacific front storms moving inland from the coast. About 85 percent of the annual precipitation occurs during November through March. Because of its elevation, size and orientation, the Cache Creek basin can produce significant flood flows to lower portions of the basin and valley floor in a very short period of time. An example of this extremely flashy nature occurred in March, 1995 when the flow in the creek rose from less than 500 cfs to more than 50,000 cfs in less than 24 hours (according to DWR stream flow records at Rumsey).

<u>Previous Studies</u>

Detailed hydrologic analyses were performed on the Cache Creek Basin by the Corps of Engineers. Results from their extensive analyses are reported in *"Cache Creek Basin, California, Feasibility Report,"* (USACE, 1979), *"Cache Creek Basin Hydrology Review Report,"* (USACE, 1985), "*Final General Design Memorandum*," (USACE, July 1990), "*Hydrology of the Westside Tributaries of the Yolo Bypass, California, Reconnaissance Study*," (USACE, August 1993) and "*Hydrology for Cache Creek, Yolo County, California, Reconnaissance Study (Draft)*," (USACE, July 1995). Precipitation and runoff for the major storms of recent record were analyzed by the

Corps investigations. The rainfall and runoff data, flood flow frequency curves, and HEC-1 modeling results developed by the Corps were used as the hydrological basis for the hydraulics and sediment transport investigations conducted during the Streamway Study. Tables 3.3-3 and 3.3-4 list historical references and relevant previous studies.

Methods

Streamflow data used in this investigation was compiled from gage records and reporting prepared by the US Geological Survey (USGS), US Army Corps of Engineers (USACE) and the California Department of Water Resources (DWR) for gages they maintain in the Cache Creek basin. Table 3.3-1 summarizes the location, drainage area, period of record used for developing average annual runoff values, the length of record, average annual runoff, average annual water yield, average annual discharge and agency responsible for the operation of the gage. For Rumsey (Cache Creek above Rumsey) and Yolo (Cache Creek at Yolo) gages, we plotted mean monthly flows and illustrative annual hydrographs for three years: 1983 (a wet year, Figure 3.3-2), 1977 (a dry year, Figure 3.3-3), and 1984 (a "typical" year, Figure 3.3-4). For the gages at Rumsey, Capay, and Yolo, we read values for the Q2, Q10, Q50, Q100 and Q500 from flood frequency curves prepared by the US Army Corps of Engineers.[4] We obtained values of annual runoff at the USGS Yolo gage (chosen because it has the longest continuous record) and values of annual diversions at Capay Dam (from records of the Yolo County Flood Control and Water Conservation District) and prepared a histogram showing the two values together, yielding total annual runoff. From USGS records we plotted a histogram of annual peak flows to provide a historical context for observed changes. We also obtained a copy of the USACE HEC-1 model from the County for the Cache Creek basin[5] and prepared plots of computed (50-year, 100-year, etc.) hydrographs at Capay.

Although the scope of the present investigation is specifically limited to the evaluation of channel and flow conditions through 1994, NHC obtained hourly gage heights (water surface elevations) for the USGS stream gage at Rumsey for the period leading up to and during the March 1995 flood. We applied the gauging station's rating curve to these values to obtain flow values, which we plotted as hourly and mean daily values for the months of January, February, March, and April 1995. The 1995 high flow hydrographs were compared to the Corps of Engineers computed (HEC-1) hypothetical hydrographs.

Annual basin sediment yield and single event sediment loads were developed from sediment load-water discharge relationships. Suspended loads (tons/day) calculated from 56 samples collected by the USGS at Capay and Brooks[6] were plotted and fitted to a regression curve through the data using a least-squares procedure. Bedload transport rates calculated from six Helley-Smith bedload samples collected by Harmon[7] were also plotted and fit to a curve for bedload versus flow. Because there were so few bedload samples, we chose to calculate bedload as a fixed percentage of suspended load as documented by Harmon in 1989 and Lustig and Busch in 1967. We then applied the suspended and bedload transport functions to each mean daily flow for each annual runoff period and summed the annual totals. The annual totals from 1943 to 1995 were averaged to obtain the mean annual sediment load entering the study reach. Instantaneous peak flows are typically higher than mean daily flows in this type of ephemeral system.

Table 3.3-3 Principal Historical References

Year	Author	Title	Description
1870	Sprague & Atwell	Western Shore Gazetteer and Commercial Directory	Editorial description of early settlement period in Yolo County
1879	Gilbert, Frank T.	The Illustrated Atlas and History of Yolo County	Early history of county, including many historical accounts of early settlement period
1880	Office of the State Engineer, William Hammond Hall	Report of the State Engineer to the Legislature of the State of California -- Session of 1880	Report on the potential for development of major irrigation and drainage works in the Sacramento Valley, including a description of Cache Creek irrigation works
1901	USGS , Albert E. Chandler	Water Storage, Cache Creek, California	Description of existing and potential water storage and irrigation works on Cache Creek
1940	Russell, William O.	History of Yolo County, California	General history of Yolo County from pre-settlement to 1940
1950	Obrien, J.C.	Mines and Mineral Resources of Yolo County	Description of mineral resources and existing mining operations in Yolo County, including aggregate extraction on Cache Creek
1958	Klein,I.E. and Goldman, H.B.	Sand and Gravel Resources of Cache and Yolo Counties	Description of basin geology, geomorphology, aggregate properties, and existing aggregate mining operations on Cache Creek
1986	Merhoff, Ada	Capay Valley, The Land & The People, 1846-1900	Detailed history of Capay Valley, including history of settlement and land division, and biographical information on important settler families to 1900
1987	Larkey, J.L. and Walters, S.	Yolo County, Land of Changing Patterns	General history of Yolo County from pre-settlement to 1987

Sources of Maps, Historical Photos, and Aerial Photography

State Lands Commission
California State Archives
Yolo County Archives
UC Berkeley Library
UC Davis Library
Bancroft Library

California State Library
CSUS Library
US Bureau of Reclamation
Yolo County Flood Control and Water Conservation District
Department of Water Resources

US Army Corps of Engineers
National Archives
Natural Resource Conservation Service
Caltrans

Table 3.3-4 Relevant Previous Studies

Year	Author	Title	Study Area	Description
1976	Woodward-Clyde Consultants	Aggregate Extraction in Yolo County	Capay Dam to Yolo	Compiled existing data only. Report presented observation and conclusions, but few data. Stated that active channel width essentially unchanged 1939-1972
1981	Wahler Associates	Preliminary Hydrologic Report, Cache Creek Aggregate Resources Yolo County, California	Capay Dam to Yolo	Summarizes Stage 1 hydraulic study of Cache Creek based on analysis and evaluation of existing well drillers logs compiled by County and DWR. Streamflow and irrigation records were also utilized
1981	Wahler Associates	Geology Report, Cache Creek Aggregate Resources, Yolo County	Capay Dam to Yolo	Geologic evaluation of the aggregate resources from Capay to Yolo along Cache Creek
1983	US Army Corps of Engineers, Sacramento Dist.	Cache Creek Basin, California	Clear Lake to Yolo Bypass	Evaluates flood control, sediment control, and fish and wildlife enhancement of the Cache Creek Basin, CA
1984	Aggregate Technical Advisory Committee (Ag TAC)	Resource Management Plan for the Area Along Cache Creek Between Capay and Yolo in Yolo County, California	Capay Bridge to Yolo	Used existing data to create and evaluate opportunities for the Cache Creek Corridor. The Cache Creek Corridor includes land 4 miles on either side of Cache Creek and is approximately 14.5 miles in length
1984	Harmon (USGS)	Streamflow, sediment discharge, and streambank erosion in Cache Creek, Yolo County, California, 1953-86.	Rumsey to Capay	Analyzed streamflow data, collected and analyzed suspended and bedload sediment samples, and conducted repeat surveys of channel cross sections
1987	Simons, Li & Associates	Geomorphic Analysis of Cache Creek Between Rumsey and Madison	Capay Valley to I-505	Measured channel widths from air photos 1939, 1972, and 1986 to estimate bank erosion rates as part of basis for evaluating potential effects of changed hydrology on channel erosion. Speculated that in Hungry Hollow and Madison reaches, channel had become braided in response to mining
1988	US Army Corps of Engineers, Sacramento Dist.	Sediment Engineering Investigation, Cache Creek Basin, Clear Lake Outlet Channel	Hwy 16 above Rumsey to Hwy 505 Bridge near Madison	Sediment engineering investigations to determine potential impacts of the Clear Lake Outlet Channel Modification Project on the study reach downstream from Clear Lake

Table 3.3-4 Cont.

Year	Author	Title	Study Area	Description
1989	Rivertech, Inc.	Assessment of Impact of Proposed Mining on Bank Protection and Erosion Control for Cache Creek, Parcels 49-470-10, 49-470-11, 49-140-01 and 48-140-20	One mile portion of Cache Creek, immediately downstream from Capay Bridge	Performed reconnaissance level fix-bed hydraulics investigation to determine potential benefits for reducing bank erosion problems by implementing bar skimming and the installation of protective spur dikes
1989	Water Engineering & Technology, Inc.	Cache Creek Erosion Mitigation Alternatives Final Report, Contract No. DACW05-88-D-0044	Hwy 16 Bridge above Rumsey to Hwy 505 Bridge at Madison	Extended data base on geomorphic and sediment transport characteristics of Cache Creek and evaluated methods for mitigating channel erosion
1990	US Army Corps of Engineers, Sacramento Dist.	Cache Creek Basin (Outlet Channel), Draft General Design Memorandum	Clear Lake to Clear Lake Dam	Developed detailed basis of design for 4.5-mile long Clear Lake outlet channel. Basin hydrologic characteristics are detailed
1991	Dames & Moore	Second Administrative Draft Program Environmental Impact Report	Capay to I-5	Presents evaluation of fourteen potential future aggregate mining activities in the study area a five Yolo County policy alternatives that might be used as the basis of County regulation of mining activities
1992	US Army Corps of Engineers, Sacramento Dist.	Cache Creek Basin (Lake County), CA Reconnaissance Report	Clear Lake Basin	Reconnaissance evaluation of need for additional flood protection in the Clear Lake area. Basin hydrologic characteristics are detailed
1993	Yolo County and YCAPA	Cache Creek Gravel Mining Alternatives	Capay Dam to Yolo	Describes the philosophy upon which future mining activities along Cache Creek should be based (as of July, 1993)
1994	US Army Corps of Engineers, Sacramento Dist.	Reconnaissance Report - Westside Tributaries to Yolo Bypass, California	Capay to Yolo Bypass, Cache Creek Willow Slough, Putah Creek	Reconnaissance level investigation of flooding and related water resources problems associated with the westside tributaries to Yolo Bypass

Bedload transport is a power function of discharge, which implies that bedload transport rates could be greater if calculated on an hourly basis rather than a daily basis. This effort was not justified or possible given the coarse nature of the rating curve method itself and the fact that hourly flow data for the years since 1943 were not readily available. The suspended load was also broken down by size class based on suspended load size analyses conducted by the USGS for their samples collected at Capay. Bedload and sand-sized suspended load was summed in order to develop an estimate of the total bed material load. Annual sediment loads were also summed to show how much sediment loading (tons of sand and gravel) have moved into the study reach over time.

Flow Variability

Flow (water discharge in cfs) in Cache Creek has large seasonal and annual variability (refer to Figures 3.3-2 to 3.3-4). Because of water diversions, there is also a significant spatial variation in flow along the creek. Figure 3.3-5 illustrates and compares the seasonal variations in monthly discharge at Rumsey and Yolo as well as the spatial variability during winter and summer months. The variability in discharge is amplified below Capay Dam, where irrigation diversions are made to the West Adams and Winters Canals. According to Todd,[8] water diversions from the Capay Dam may account for more than fifty percent of the annual flow past the dam during drought periods to less than ten percent of the annual flow in a wet year. This is illustrated well in Figure 3.3-6. While 10 to 50 percent of the total annual runoff is diverted, the diversions are concentrated during the irrigation season, with 100 percent of runoff diverted in many summer months, resulting in zero flow below Capay for extended periods in most years. According to Todd (refer to Section 4.2) significant spring and summer diversions at Capay have occurred since the construction of the Capay Diversion Dam in 1912.

