APPENDIX C

# HYDROLOGY APPENDIX FOR
# LOWER CACHE CREEK FEASIBILITY STUDY
# YOLO COUNTY, CALIFORNIA

March, 2001

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

# AN EXECUTIVE SUMMARY FOR CACHE CREEK HYDROLOGY

This paper presents a summary of some main points presented in the Hydrology Appendix. It describes the watershed, streamgage records, historic flooding, and a discussion of past and present hydrologic studies.

Basin Description: The Cache Creek Basin drains 1139 $mi^2$ of land upstream of the Highway 5 Bridge. The watershed contains two major reservoirs, Clear Lake and Indian Valley Dam. Almost half of the entire watershed (528 $mi^2$) drains into Clear Lake. The Clear Lake outlet consists of a narrow channel, which meanders about 5 miles before reaching Clear Lake Dam. Within this narrow channel is a natural constriction called the Grigsby Riffles, which typically restricts the outflow from Clear Lake to about a maximum of 5,000 cfs during the largest floods. The Grigsby Riffles makes Clear Lake a natural flood control structure that greatly reduces the amount of flooding on lower Cache Creek. Excluding the Clear Lake drainage area, Cache Creek consists of 611 $mi^2$ of drainage. Within this 611 $mi^2$, Indian Valley Dam on the North Fork of Cache Creek, regulates 121 $mi^2$ or 20% of the area. The bulk of the water that causes flooding on lower Cache Creek comes from the 490 $mi^2$ of unrestricted watershed below Clear Lake and Indian Valley Dam. The Rumsey streamgage, a key analysis point in this study, has a total drainage area of 960 $mi^2$, of which 311 $mi^2$ is unregulated. The Rumsey gage is therefore effected by 63% of the drainage area (311 $mi^2$/490 $mi^2$) that contributes unregulated flow to County Road 94B.

Streamgage Records: Important streamgages on lower Cache Creek include the Rumsey gage (36 miles upstream of Highway 5, 1961 - present), Capay gage (20 miles upstream of Highway 5, 1942 – 1976), and the Yolo gage (located at the Highway 5 Bridge crossing, 1907 – present). The Yolo gage information is somewhat useless for analyzing floods that exceed 36,000 cfs (flow rate that overtops the existing channel banks). Overbank flow and flooding, in locations between Road 94B and the Highway 5 bridge, cause this gage to measure less than the total runoff for large events. Storms that have exceeded this flow include the years 1958, 1965, 1983, 1995 and 1997. When comparing historic flood events, it is important to note that Indian Valley Dam did not start operation until June of 1974. This causes the period of record of some gages to be non-homogenous. Recorded flow measurements can be viewed on Table 4, page 6, of Appendix C.

Floods: The City of Woodland was incorporated in 1871 and has never been flooded. There are several explanations for this fact: 1) A likely reason is that lower Cache Creek has not experienced a 1% chance exceedence flood since the city was built. It is possible that a 1% chance exceedence flood (1/100 probability of occurrence each year) may not occur within a hundred-year period. Statistically, there is only a 63% chance that a flood of this magnitude will occur in any given century. 2) Another reason is that conditions on the creek and in the City of Woodland have changed over the years. The city of Woodland had a smaller footprint in the past and areas once vacant are now developed.