Flood flows in the basin are primarily caused by runoff during high intensity rainstorms during winter and spring. Because Cache Creek is relatively steep and confined above Capay, peak floodflows usually pass through the basin within 24 hours. However, recessionary flows on the order of 10,000 to 15,000 cfs can last for many days following a significant runoff event. Consequently, the effects of such floods are different for the upper and lower portions of the basin. All record floods in the basin have been rainflood type events characterized by relatively high peaks of short duration and relatively small total volume.[9]

Because precipitation is highly variable from year-to-year,[10] runoff is highly variable from year-to-year. Figures 3.3-7 and 3.3-8 present annual precipitation at Woodland and peak annual flow at the Yolo gage on Cache Creek. It is important to emphasize that rainfall intensity and volumes vary greatly over the entire Cache Creek drainage basin and that peak flows arriving at Yolo are predominantly controlled by precipitation conditions occurring in the upper basins above Capay. Total runoff is shown in Figure 3.3-6 as the sum of the flows in the creek at Capay and diversions to the West Adams and Winters Canals at the Capay Dam. In dry years, a larger portion of the runoff is diverted, thus illustrating the greater effects of the diversion in dry years (see Figures 3.3-3 and 3.3-6). However, the water flowing into Capay Dam in summer months during dry years has been increased since 1978 with storage releases from Indian Valley Reservoir on the North Fork of Cache Creek. Summer releases from the Indian Valley Reservoir do not necessarily effect flows in the creek downstream from the Capay Dam during years when 100 percent of the creek flow is diverted.

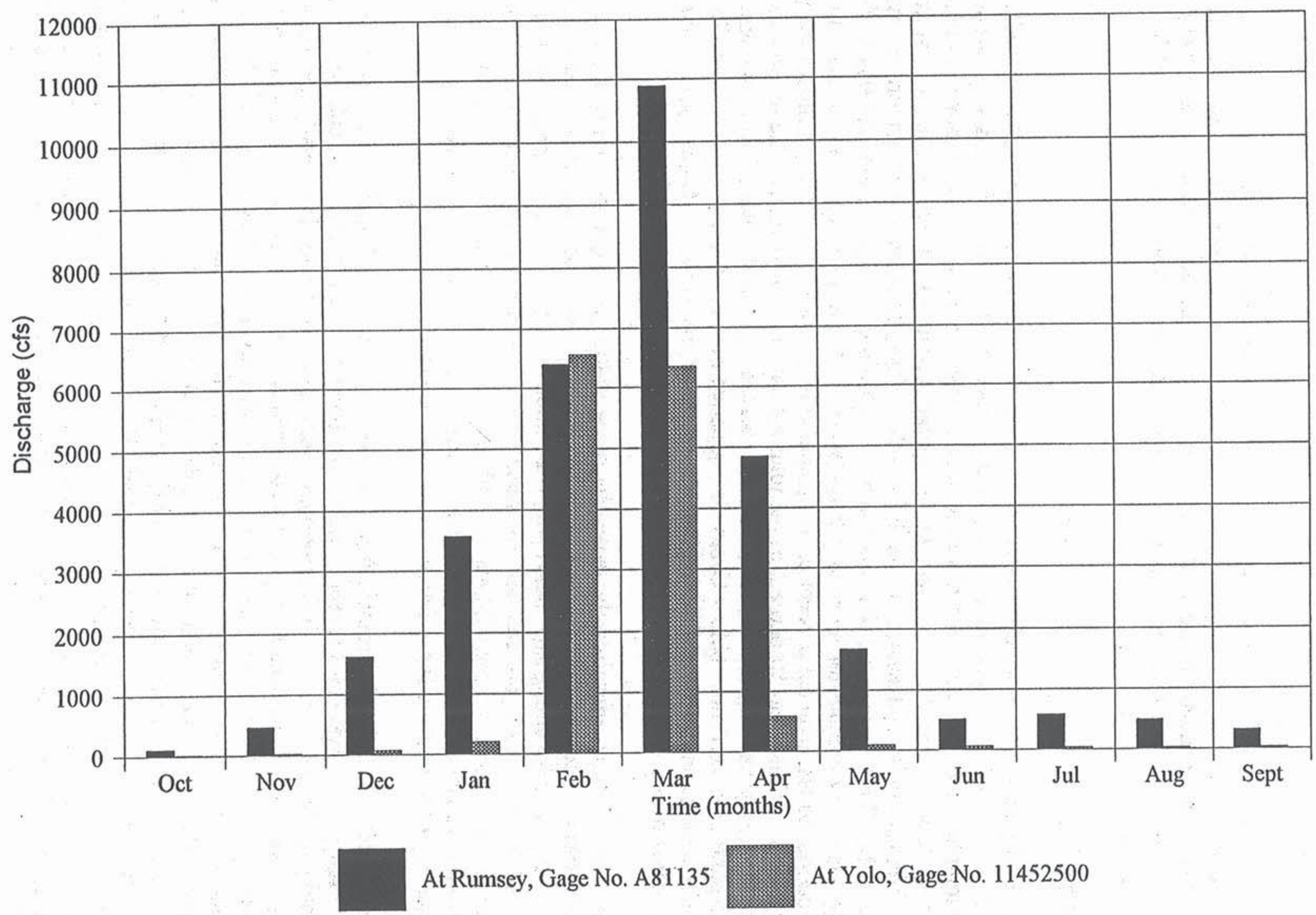


Figure 3.3-2 Mean Monthly Flows for a Wet Year, 1983

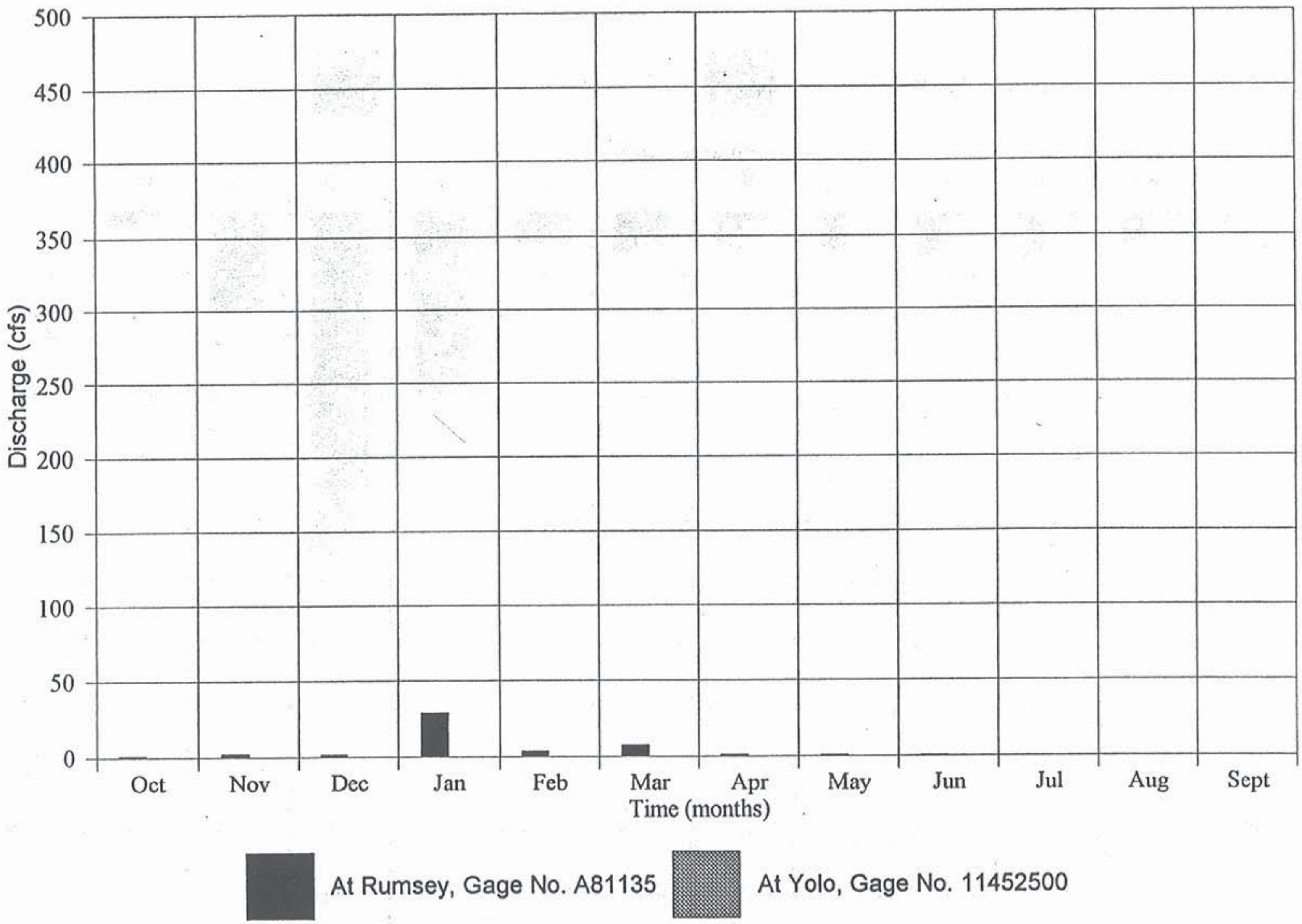


Figure 3.3-3 Mean Monthly Flows for a Dry Year, 1977

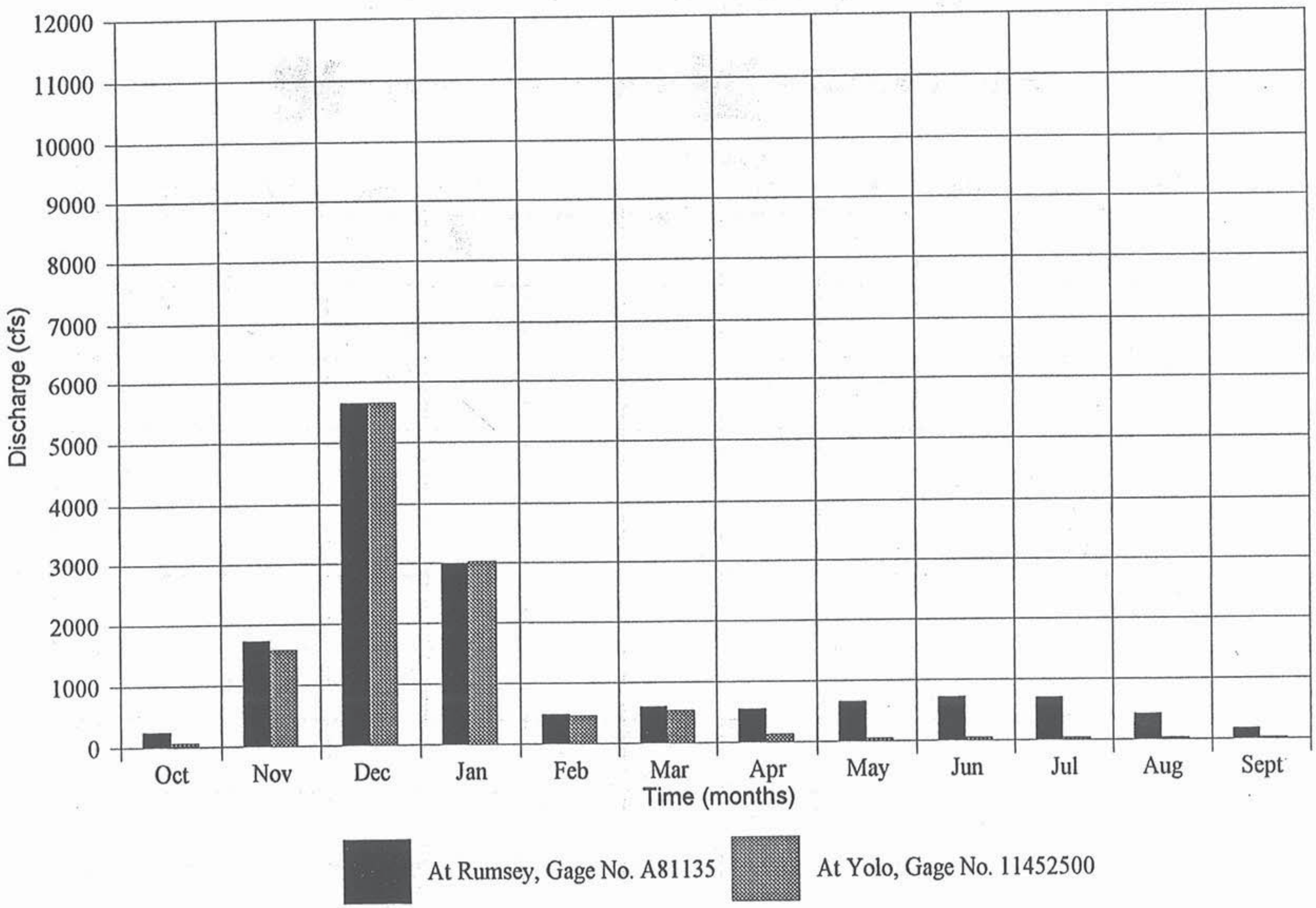


Figure 3.3-4 Mean Monthly Flows for a Typical Year, 1984

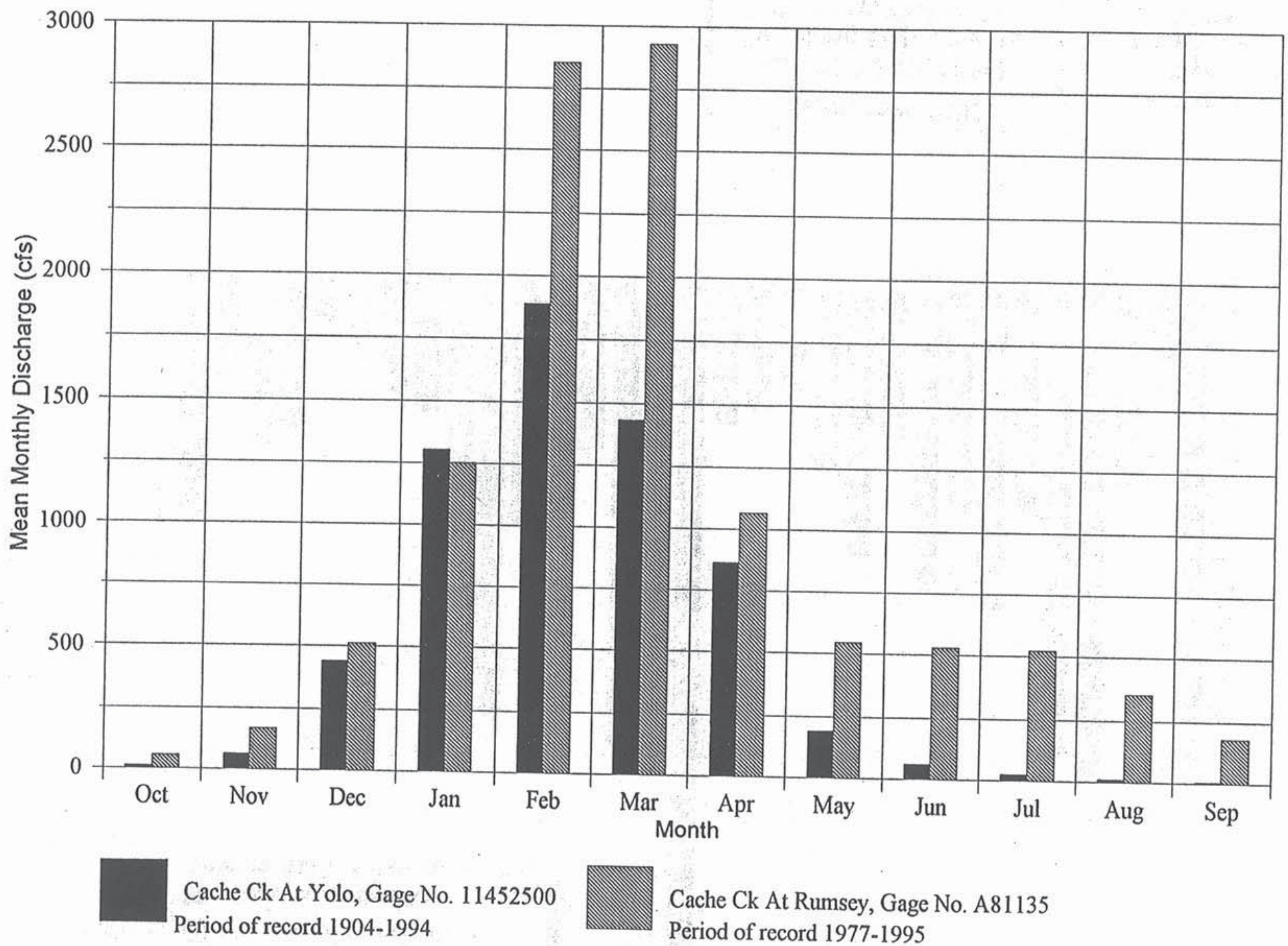
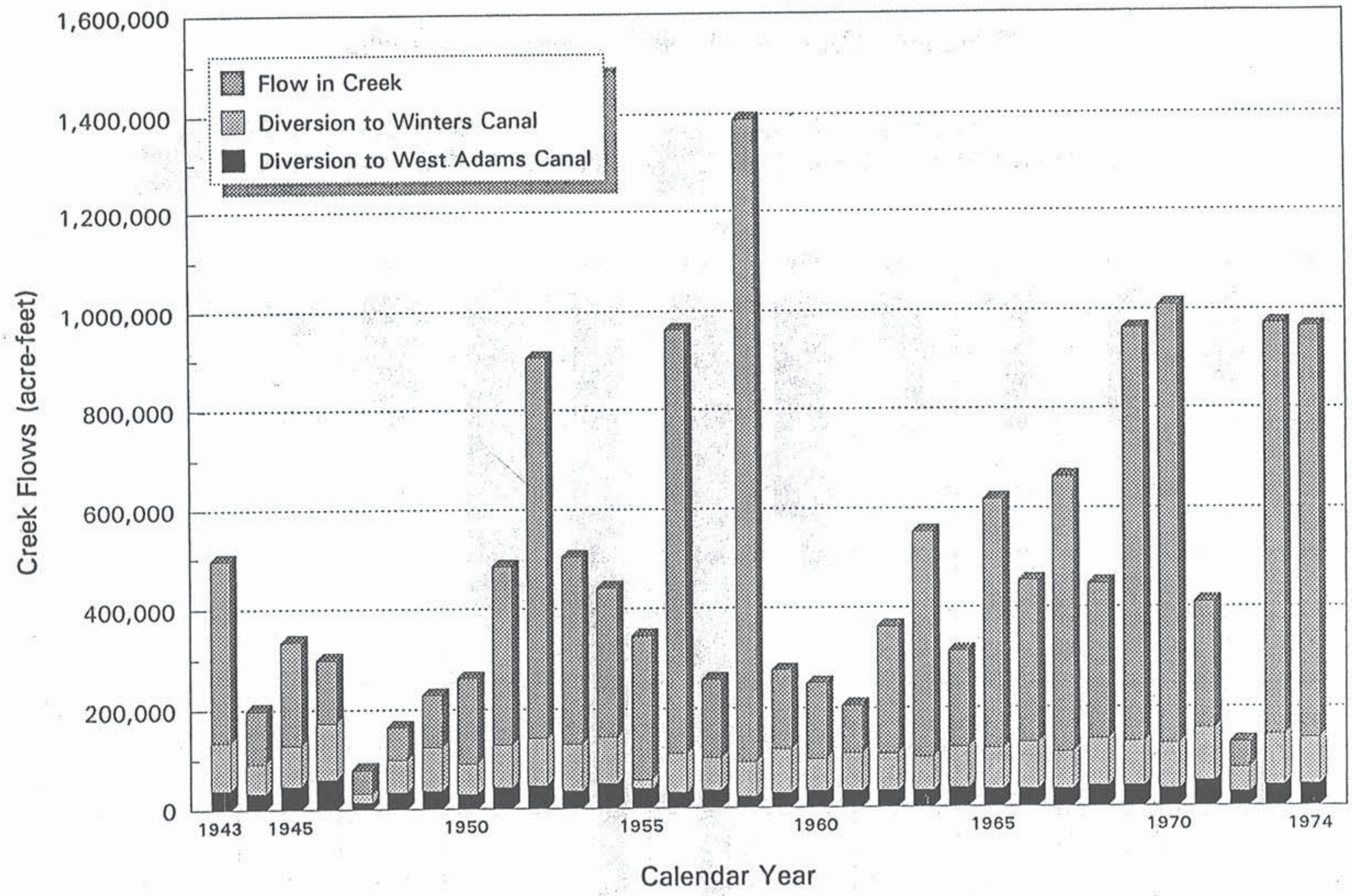


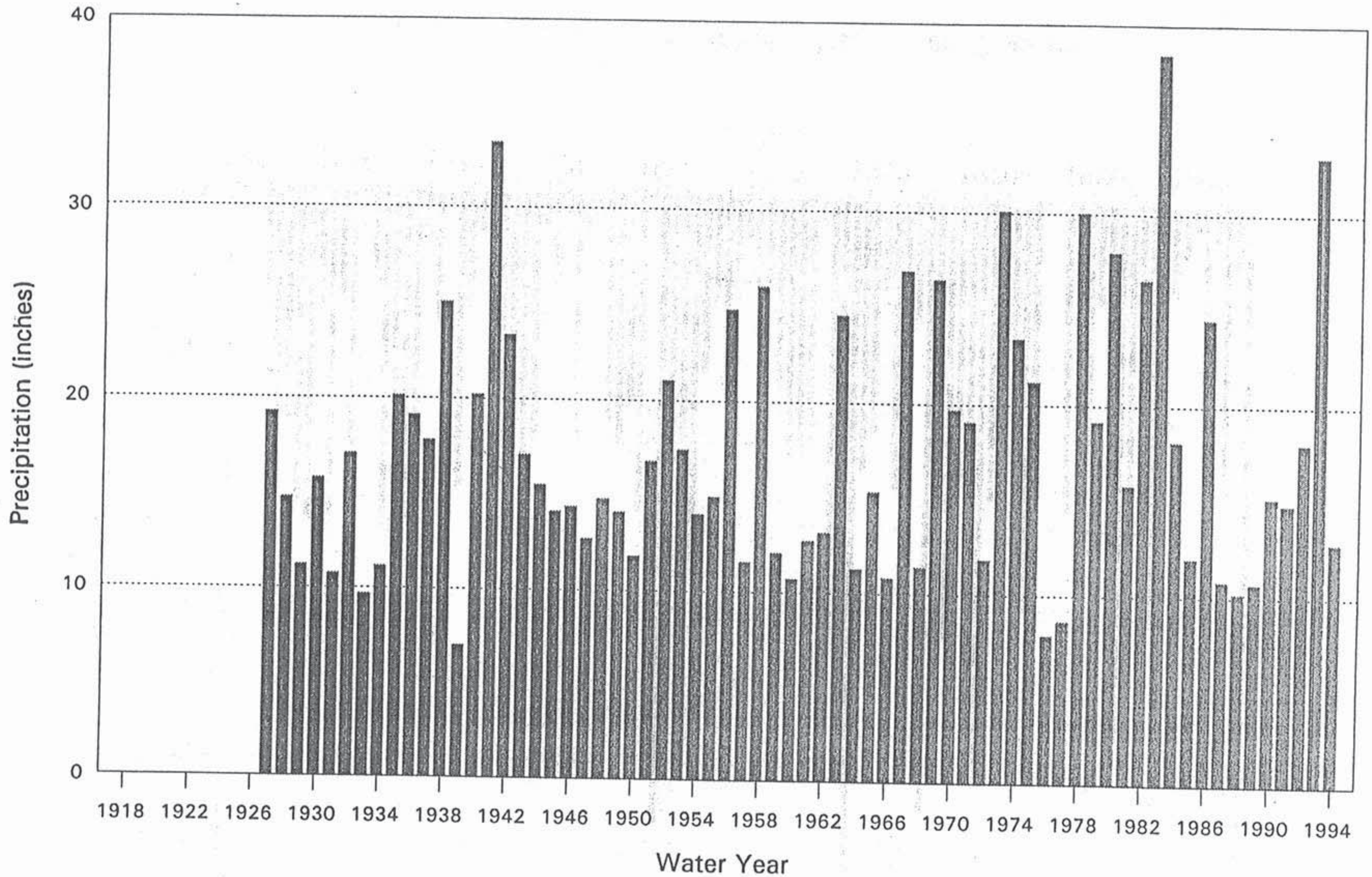
Figure 3.3-5 Mean Monthly Flows at Yolo and Rumsey