Areas that flooded in the past (1983) are now inside the city limits. It is also theorized that in the early part of the century, flows might have overtopped the channel farther upstream and followed a path that took it away from the City of Woodland – like the drainage path of the Willough Slough to the south (from reference #1 in Hydrology Appendix, page 12). Gravel pit mining and streambed erosion have increased the carrying capacity of the creek so that more water reaches lower Cache Creek during big storms than occurred in the past. It is also known that the first half of this century was relatively dry while the last half has been relatively wet. While out-of-bank flows just upstream of Yolo used to flow eastward into the Yolo Bypass, they are now partially diverted south into the City of Woodland by Interstate 5. Additionally, out-of-bank flows that reach the Cache Creek Settling Basin are forced south into the east side of the city by the new (1990) west levee of the settling basin. 3) The potential for flooding in Woodland has occurred numerous times. The fact that it hasn't is partly due to circumstance and flood-fighting efforts. Despite intense flood-fighting and sandbagging efforts, the January 1983 flood caused the south levee to break to the east of Road 102. Six hundred acres of farmland were flooded to the east of the city, but the damages might have been worse if the levee had failed farther upstream, putting the water in a more direct path towards the City of Woodland. The March 1995 flood overtopped the levee upstream of the Interstate 5 Bridge and resulted in the city declaring a State of Emergency and advising voluntary evacuation of properties north of Woodland Avenue. The water moved south along Highway 5, flooding hundreds of acres before the water came to a stop at the edge of a developed portion of the city. The extent of flooding would have been worse if the south levee had failed rather than just being overtopped because this would have decreased channel capacity from 36,000 cfs to between 20,000 - 25,000 cfs (as determined by MBK Engineers). In addition, while the peak flow at Road 94B had a 2.5% chance exceedence (40-year return period), the 72-hour volume was determined to only be a 5% chance (20-year return period). More volume would have resulted in Woodland being flooded.

Past Studies: Studies conducted by the Corps on Lower Cache Creek include reports published in 1974, 1985, 1994, and 1995. A table comparing the results of each study is shown in Table 1 for the Capay gage location. The hydrology has changed very little since the 1985 Study.

Table 1. Example Flow- and Volume-Frequency Values at Capay Gage Site

| Study | 2% chance (50-yr) **peak** | 1% chance (100-yr) **peak** | 0.2% chance (500-yr) **peak** | 2% chance (50-yr) **72-hour** | 1% chance (100-yr) **72-hour** | 0.2% chance (500-yr) **72-hour** |
|---|---|---|---|---|---|---|
| 1974[(1)] Study | 42,000 | 47,000 | 58,000 | Not in report | Not in report | Not in report |
| 1985 Study[(2)] | 51,000 | 58,000 | 75,000 | 25,000 | 28,500 | 37,500 |
| 1994 Westside Tributaries | 55,500 | 62,000 | 79,000 | 30,500 | 34,000 | 43,000 |
| 1995 Re-Evaluation | 55,000 | 61,000 | 74,000 | 30,000 | 34,500 | 44,500 |
| 2002 Feasibility | 51,500 | 61,500 | 75,000 | 25,500 | 32,500 | 42,500 |

Notes:
- Capay gage was discontinued in 1976. Values shown in table may be calculated by means other than a frequency curve (such as a rainfall-runoff simulation model).
- All values in this table include effects of Indian Valley Dam operation. Capay is downstream of the dam.
(1) The 1974 Study used a rainfall-runoff model with a storm centered above Indian Valley Dam. Studies after 1983 have used a storm centered over the unregulated area below Clear Lake and Indian Valley Dam - similar to the Jan. 1983 storm. Modeling determined that this centering causes higher peak flows on Lower Cache Creek.
(2) Volume-frequency values from the 1985 Study are 3-day values from a frequency analysis using mean daily flows, not 72-hour values.

Two recent studies by private engineering firms include the following: 1) Hydrology Report, Flood Insurance Restudy, Cache Creek, October 1997, A&M Consultants of California. This study analyzed previous Corps of Engineer studies and concluded that the 1995 Corps hydrology was acceptable for use by FEMA to create floodplain maps. 2) In 2000, an engineering firm (Norman S. Braithwaite, Inc.) determined the 1% chance exceedence peak flow for the design of a new Road 99 Bridge near Yolo should be 67,000 cfs.

Corps of Engineer studies included the use of a computer-based rainfall-runoff model of the entire basin. Model parameters such as soil loss rates were adjusted by calibrating the model to observed storms (large storms in which rainfall and the corresponding runoff were recorded). The Rumsey and Capay gages were important calibration points. After calibration, hypothetical rainfall of a given frequency like the 1% chance exceedence storm is input into the model to produce runoff in the form of hydrographs

(graphs of flow rate versus time). Flow frequency curves, based upon a statistical analysis of streamgage records, are used to verify the results of the model at specific locations in the watershed.

Feasibility Study: In this latest study, the analysis included a review of previous studies, the generation of new frequency curves at Rumsey, and modification of model parameters for subbasins downstream of the Rumsey gage. A new family of unregulated flow frequency curves was derived for the Rumsey gage using the latest available information (including the January 1997 storm). Unregulated flow data allows the generation of statistical frequency curves – useful for the prediction of rare floods. The new curves were used to verify the model hydrographs produced at Rumsey. Only the 2% event needed adjustment. Farther downstream, the Capay gage, discontinued in 1976, had no new data available for a new frequency curve. The creation of a frequency curve at Yolo is not useful since the gage does not record all the runoff during large floods exceeding 36,000 cfs. Model parameters downstream of Rumsey were re-evaluated using overlapping recorded events for the Rumsey, Capay and Yolo gages. The analysis included the development of regression equations that predict the relative increase in volume of water (upstream to downstream) during a storm. Channel bed loss rates were added and constant rainfall loss rates increased for these areas when the analysis indicated that the model was producing too much volume. Muskingum flow routing parameters, which affect the timing and peak of the hydrograph as it moves downstream were revised based on a review of historic attenuation in this reach. Finally, the reservoir operation of Indian Valley Dam was put back into the HEC-1 model to get hydrographs representing existing conditions. The model changes resulted in a 1% chance exceedence event that has the same approximate peak flow and 6% less volume (72-hour volume) than the 1995 Study (comparison at the Capay index point). Although no gage exists at Road 94B, a regulated frequency curve was generated for this location since it represent the point of input of the HEC-1 design hydrographs into MBK Associates UNET model (hydraulic model for routing flows to determine areas of levee overtopping and failure). The HEC-1 model produces a 1% chance flood at Road 94B that has a peak of 63,500 cfs and a maximum 72-hour volume of approximately 217,000 acre-feet.

In conclusion, studies conducted by the Corps since 1985 have not resulted in significant changes to the hydrology. Floods threatened the City of Woodland in 1983 and 1995 and this threat still exists. It is believed that the hydrology presented in the Hydrology Appendix is sufficient for the design of proposed alternatives with the purpose of protecting the City of Woodland and surrounding areas from flooding.

TABLE OF CONTENTS

TABLE OF CONTENTS

## List of Tables



## List of Charts

## 1. Purpose of Report

The purpose of this appendix is to provide a feasibility level analysis of the hydrology for Lower Cache Creek, Yolo County, California. The study reach extends from Cache Creek at Road 94B down to the Cache Creek Settling Basin, where Cache Creek has its confluence with the Yolo Bypass of the Sacramento River, about 17 river miles. Key products of the analysis include: a) a family of regulated frequency curves for Cache Creek at Road 94B, and b) synthetic hydrographs of the 2%, 1%, 0.5%, and 0.2% chance exceedence flows on Cache Creek at Road 94B.

## 2. Discussion

**2.1 General.** The Lower Cache Creek Feasibility Study will analyze proposed project alternatives designed to reduce the flood risk to property and communities within the study reach, including the City of Woodland. Hydrographs of the 2%, 1%, 0.5%, and 0.2% (1 in 50, 1 in 100, 1 in 200, and 1 in 500) chance exceedence events were produced for the index point called 'Cache Creek at Road 94B' using a calibrated rainfall-runoff model (HEC-1). The hydrologic analysis for the Feasibility Study included: 1) review of previous hydrology reports for this watershed, 2) creation of updated unregulated flow frequency curves, 3) review and modification of the existing Corps of Engineers HEC-1 model for Cache Creek, 4) creation of design hydrographs for specific frequencies, and 5) creation of regulated frequency curves.
It is important to understand that the probability of a certain size flood is independent of what happened in previous years. The 1% chance exceedence flood has a 1 in a 100 chance of happening this year, even if a flood of similar size occurred last year.

**2.2 Previous Studies.** Many studies have been done either on portions or on the entire Cache Creek watershed, which is over 1,000 square miles in area. The following studies are listed for reference:

1. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Standard Project Floods," May 1974.

2. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Feasibility Report and Environmental Statement for Water Resources Development," February 1979.

3. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Hydrology Review Report," March 1985.