September 1995

DAVID KEITH TODD
Consulting Engineers, Inc.
Berkeley, California

Figure 3.3-6
Distribution of
Water at Capay Dam
1943 - 1974



Note: Station no. 9781-00

September 1995	Figure 3.3-7
DAVID KEITH TODD Consulting Engineers, Inc. Berkeley, California	Woodland Precipitation 1927 - 1994

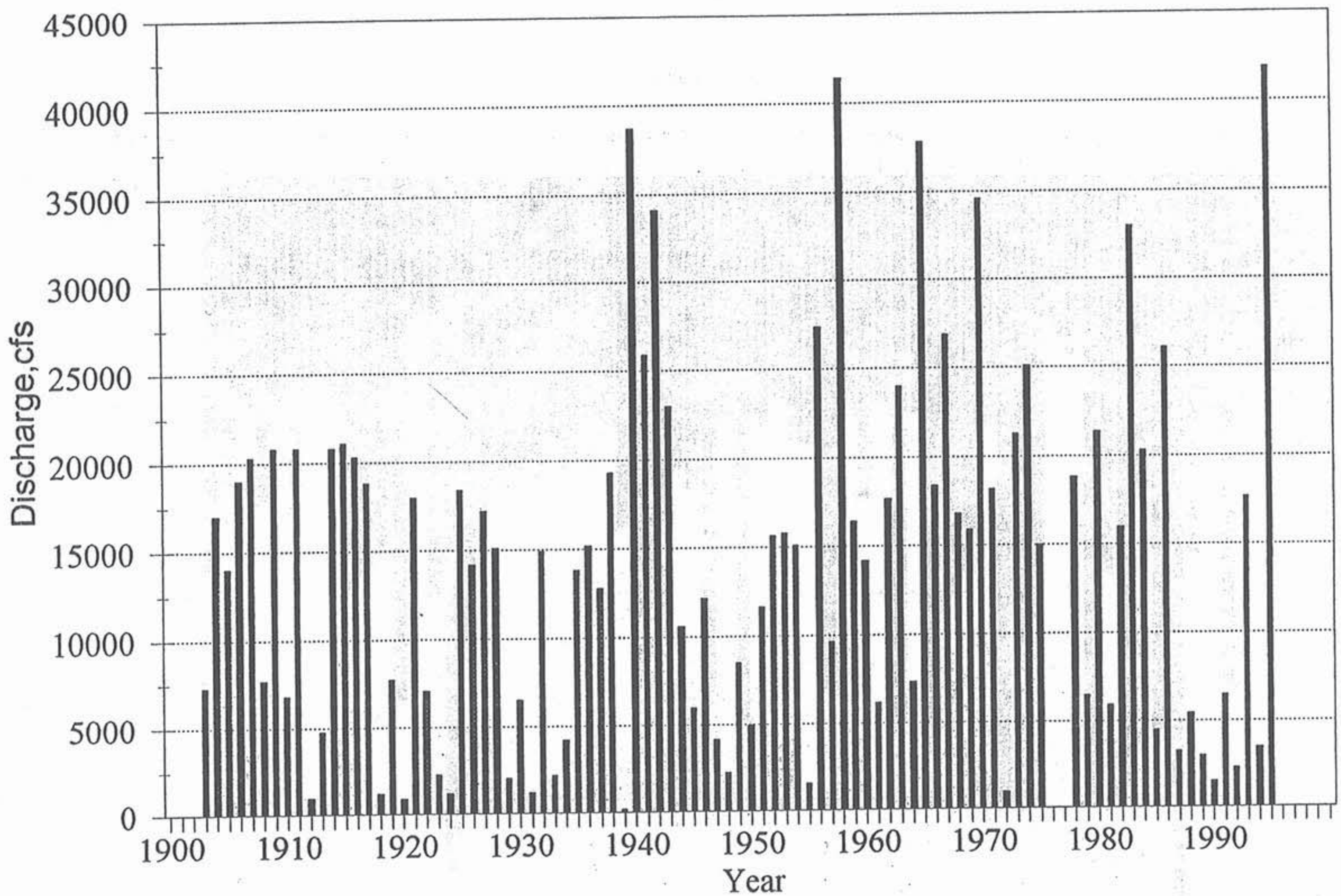


Figure 3.3-8 Cache Creek at Yolo, Peak Annual Discharge

Cache Creek can experience large floods during winter and spring months and rapid changes in discharge in relatively short periods of time (less than 24 hours). This type of system is extremely "flashy", or “episodic” in that it responds quickly to periods of intense precipitation in the upper basin, producing flow increases from a small base flow to a raging flood in a few hours. This episodic characteristic is illustrated in Figure 3.3-9 by the flow records observed in January and March, 1995. Two significant runoff events occurred in 1995. Figure 3.3-9 shows the mean daily flows rise dramatically from approximately 350 cfs on March 7 to a peak flow in excess of 50,000 cfs on March 9, 1995. However, within a twelve hour period on March 9th, the flow rate increased from approximately 3,600 cfs to more than 52,000 cfs. These values of discharge were estimated by comparing the observed peak Rumsey gage elevation to the DWR stage-flow rating curves 30 and 32. A similar event with a quick time to peak was also observed in January 1995. The March 1995 runoff event is estimated as greater than a 50 year flood event and the January event may have been about a 10 year event according to preliminary information being developed by the Department of Water Resources.

The U.S. Army Corps of Engineers published recent results on the hydrologic characteristics of the Cache Creek basin in their *West Side Tributaries Report* (USACE, 1994) and *Draft Cache Creek Environmental Restoration Reconnaissance Investigation - Hydrology for Cache Creek, Yolo County, California* (USACE, July 1995). They developed hypothetical 100-year flood conditions and used computer program HEC-1 to generate a 100 year (1 percent) flood hydrograph. Figure 3.3-10 presents the Corps of Engineers’ hypothetical (HEC-1 generated) 100-year hydrograph. Figure 3.3-11 presents the Corps’ hypothetical (HEC-1 generated) 50-year hydrograph along with the March 1995 storm hydrograph. DWR flow records indicate that the shape and characteristics of the 1983 flood event was quite similar to that of 1995. For the purposes of evaluating channel dynamics and system response to large flood events, it is important to use flow records that match actual storm characteristics as much as possible. Even though the peak flows from the HEC-1 model approximately match observed peaks of the same frequency, it is apparent that the shape and volume of recent storm events may differ from the hypothetical design hydrographs generated with the Corps’ HEC-1 model (see Figure 3.3-11). Accurate peaks are important for establishing safe levee heights, while the shape and duration are more important to the sediment transport processes, bed and channel stability, bridge scour, and environmental and habitat considerations during an event. For the purposes of this investigation, NHC developed single event hydrographs by matching 1995 measured peak flows (from DWR and USGS) to the peak discharges reported in the Corps (1992) flow frequency curves. The shape and approximate duration of the single event hydrographs were developed by scaling the ordinates of the 1995 flood events by the ratio of the target peak to the observed 1995 peak. Thus, individual event hydrographs with a more realistic shape and duration were developed for the purposes of the hydrologic evaluations performed herein.

Further refinement of design storm hydrology is suggested. Such work is beyond the scope of the present investigation and should be closely coordinated with the Corps of Engineers and the Department of Water Resources during future investigations.

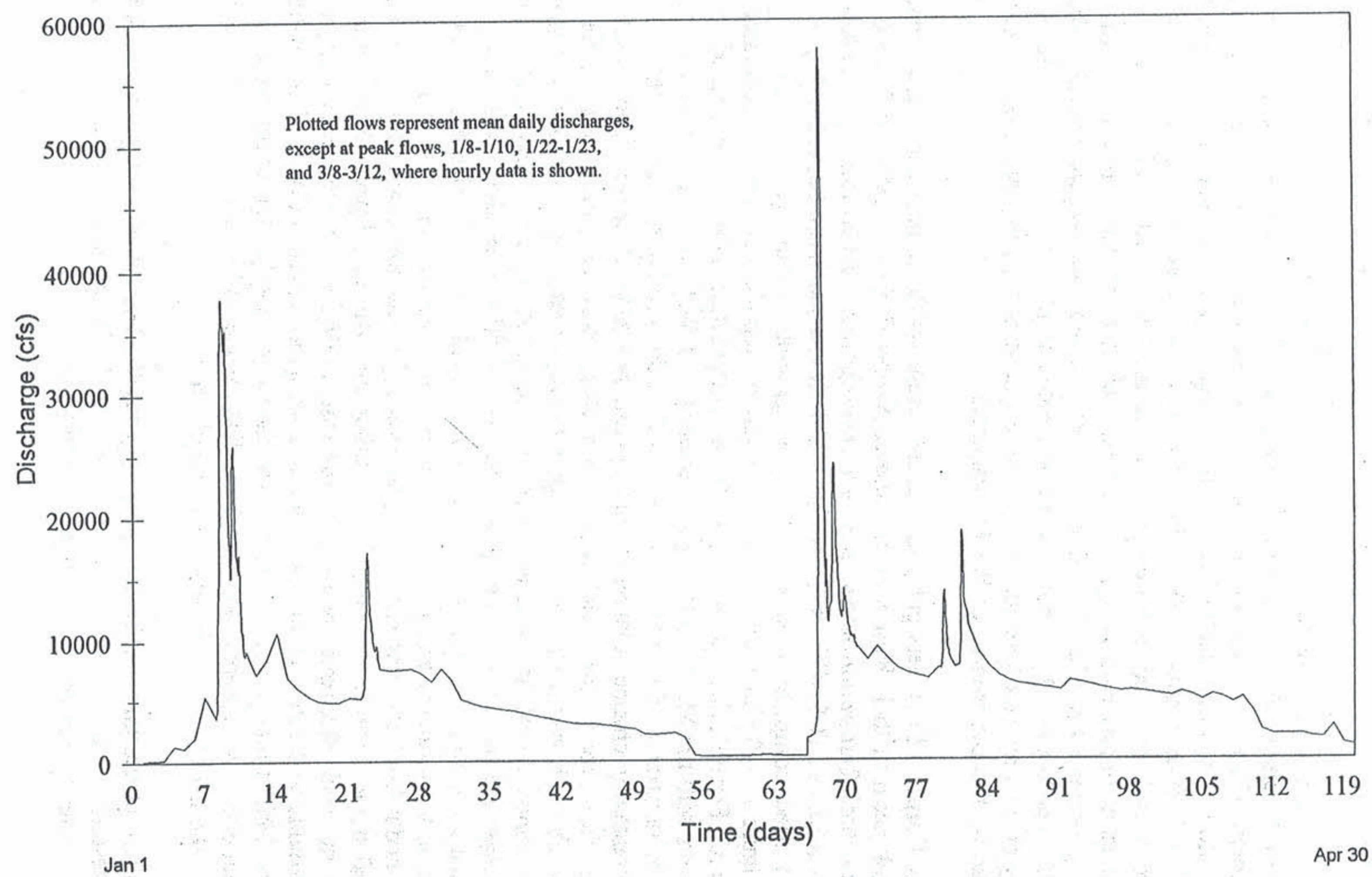


Figure 3.3-9 Provisional Measured Flows At Rumsey, Gage No. A81135, from Jan 1 to April 30, 1995