4. U.S. Army Corps of Engineers, Sacramento District, "Final General Design Memorandum, Cache Creek Basin (Outlet Channel)," California, July 1990.

5. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Feasibility Report and Environmental Statement for Water Resource Development," February 1992.

6. U.S. Army Corps of Engineers, Sacramento District, "Westside Tributaries to Yolo Bypass, California," Reconnaissance Report, June 1994

7. U.S. Army Corps of Engineers, Sacramento District, "Hydrology for Cache Creek, Yolo County, California," August 1995.

8. A&M Consultants of California, San Diego, CA, "Hydrology Report for Yolo County, California and City of Woodland, California," February 1997.

## 3. Basin Description

**3.1 General.** Cache Creek basin is located about 100 miles northeast of San Francisco in the coastal mountain ranges. Clear Lake, the prominent feature of the basin, is the largest natural body of fresh water entirely within the State of California. Cache Creek drains about 1,139 square miles. See Chart 1 for a general map. The outlet of Clear Lake is the origin of Cache Creek, which flows generally northeast about 8.5 miles to the confluence with its North Fork, through Capay Valley, south to the irrigation dam at Capay, north past the town of Yolo, and east and south into the Cache Creek settling basin before finally flowing into the Yolo Bypass. The watershed contains many diversion dams and reservoirs of various sizes. Clear Lake Reservoir and Indian Valley Dam contain the two largest bodies of water in the watershed and have a significant influence on the flows on Lower Cache Creek. A more detailed description of the operation of the two reservoirs is explained in Section 4.4.

**3.2 Vegetation and Land Use.** Vegetation in upper Cache Creek consists mainly of deciduous trees and brush, such as blue oaks and chaparral. In middle elevations, riparian forest and valley oaks predominate. Irrigated crops, orchards, and vineyards occupy the lower elevations. Most of the basin is undeveloped. Primary land use includes national forest, recreation, grazing and agriculture. Future development of the watershed is not expected to be significant.

**3.3 Topography.** The topography of the basin varies from steep, rugged hill slopes of the Coast Ranges to the gentle slopes of the valley floor, beginning near Capay, located on the western edge of a large alluvial plain. The elevation ranges from 6,120 feet at Goat Mountain on the northern basin perimeter to nearly sea level near Yolo. Chart 2 shows the topography of the basin. Chart 3 shows the channel profile.

**3.4 Geology.** The geology of the basin consists of the Franciscan formation, which forms the core of much of the Coast Ranges. Rock outcrops of this formation can only be found in the upper part of Cache Creek Basin and consist of marine sedimentary and volcanic rock. To the east of Clear Lake and in the central portion of the basin, rocks are predominantly of massive sandstone with imbedded conglomerates and silty shales. Continental deposits in the lower portion of the basin consist of clay, sand, and gravel, and occur as discreet units and heterogeneous mixtures. The younger overlying alluvium is similar and generally not as coarse as the continental deposits. Underground aquifers underlie the valley portion of the basin downstream from Rumsey. The size and extent of these aquifers are not known. Intensive agriculture, and to a lesser degree the seasonal recreation industry, comprise the main economic features of the basin. State Highways 16, 20, 29, 53 and Interstate Highway 5 are the main traffic arteries.

**Climate.** The climate of the Cache Creek Basin is characterized by cool wet winters and hot dry summers. Temperatures range from slightly below freezing in winters to highs of over 100 degrees Fahrenheit at times during the summer. The climatological stations "Lakeport," "Clear Lake Highlands," and "Brooks Farnham Ranch" are representative of the Lower Creek watershed. The following table (Table 1) from Reference 3 shows the average temperature and precipitation at those stations.