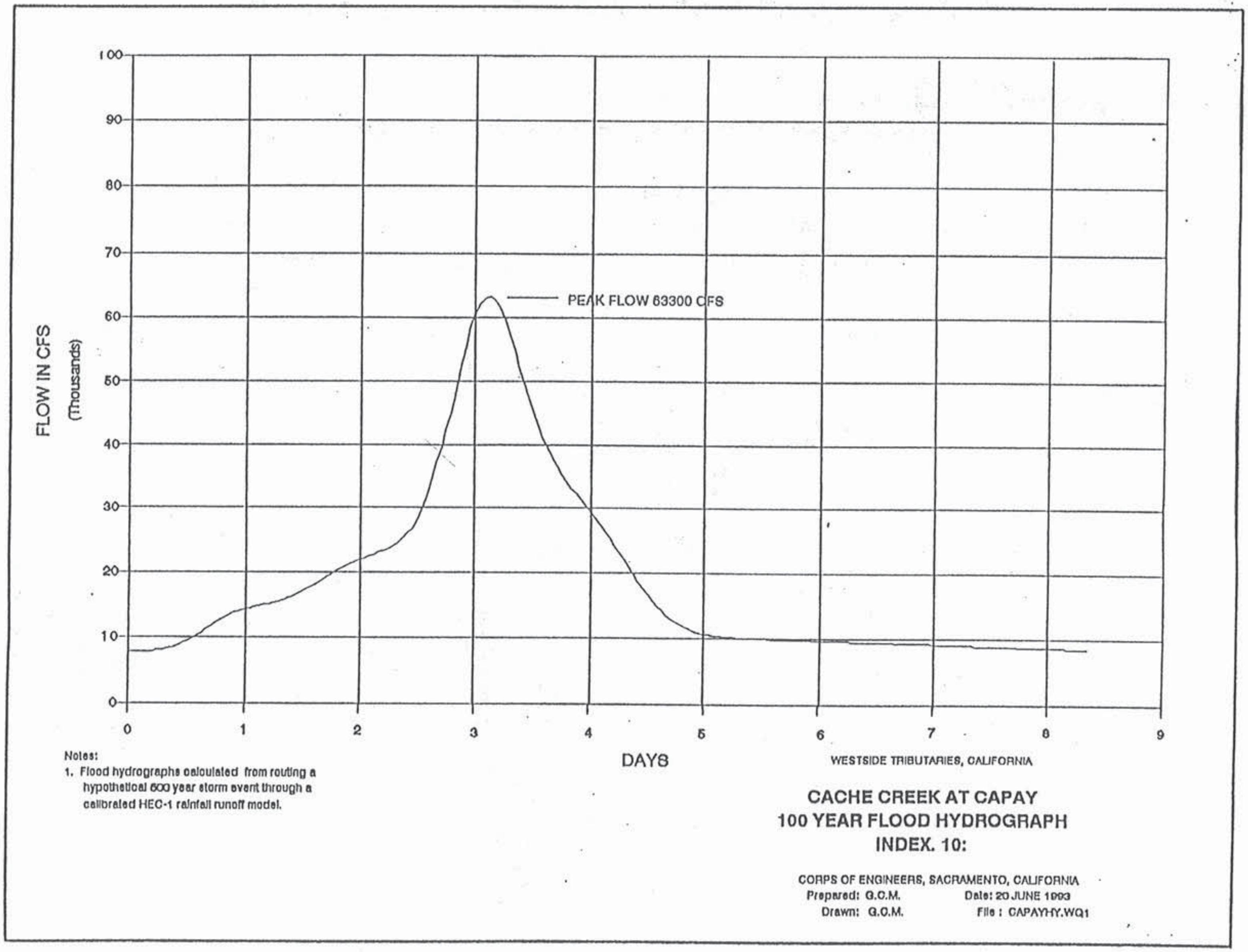


Figure 3.3-10 100 Year Synthetic Hydrograph (Source: COE, Westside Tributaries Report Chart 4, June, 1994)

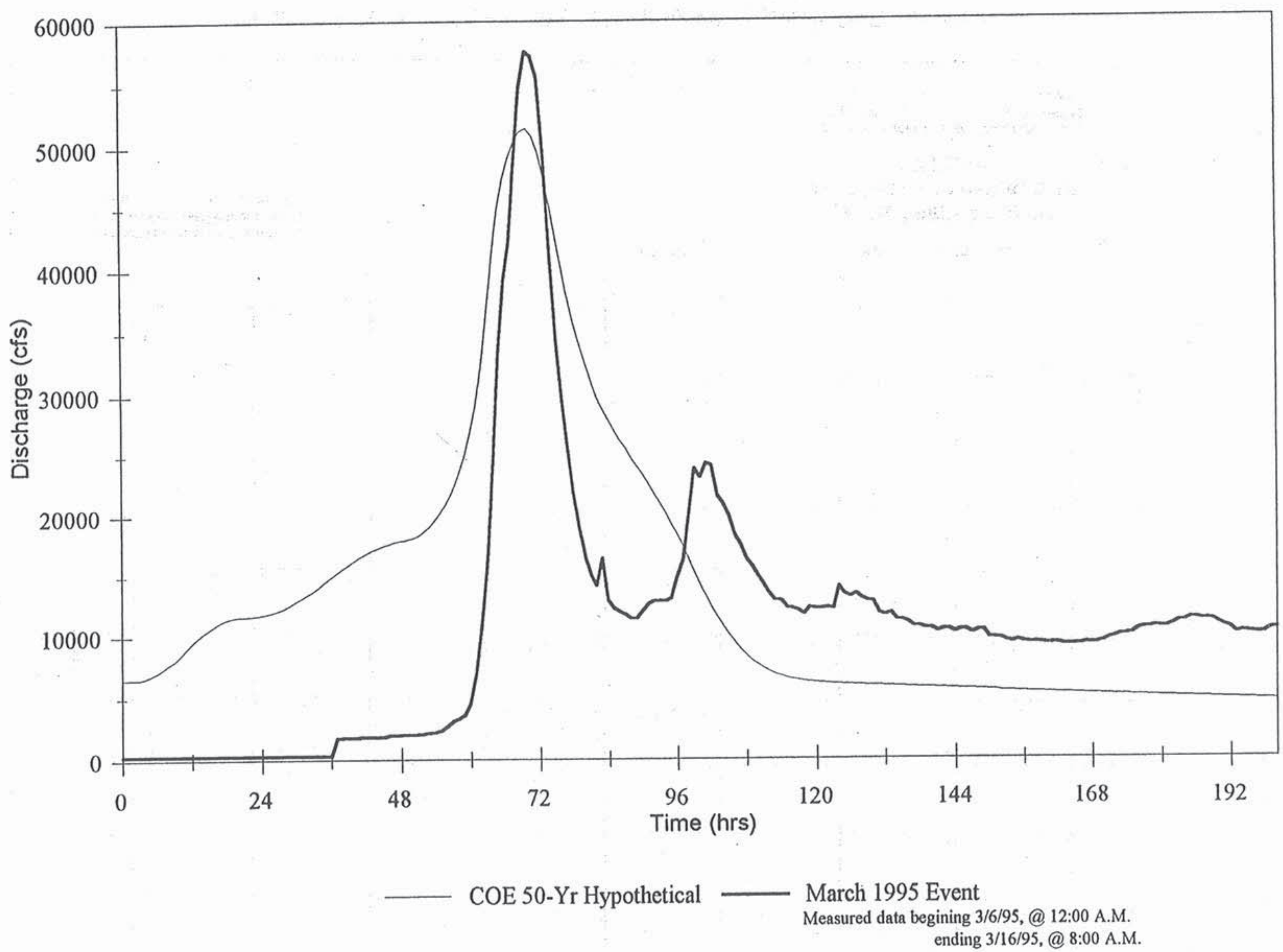


Figure 3.3-11 50-Year Hypothetical vs. Measured March 1995 Event

Peak Flow Variation

Peak flow magnitude varies widely from year-to-year. At Yolo, annual peaks have ranged from near zero in years such as 1976 and 1977 to over 40,000 cfs in years such as 1958 and 1995 (see Figure 3.3-8). One result from this amount of periodic flow change is that the channel adjusts its shape and slope due to the amount of flow energy and bed material movement resulting from the magnitude and duration of the high flows that occurs during an event. Consequently, the channel may have either been scoured by a recent large flood (such as in 1995) or has experienced several years without large flows. During extended periods of lower flow regime, the channel can recover through revegetation and the net accumulation of sediment materials washed into the system with the more frequent, less energetic runoff events. This pattern of flood pulse response and readjustment is typical in flashy ephemeral systems.

Flow Records at Yolo

The pattern of annual peaks flows at Yolo shown in Figure 3.3-8 is curious: in the 37-year period from 1903-1939, no flows exceeded 22,000 cfs, while in the 54-year period from 1940-1993, there were 14 floods greater than this value. Ruling out climate change, two possible explanations suggest themselves: errors or changes in gauging procedure, or, a change in the way flood waters are transmitted downstream through the study reach. USGS field office staff suggested three possible explanations (or combined explanations) for the unusual flow record:[11]

- Changes in operating criteria for regulation of Clear Lake (the outlet channel of Clear Lake was deepened in 1940).
- Under-reporting of peak discharges during the period prior to 1930 when the Yolo gage was non-recording.
- Bypasses of flood flows around the gage, not accounted for in records prior to 1940.

The third explanation listed above is supported by the fact that the 1940 and 1942 floods are the first reported as including "estimated overflow." Estimated overflow accounted for a relatively large percentage of the total flow in those years, being 26 and 18 percent, respectively of the reported peaks. This explanation appears to be the most plausible of the explanations, but definite conclusions are not possible. The flow records may reflect a combination of all suggested explanations, with the potential effects of channel incision and subsidence contributing to more recent gage shifts. In any case, the flow records are thought to underestimate flood peaks prior to 1940, and flood frequency relationships based on these data may be incorrectly low. It is not known how this anomaly might effect the Corps of Engineers flood flow frequency curves for Yolo, or if similar unexplainable limitations may exist in some of the early flow records at Rumsey or Capay. Again, this is beyond the scope of the present investigation and further refinement of these issues needs close coordination with the USGS, DWR and Corps of Engineers.

Sediment Yield

Best-fit lines through USGS[12] published suspended sediment loads plotted against discharge generated the flowing relationships: $Q_s = 0.00018Q^{2.2}$ for flows less than 6,000 cfs, and $Q_s = 0.2Q^{1.4}$ for flows greater than 6,000 cfs where Q_s = sediment discharge and Q = water discharge. Figure 3.3-12 presents the resulting suspended load-water discharge rating curve. Similar relationships were developed for bedload transport rates plotted against discharge (Figure 3.3-13). The USGS[13] collected relatively few bed load measurements and the data show considerable scatter, even when eight points estimated by the USGS are added to the 6 points calculated from bedload measurements. Also shown on Figure 3.3-13 is a line for the bedload transport relation obtained as an average of 6 percent of the measured suspended load. Information from the USGS[14] and Division of Mines and Geology[15] indicate that bedload may vary from 1 to 12 percent of the total load, depending on antecedent basin conditions and individual flood characteristics. Because there were so few bedload samples, we chose to calculate bedload as a fixed percentage of suspended load as documented by Harmon[16] and Lustig and Busch.[17] We then applied the suspended and bedload transport functions to each mean daily flow for each annual runoff period and summed the annual totals.

NHC estimates the average annual total sediment supply to the study reach above Capay to be about 927,600 tons, of which about 114,000 tons is sand and 49,000 tons is gravel. These estimates come from the combined application of the suspended and bed load curves shown in Figures 3.3-12 and 3.3-13 to published mean daily flow records from 1943 through April, 1995. Table 3.3-5 lists the average annual sediment yields that were calculated for each of the 53 years of record that were analyzed. It is apparent that specific annual sediment production from the basin may vary significantly from year to year depending on the magnitude and duration of annual flows and changing watershed conditions. The average annual basin yield to the upstream end of the Streamway Study reach near Capay Dam was estimated by averaging all of the annual values for the 53 year period.

Summing the estimated sand and gravel loads in Cache Creek near Capay from 1943-1995 indicates that the cumulative total loads of sand and gravel over the past 53 years is approximately nine million tons. The cumulative annual load values for each size classification (fines, sands and gravels) is listed in the last three columns on the right in Table 3.3-5. Figure 3.3-14 presents the cumulative sand and gravel yield (in tons) for Cache Creek near Capay estimated for this investigation. The values shown do not include contributions to the total load from fine silts or clay materials. Another approximate 40 million tons of fine materials are estimated to have been transported trough the system since 1943. Fine material load effects the sediment transport characteristics of the creek but does not contribute significantly to aggradation processes in the study reach.