**Table 1. Cache Creek Basin Climatic Data**

| | Station | | | | | |
|---|---|---|---|---|---|---|
| | **Lakeport** El 1347 ft. | | **Clearlake Highlands** El 1365 ft. | | **Brooks Farnham Ranch** El. 294 ft. | |
| Years record | 27 yrs | 71 yrs | 9 yrs | 18 yrs | 45 yrs | 51 yrs |
| Month | Ave Temp F | Ave Precip Inches | Ave Temp F | Ave Precip Inches | Ave Temp F | Ave Precip Inches |
| Jan | 41.2 | 6.18 | 41.8 | 5.85 | 44.8 | 4.06 |
| Feb | 46.7 | 4.90 | 45.0 | 4.46 | 48.5 | 4.10 |
| Mar | 53.7 | 3.36 | 48.1 | 2.13 | 52.9 | 2.63 |
| Apr | 52.4 | 2.03 | 51.5 | 1.84 | 58.2 | 1.31 |
| May | 61.7 | 0.88 | 60.2 | 0.50 | 65.3 | 0.60 |
| Jun | 69.8 | 0.45 | 67.3 | 0.19 | 72.4 | 0.20 |
| Jul | 75.0 | 0.04 | 73.5 | 0.01 | 78.4 | 0.01 |
| Aug | 74.8 | 0.05 | 73.3 | 0.17 | 75.8 | 0.02 |
| Sep | 65.3 | 0.24 | 66.5 | 0.37 | 72.1 | 0.19 |
| Oct | 56.7 | 1.74 | 57.5 | 1.29 | 63.4 | 0.96 |
| Nov | 47.2 | 2.88 | 48.6 | 3.35 | 52.6 | 1.75 |
| Dec | 38.4 | 5.87 | 41.4 | 4.61 | 46.0 | 4.17 |
| Annual | | 28.52 | | 24.77 | | 20.00 |

Normal annual precipitation varies from a minimum of about 17 inches near the community of Yolo, and averages about 32 inches over the watershed. The major portion of the annual rainfall occurs from October through April. Snowfall is very rare and has no significant effect on the streamflow in the basin. See Chart 4 for a normal annual precipitation map.

**Table 2. Normal Annual Precipitation and Maximum Observed Daily Rainfall, Selected Stations and Dates, Cache Creek and Vicinity**

| Station | Elevation (ft) | N.A.P.(1) (in) | Maximum Daily Rainfall (in) (4) (5) Feb 1958 | Jan 1965 | Jan 1983 | Feb 1986 |
|---|---|---|---|---|---|---|
| Bartlett Springs | 2600 | 40.5 (3) | Na | Na | Na | 7.01 * |
| Brooks Farnham Ranch | 294 | 23.0 (2) | 2.55 19th | 1.50 6th | 1.35 24th | Na |
| Capay 4W | 300 | 22.5 (3) | 3.64 * | 1.85 * | 3.86 * | 2.38 |
| Lakeport | 1343 | 28.7 (3) | 2.02 26th | 2.37 5th | Na | 3.97 17th |
| Potter Valley PH | 1084 | 44.8 (3) | 3.83 24th | 2.87 5th | 2.42 26th | 5.09 17th |
| Williams | 90 | 15.5 (3) | 2.24 19th | 1.09 3rd | 1.43 26th | 1.91 13th |
| Woodland 1 WNW | 68 | 17.4 (3) | 2.30 19th | 0.95 6th | 2.04 27th | 1.61 19th |

(1) N.A.P. = Normal Annual Precipitation.
(2) From Cache Creek Basin, California, Hydrology Review Report, Sacramento District Corps of Engineers, March 1985.
(3) From Depth-Duration-Frequency analysis by Jim Goodridge, retired State Climatologist, State of California.
(4) Depending on type of gage, rainfall totals may be one of the following:
a. Recording gage: maximum 24-hour precipitation ending any time on day indicated, or,
b. Non-Recording gage: daily observation of rainfall from gage read one time each day, at a specified time; total for previous 24-hour period.
(5) January 10, 1995 Daily Rainfall at Capay 4W = 3.01 in.

* Day of observation not investigated.
Na = not available

## 4. Runoff

**4.1 Terminology used to describe flood frequency.** The magnitude or size of a flood event is often described in terms of its probability of occurrence in any year (percent chance exceedence). For example, the 1% chance exceedence peak flow at Cache Creek at Road 94B is given as 63,500 cfs (Table 9). This means that this flow rate has a 1% (1 in a 100) chance of being "equaled or exceeded" in any given year at this location. Large flows that exceed channel capacity and cause flooding occur infrequently (low probability). A rule of thumb is that the larger the flood, the smaller the chance that it will occur. For example, a 1% chance exceedence flood (probability of 1 in 100 each year) is larger than a 5% chance exceedence flood (probability of 5 in 100 or 1 in 20). In this appendix, flows and/or floods will be described in terms of percent chance exceedence. A list of commonly referenced events and their associated probability in terms of 1 in "n" chance is listed below.

**Table 3. Exceedence Frequency**

| Percent chance exceedence | Probability of occurrence each year |
|---|---|
| 50% | 1 in 2 chance |
| 10% | 1 in 10 chance |
| 5% | 1 in 20 chance |
| 2% | 1 in 50 chance |
| 1% | 1 in 100 chance |
| 0.2% | 1 in 200 chance |
| 0.5% | 1 in 500 chance |

**4.1 Cache Creek Basin.** Streamflow and lake stage records were obtained from the U.S. Geological Survey (USGS) and the California Department of Water Resources (DWR) for stream gages listed in the following table.

**Table 4. Cache Creek Basin Stream Gaging Stations [(a)]**

| Location | Drainage Area (mi2) | Period of Record Used | Length of Record (yrs) | Ave Annual Runoff (ac-ft) | Station Operator |
|---|---|---|---|---|---|
| Clear Lake at Lakeport [(b)] | 528.0 | 1913 - 1984 | 72 | 5 [(b)] | USGS |
| Cache Creek near Lower Lake | 528.0 | 1944 - 1991 | 47 | 256,000 | USGS |
| North Fork Cache Creek at Hough Springs near Lower Lake | 60.2 | 1971 – 1991 | 20 | 67,900 | USGS |
| North Fork Cache Creek near Lower Lake [(c)] | 197.0 | 1930 – 1981 | 52 | 136,500 | USGS |
| Bear Creek near Rumsey [(c)] | 100.0 | 1958 – 1980 | 23 | 35,760 | DWR, CA |
| Cache Creek above Rumsey [(c)] | 955.0 | 1961 – 1986 | 19 | 541,200 | DWR, CA |
| Cache Creek at Rumsey Bridge | ~960.0 | 1987 – present | 13 | Not available | DWR, CA |
| Cache Creek near Capay [(c)] | 1044.0 | 1942 – 1976 | 35 | 556,900 | USGS |
| Cache Creek at Yolo | 1139.0 | 1903 – 1991 | 89 | 378,900 | USGS |

(a) Pertinent data for each stream gaging station were adapted to reflect the latest data available.
(b) Average annual lake stage in feet above datum of gage, 1,318.65 feet.
(c) Stream gage recorder discontinued.

**4.2 Flood Problems.** General rainstorms produce the largest flood events on Cache Creek. Local cloudburst storms have not produced any major recorded events.

**4.3 Historical Flooding.** The following are descriptive accounts of flood events and a table of peak flows and 3-day volumes, where available:

a. January 26, 1983. This flood had the highest peak flow of record at Rumsey since construction of Indian Valley Dam was completed in 1974. The peak flow at Rumsey was estimated to be 53,500 cfs (a 2% or 1 in 50 chance exceedence). No estimate of the peak flow at Capay is available. The peak flow at the Yolo gage was 33,000 cfs. Due to the large difference between the peak at Rumsey and at Yolo, it is hypothesized that overbank flow occurred in areas upstream of the Yolo gage. Flood-fighting efforts were undertaken including protective measures to save the town of Yolo. Early in the morning of the 27th, the south levee of Cache Creek failed to the east of Road 102 (about 2 miles east of Woodland) and north of Interstate 5. Following the break, 12 flood fighters were stranded for a few hours between the break site and the stub end of the levee system. A California Highway Patrol Helicopter rescued the flood crews. The water from the break flowed in a southern direction toward the Cache Creek Settling Basin and flooded about 600 acres of agricultural land. If the levee had broken upstream of Highway 5, it would have threatened Woodland since the embankment of the freeway would have directed the flow southeast towards the city. At Rumsey, the 1983 event is estimated to have produced about 25% more runoff than the March 9th, 1995 event (comparison of 3-day volumes).