We compared our basin-wide estimates with observed annual yields from similar east-draining Coast Range basins and published Soil Conservation Service's Regional Sediment Yield Rate Maps for California.[18] The SCS yield maps show approximately 0.39 Ac-Ft/Sq mi/yr for the Cache Basin area. This is equivalent to approximately 879,200 tons of sediment per year from

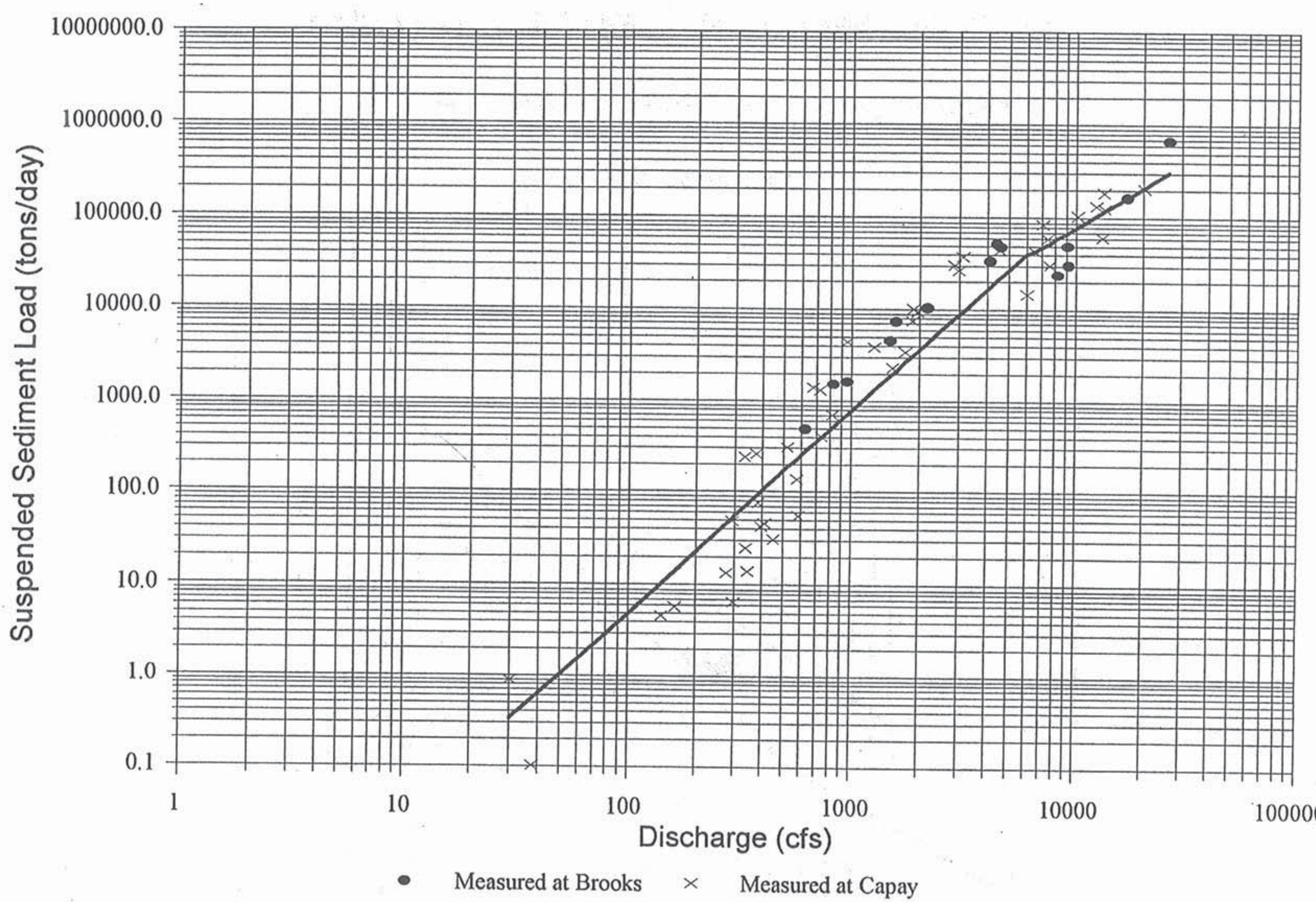


Figure 3 3-12. Suspended Sediment Rating Curve for Cache Creek Based on Samples Measured at Capay and Brooks

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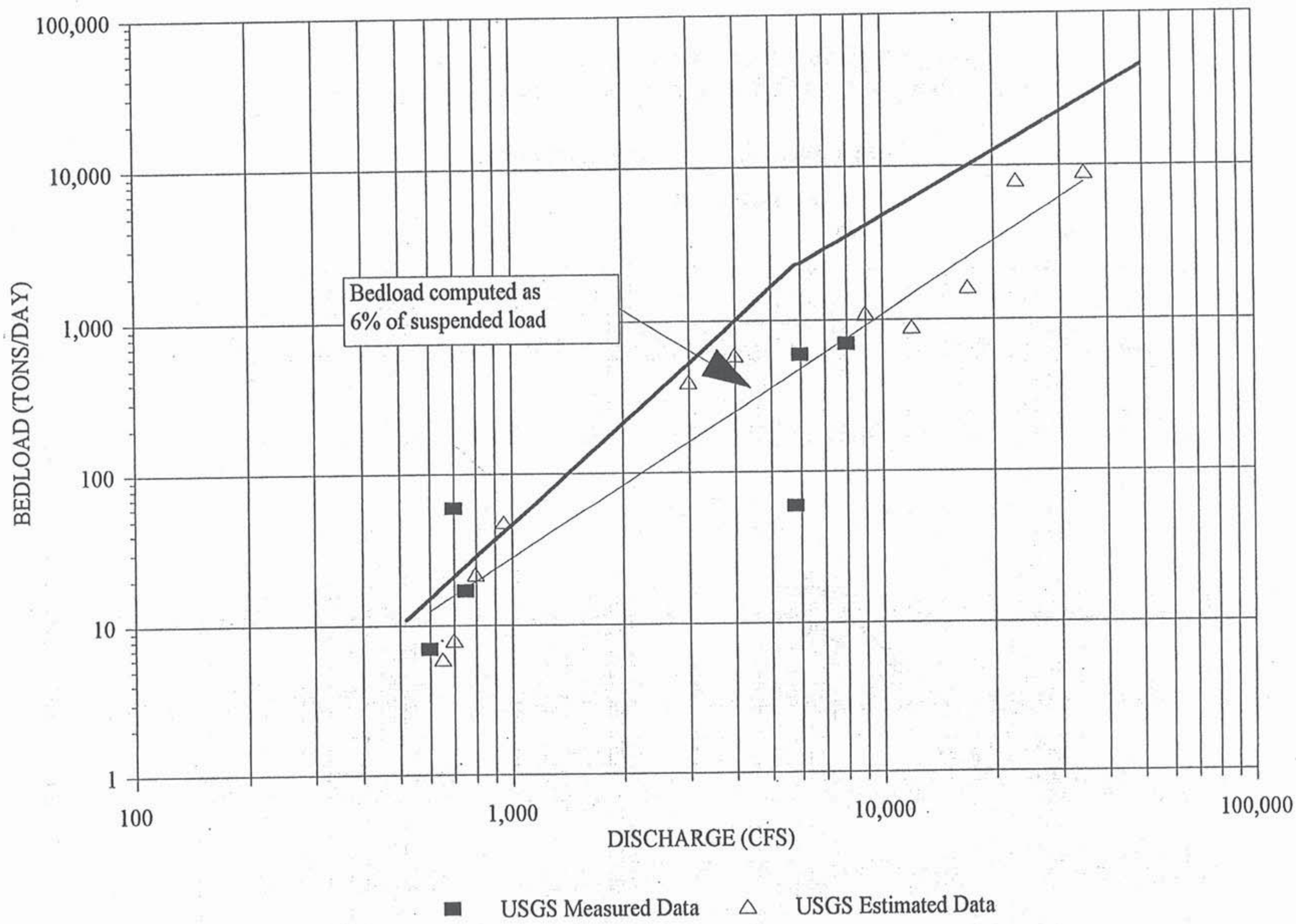