b. March 9, 1995. High flows in January were followed by an even larger event in March. The estimated peak flows at Rumsey were 33,000 and 52,000 cfs in January and March, respectively. This was the 2nd largest peak flow of record at Rumsey since Indian Valley Dam was built. Heavy bank erosion and debris endangered the Capay Bridge and buildings along the creek. Rock was dumped at the bridge to stabilize the banks. Farther downstream, sandbagging and bank protection measures were used to protect the Cache Creek levees. In this event, overbank flow is estimated to have started at 36,500 cfs. The levees were originally designed to convey about 30,000 cfs (not including the additional levee freeboard). Although the levees did not fail, overtopping did occur upstream of the Highway 5 Bridge on both the north and south sides of the levee. Water overtopping the south levee flowed southeast along the freeway embankment, eventually inundating it and stopping traffic in both directions. The City of Woodland declared a State of Emergency and advised voluntary evacuation of properties north of Woodland Avenue. Floodwaters continued south and came to a stop at the edge of the developed portion of the city. As in 1983, hundreds of acres of land were flooded. Flooding of the city would have been more likely if the south levee had failed rather than being overtopped. The failure of the levee would have decreased channel capacity from 36,000 cfs to about 20,000 – 25,000 cfs (as determined by MBK Engineers). The volume of water in this flood was also a factor. The peak flow at Road 94B was determined to have a 2.5% chance exceedence (1 in 40). The 72-hour volume of the hydrograph, however, was much smaller – only about a 5% chance exceedence (1 in 20). Had the frequency of the hydrograph volume been similar to its peak flow, worse flooding would have occurred. The following table provides historical peak flow and volume data for Cache Creek gages.

**Table 5. Peak Flow and Volume Data, Cache Creek Basin**

| Location | Date | Flood Peak (cfs) | 3-Day Flow Volume (ac-ft) |
|---|---|---|---|
| Cache Creek near Lower Lake (1944 – 1991) | 24 Feb 58 | 8,000 | 30,550 |
| | 22 Dec 64 | **(a)** | **(a)** |
| | 5 Jan 65 | 5,320 | 23,720 |
| | 23 Jan 70 | 6,320 | 26,620 |
| North Fork Cache Creek at Hough Springs near Lower Lake (1971 - 1991) | 26 Jan 83 | 6,220 | 19,400 |
| North Fork Cache Creek near Lower Lake [(b)] (1930 – 1981) | 24 Feb 58 | 13,500 | 31,860 |
| | 22 Dec 64 | 19,700 | 61,800 |
| | 5 Jan 65 | 15,700 | 40,060 |
| | 23 Jan 70 | 16,000 | 37,410 |
| Bear Creek near Rumsey [(b)] (1958 - 1980) | 22 Dec 64 | 6,820 | 10,680 |
| | 5 Jan 65 | 9,720 | 12,710 |
| | 23 Jan 70 | 5,900 | 10,400 |
| Cache Creek at/above Rumsey (1961 – present) | 5 Jan 65 | 59,000 [(c)] | -- |
| | 24 Jan 70 | 43,400 | -- |
| | 26 Jan83 | 53,500 | 102,730 |
| | 9 Mar 95 | 52.000 | 75,530 |
| Cache Creek near Capay [(b)] (1942 - 1976) | 24 Feb 58 | 51,600 | 98,980 |
| | 23 Dec 64 | 32,400 | 84,350 |
| | 5 Jan 65 | 44,500 | 96,620 |
| | 24 Jan 70 | 36,200 | 92,230 |
| Cache Creek at Yolo --> (1903 - Present) | Channel capacity restrictions upstream of this gage prevent it from recording the full amount of runoff generated during large events. Therefore, this data is not included in the table. | | |

(a) Data is unavailable.
(b) Station discontinued.
(c) Value seems unreasonably high possibly due to the extension of the low-flow rating table and slope-area measurements.