Figure 3.3-13 Bedload Rating Curve for Cache Creek at Brooks

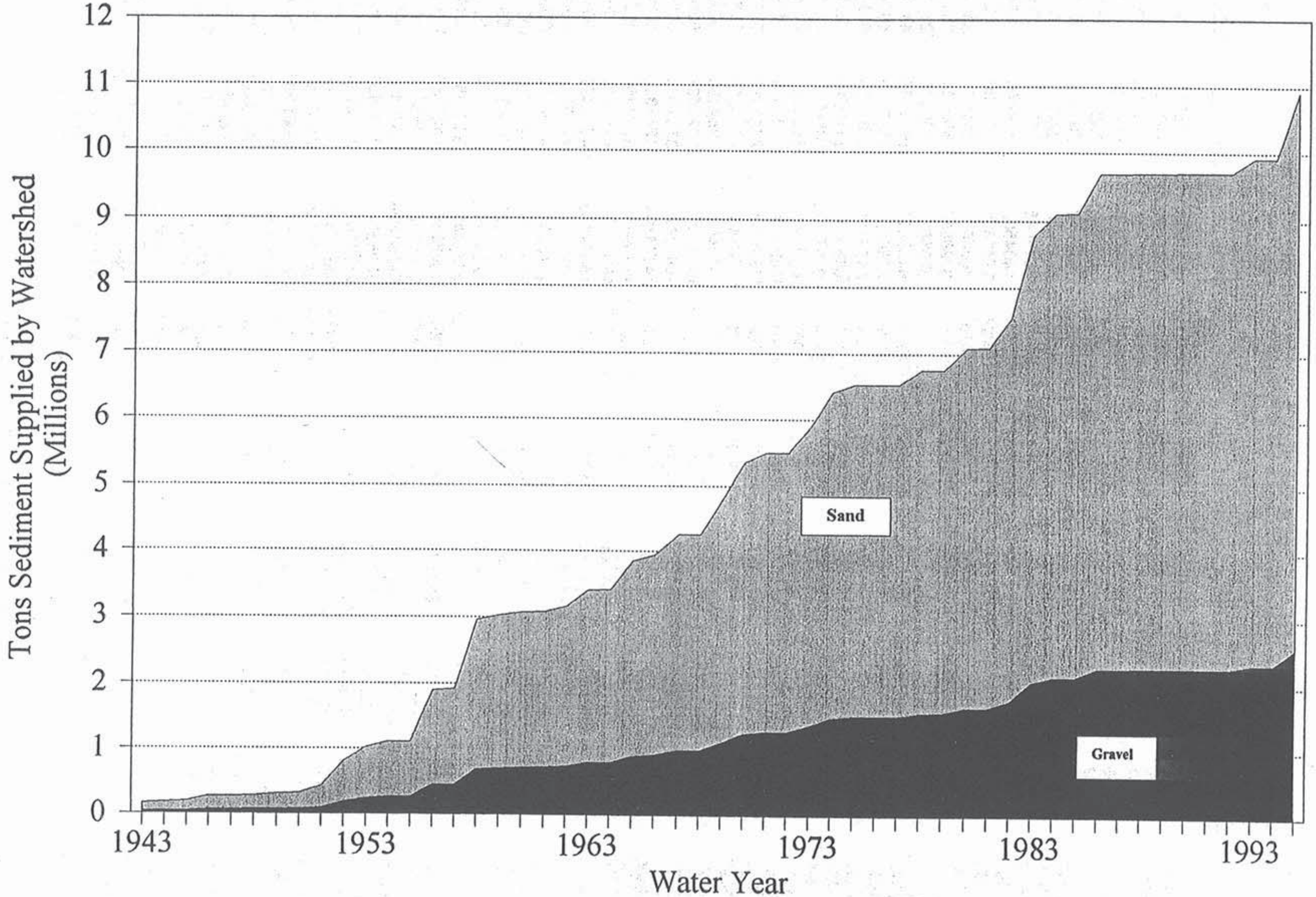

Figure 3.3-14 Cumulative Sand & Gravel Yield for Cache Creek near Capay

Table 3.3-5 Estimated Annual Sediment Loads

Year	Estimated Annual Sediment Loads						Cummulative Sediment Load Break Down		
				Break Down					
	Total Suspended Load (tons)	Total Bed Load (tons)	Total Load (tons)	Fines D<0.062mm (tons)	Sand 0.062<D<2.0 (tons)	Gravel D>2.0mm (tons)	Cumulative Fines D<0.062mm (tons)	Cumulative Sand 0.062<D<2.0 (tons)	Cumulative Gravel D>2.0mm (tons)
1943	627849	37671	665520	514836	115273	35411	514836	115273	35411
1944	70641	4238	74879	57925	12970	3984	572762	128243	39395
1945	71398	4284	75682	58547	13109	4027	631309	141352	43422
1946	315931	18956	334887	259064	58005	17819	890372	199357	61240
1947	14786	887	15673	12124	2715	834	902496	202071	62074
1948	32021	1921	33942	26257	5879	1806	928753	207950	63880
1949	113076	6785	119860	92722	20761	6377	1021476	228711	70258
1950	46792	2808	49600	38370	8591	2639	1059845	237302	72897
1951	420386	25223	445609	344717	77183	23710	1404562	314485	96606
1952	1630180	97811	1727991	1336748	299301	91942	2741309	613786	188549
1953	911706	54702	966408	747599	167389	51420	3488908	781175	239969
1954	375546	22533	398079	307948	68950	21181	3796856	850125	261150
1955	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3796856	850125	261150
1956	3272946	196377	3469323	2683816	600913	184594	6480672	1451038	445744
1957	92631	5558	98189	75957	17007	5224	6556629	1468045	450968
1958	4352638	261158	4613796	3569163	799144	245489	10125792	2267190	696457
1959	285764	17146	302909	234326	52466	16117	10360118	2319656	712574
1960	166999	10020	177019	136939	30661	9419	10497057	2350317	721993
1961	35589	2135	37725	29183	6534	2007	10526241	2356851	724000
1962	363132	21788	384920	297768	66671	20481	10824009	2423522	744481
1963	1026526	61592	1088117	841751	188470	57896	11665760	2611992	802377
1964	25697	1542	27239	21072	4718	1449	11686832	2616710	803826
1965	1838121	110287	1948408	1507259	337479	103670	13194091	2954189	907496
1966	393869	23632	417501	322972	72314	22214	13517063	3026503	929710
1967	1287512	77251	1364763	1055760	236387	72616	14572824	3262891	1002326
1968	2400	144	2543	1968	441	135	14574791	3263331	1002461
1969	2237632	134258	2371890	1834858	410829	126202	16409649	3674160	1128664
1970	2329205	139752	2468957	1909948	427642	131367	18319597	4101802	1260031
1971	613704	36822	650527	503238	112676	34613	18822835	4214479	1294644
1972	4802	288	5090	3937	882	271	18826772	4215360	1294915
1973	1628787	97727	1726514	1335605	299045	91864	20162377	4514405	1386778
1974	2162576	129755	2292330	1773312	397049	121969	21935690	4911454	1508747
1975	519449	31167	550616	425948	95371	29297	22361638	5006825	1538044
1976	3426	206	3631	2809	629	193	22364447	5007454	1538238
1977	9	1	10	7	2	1	22364454	5007456	1538238
1978	852069	51124	903193	698696	156440	48057	23063151	5163896	1586295
1979	25831	1550	27381	21181	4743	1457	23084332	5168638	1587752
1980	1398777	83927	1482704	1146997	256815	78891	24231329	5425454	1666643
1981	30871	1852	32724	25314	5668	1741	24256644	5431122	1668384
1982	1858344	111501	1969844	1523842	341192	104811	25780486	5772314	1773194
1983	5113482	306809	5420291	4193055	938835	288400	29973541	6711149	2061595
1984	1397796	83868	1481664	1146193	256635	78836	31119733	6967784	2140430
1985	11999	720	12719	9839	2203	677	31129572	6969987	2141107
1986	2433364	146002	2579366	1995358	446766	137242	33124931	7416753	2278349
1987	14099	846	14945	11561	2589	795	33136492	7419341	2279144
1988	38711	2323	41033	31743	7107	2183	33168235	7426449	2281327
1989	11331	680	12011	9291	2080	639	33177526	7428529	2281966
1990	2604	156	2760	2135	478	147	33179661	7429007	2282113
1991	23039	1382	24421	18892	4230	1299	33198553	7433237	2283413
1992	6615	397	7012	5425	1215	373	33203978	7434452	2283786
1993	861431	51686	913116	706373	158159	48585	33910351	7592610	2332370
1994	10475	628	11103	8589	1923	591	33918940	7594533	2332961
1995	4138912	248335	4387246	3393908	759904	233435	37312848	8354438	2566396
Average	875,067	52,504	927,571	717,554.8	160,662.3	49,353.8			

the basin, which is within five percent of the NHC estimated annual yield. Lustig and Bush[19] measured suspended sediment yield from the basin for a four-year period. Their average annual sediment yield (estimated up by six percent to account for unmeasured bed load) is approximately 879,800 tons, again within five percent of the NHC estimate. The average annual sediment yield estimates for total load and the amount of sands, gravels and fines comprising the total load are summarized below.

Summary of Estimated Annual Sediment Yield at Capay

Estimated **Annual Sand Load** at Capay	160,700 tons
Estimated **Annual Gravel Load** at Capay	49,400 tons
Estimated **Annual Fine Materials** Load	717,600 tons
Estimated **Total Annual Yield** at Capay	927,600 tons

Aggregate Extraction

Figure 3.3-15 presents estimated annual Cache Creek aggregate extraction/production rates for the period 1929 to 1994. This figure provides general overview of gravel extraction from Cache Creek using both published (DMG) production records and Yolo County extraction records. These data are subject to the following limitations associated with the available data:

- Recent excavation records (after 1960) are specific to Cache Creek between Capay Valley and Yolo. Production amounts include the county as a whole, including minor production below Yolo on Cache Creek and on Putah Creek.

- The production amounts are for sand and gravel and therefore do not include fine material excavated with the aggregate.

- Excavation is reported in the year extracted from the creek, but production is reported in the year the aggregate is processed and sold, which may be delayed from the year in which it was extracted.

- Rapp (1975) [20] reports that 1 million T/year is mined in Yolo County and is reported as Sacramento production quantities.

- Historical evidence (such as the ca. 1879-1905 railroad spur into gravel mining pits near Capay) suggests that aggregate extractions were substantial in earlier years as well, but data are lacking.

Figure 3.3-16 summarizes the reported annual production and extraction data shown in Figure 3.3-15 into the cumulative extraction estimate for the period 1919 to 1994. More than 90 millions of aggregate may have been mined from Cache Creek in the 75-year period since 1919.

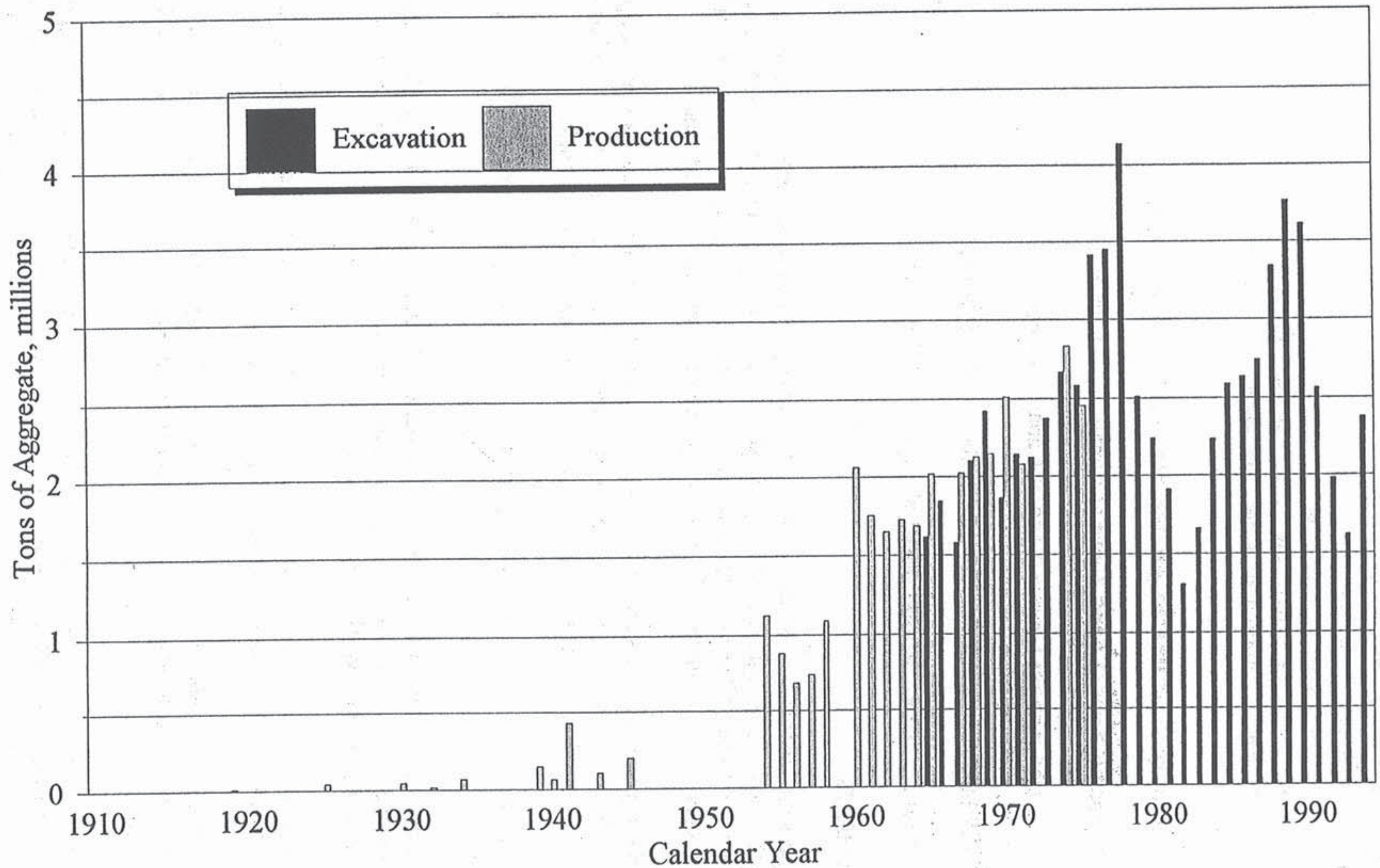

Figure 3.3-15 Cache Creek Aggregate Extraction/Production, 1919 -1995
(Source: David Keith Todd Engineers)

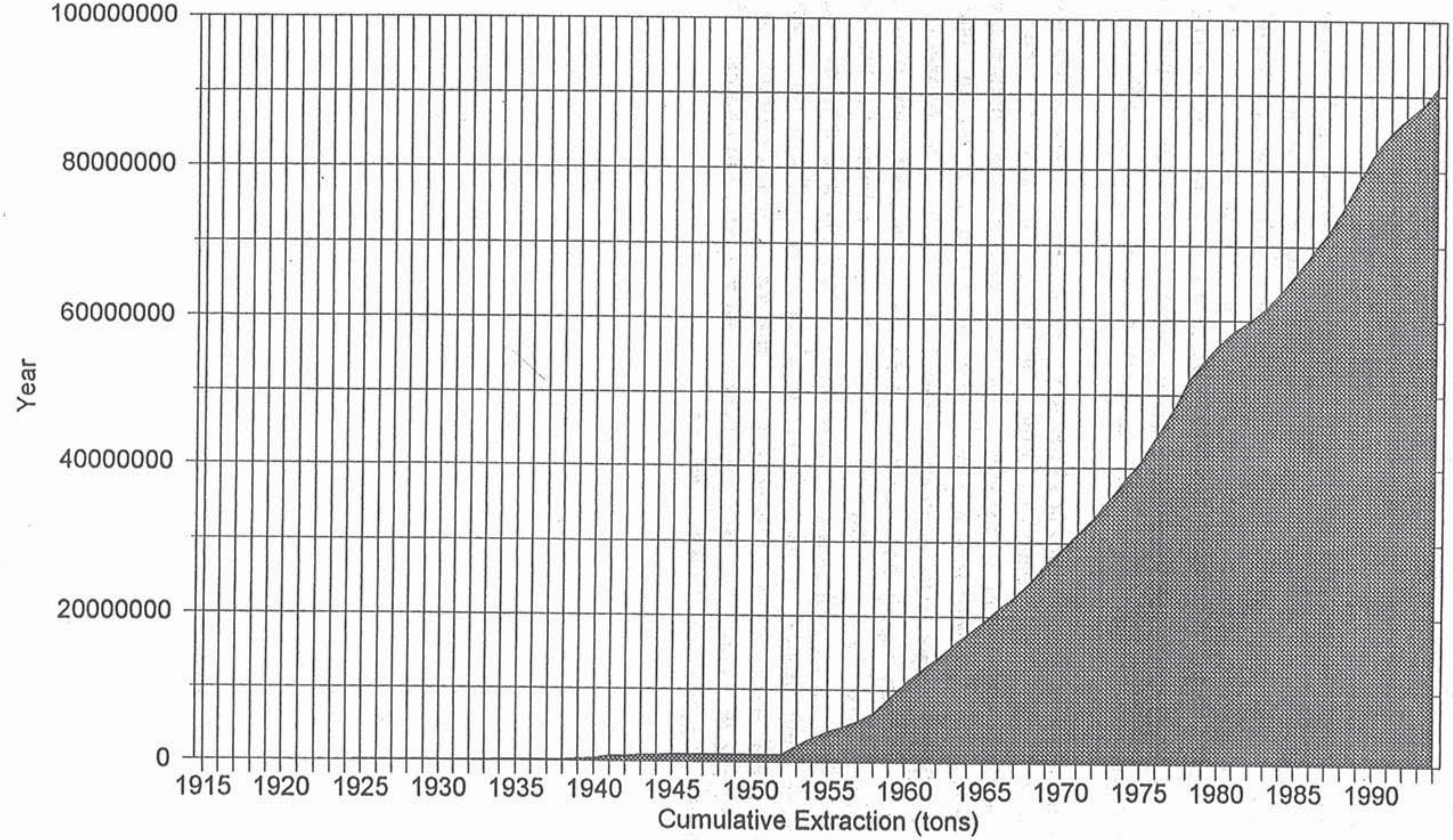

Figure 3.3-16 Cumulative Extraction, Cache Creek from 1919 to 1994

The cumulative sand and gravel loads supplied from the watershed area above Capay were estimated by applying the annual load relationships developed in Section 3.3-5 (see Figures 3.3-12, 3.3-13 and Table 3.3-5) with published mean daily flow records since 1943. Figure 3.3-14 shows the cumulative sand and gravel load estimates supplied from the watershed up to 1994.

If the cumulative extraction volumes (see Figure 3.3-16) are compared to the annual watershed supply volumes (see Figure 3.3-14), the net deficit in stream bed deposits over time (supply minus extraction) is estimated (see Figure 3.3-17). Figure 3.3-18 shows the cumulative change in stream bed sediment storage for Cache Creek below Capay. Since about 1952 more aggregate materials were mined from the 15-mile mining reach than are supplied annually from the watershed. According to Kondolf, 1994,[21] these extraction rates and cumulative volumes represent approximately five percent of the total aggregate produced in the State of California.

If it is assumed that all aggregate mining in the study reach were to cease in December of 1994 and that all sand and gravel materials that come from watershed supply upstream from Capay during future runoff events would be trapped in the existing excavated channel areas with 100 percent trap efficiency, it would take approximately 505 years to regain the sand and gravel volume deficit. This is graphically depicted in Figure 3.3-18. Such an expanding cumulative aggregate deficit between supply and extraction prevents the re-establishment of the dynamic equilibrium between river flow and sediment load. A prolonged imbalance of this magnitude can contribute to severe local as well as regional (reach averaged) channel changes (e.g., streambed lowering, bridge undermining, stream bank instability and impacts to riparian habitat). Consequently, it may not be practical or possible to "manage" Cache Creek back to geomorphic conditions similar to those observed forty years ago. Realizing these limitations is important for the development of future management practices.

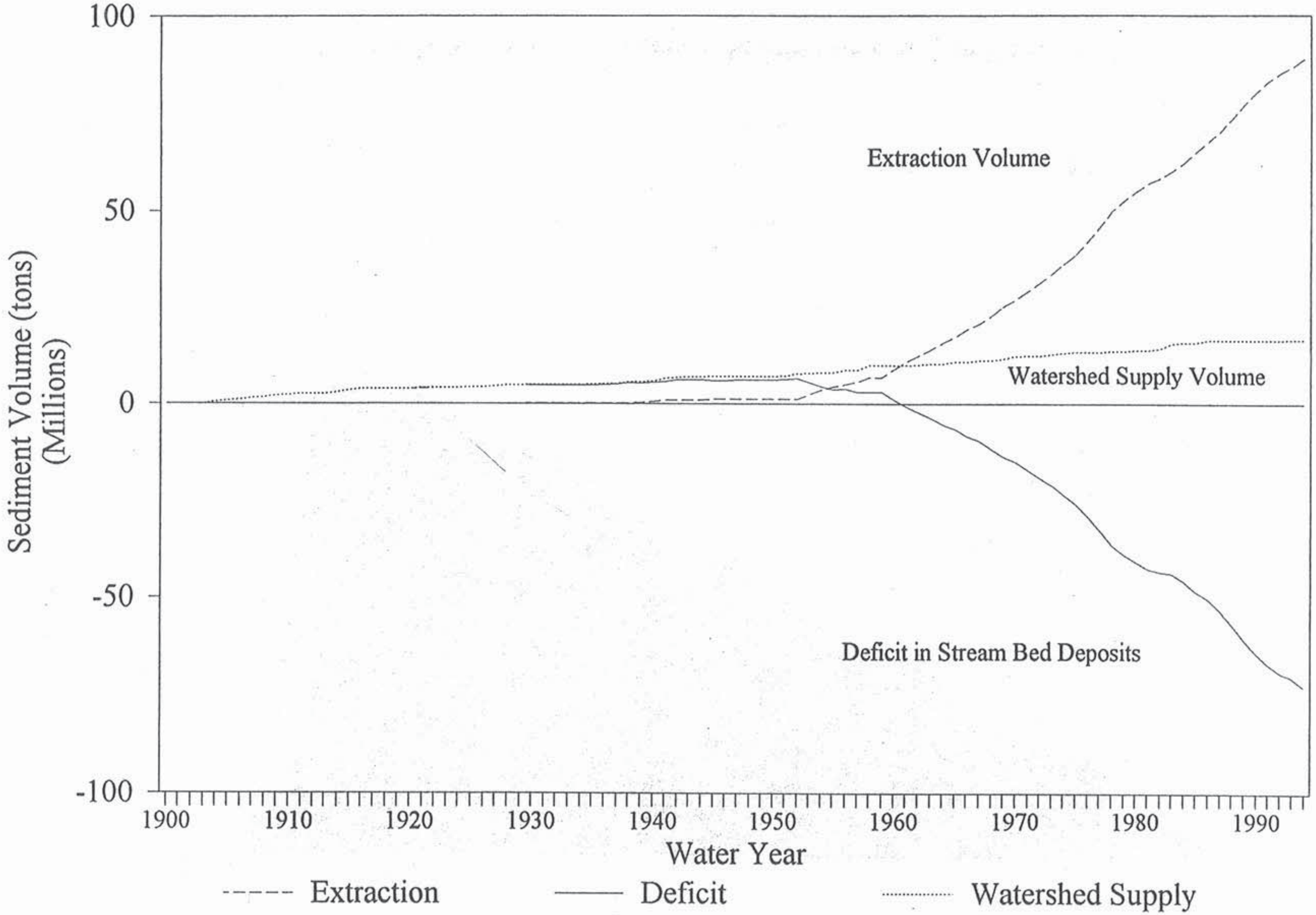

Figure 3.3-17 Cumulative Change in Stream Bed Sediment Storage
Cache Creek below Capay

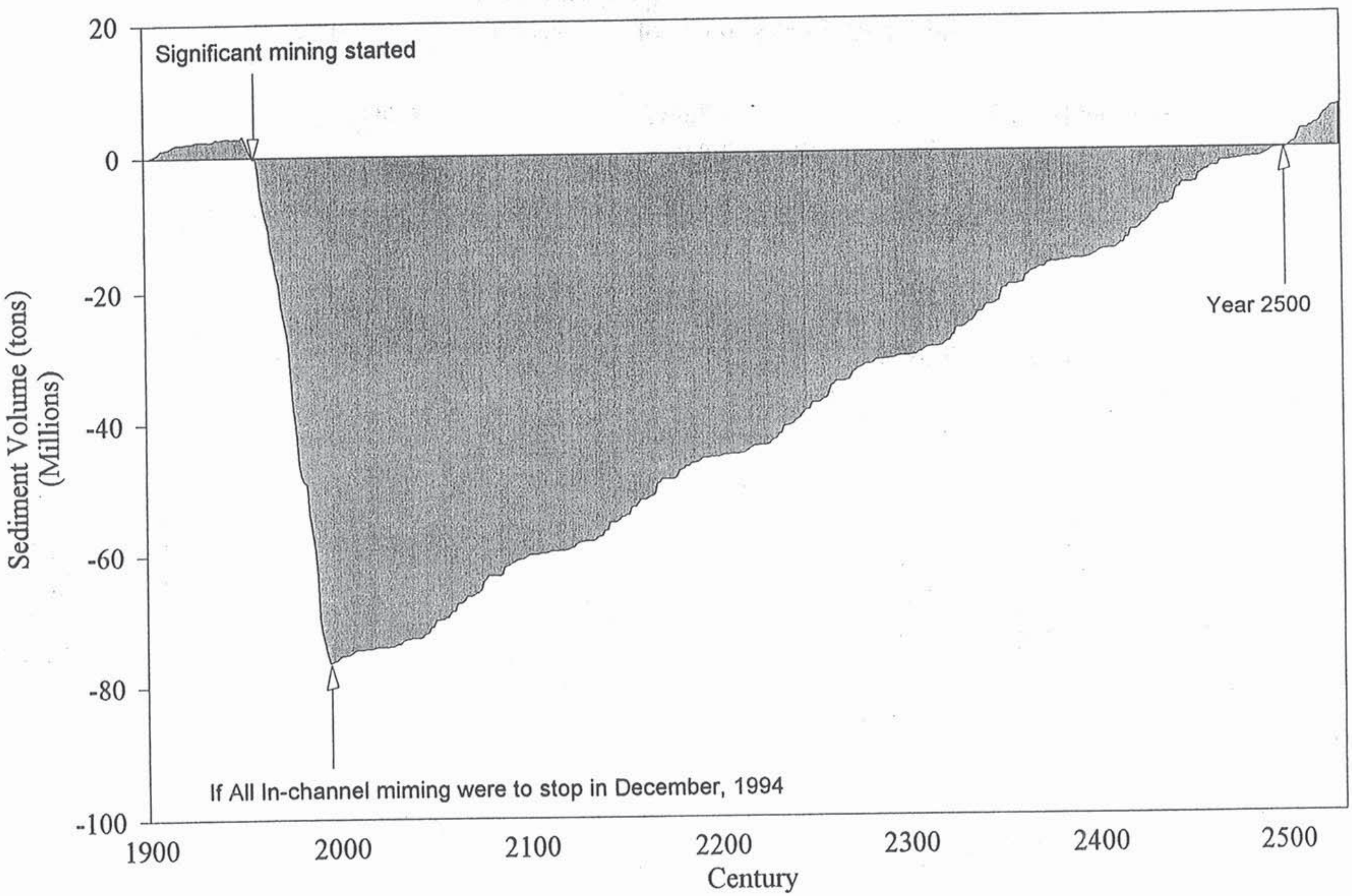

Figure 3.3-18 Projected Change in Stream Deposits With No Extraction

ENDNOTES

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