**Reservoir Regulation in the Watershed.** Clear Lake is the largest natural body of fresh water entirely within the state of California. The outlet of the lake is the start of Cache Creek and is a narrow, confined channel that winds a distance of about 5 miles before reaching the Clear Lake Dam. Clear Lake Dam began to store water in 1915. Even before the dam was built, the outflow from Clear Lake had always been limited to less than 10% of the potential Clear Lake inflow, due to a natural "weir-like" structure called the Griggsby Riffles. This shallow, hardened portion of the streambed in the narrow channel that leads to the dam acts as a weir. During large inflows, the constrained outflow causes the shallow lake to rise rapidly, sometimes resulting in flooding along the rim of the lake.

Clear Lake Dam can release more water than can physically pass over the riffles. The riffles control the volume of water that can reach the dam and, therefore, long-duration maximum outflow. The maximum flow passing over the riffles during large floods has been about 5,000 cfs. Laws regulate the maximum stage that Clear Lake can reach during the winter months before mandatory flood releases have to be made from the dam to keep the lake from rising further. The lake level will exceed this maximum stage when inflow is excessively high. The regulating affect of Clear Lake Dam during large floods can be modeled in HEC-1 with a stage-rating curve for the Griggsby Riffles. Since the Griggsby Riffles has been a feature in the Cache Creek watershed since recorded history, Clear Lake Dam regulation was not removed from the computation of the "unregulated" frequency curve for the Rumsey gage. The starting elevation used for Clear Lake in the HEC-1 model was the same elevation that occurred just one day prior to the March 9, 1995 storm (one of the two largest floods of record on Lower Cache Creek since 1941, assuming no regulation from Indian Valley Dam). The Clear Lake stage was unusually high at the start of this event.

The Yolo County Flood Control and Water Conservation District operates Indian Valley Dam. It began to store water in June of 1974. The reservoir serves dual purposes for both irrigation supply and flood control. Flood control releases are made in accordance with rules and regulations determined by the U.S. Army Corps of Engineers in the authorized Water Control Manual. The total volume of space set aside for flood control is 40,000 ac-ft. For the HEC-1 model used in this study, the starting storage at Indian Valley Dam was set to the bottom of the flood control space (260,000 ac-ft). The reservoir was designed to control a 2% chance exceedence (1 in 50) flood centered above the dam. Controlled releases from the gates are not allowed to cause the Rumsey gage to exceed 20,000 cfs. A simplified discussion of the operation of Indian Valley Dam is described below.

> "If rainfall gages in the vicinity of the basin show an accumulated rainfall of 0.5 inches or more in the last 8 hours, and the downstream Rumsey gage exceeds 5,000 cfs and is increasing, the outflow is reduced to 10 cfs (fish release) at the rate of 2,500 cfs per 2-hour period. If inflow to the reservoir causes the pool to rise above elevation 1485 feet, increase release by 5,000 cfs per hour until outflow equals inflow. Once the pool elevation has dropped below 1485 feet, reduce outflow by 2,500 cfs per 2-hour period until the minimum flow of 10 cfs has been reached. The minimum outflow should be maintained until the flow at Rumsey has dropped below 10,000 cfs and is decreasing, and less than 0.5 inch of rainfall has occurred in the last 12 hours. Then, outflow should be increased to the lesser of 10,000 cfs or the maximum rate of inflow during the current event. As much as possible, releases are not allowed to cause the Rumsey gage to exceed 20,000 cfs."

The regulation by Indian Valley Dam during rare events can be simulated in an HEC-1 model.

## 5. Hydrologic Analysis

**5.1 Introduction.** This section of the report presents a synopsis of the Cache Creek Hydrologic Analysis.

**5.2 General.** The Corps of Engineers uses a document called "Bulletin #17B, Guidelines for Determining Flood Flow Frequency" (revised September 1981 by the Interagency Advisory Committee on Water Data) to define the methodology by which it studies flood frequency in watersheds (Reference # 6). Bulletin 17B recommends three procedures for analysis of watersheds 1) statistical analysis of streamgage records, if available, 2) comparisons with similar watersheds, and 3) flood estimates from precipitation. All three methods were used in the study.

**5.3 HEC-1 Model Development.** The existing HEC-1 model has been developed and modified during several different studies. In 1979, a hydrologic analysis was done for the Cache Creek Basin California Feasibility Study. Following that study, a major storm hit Cache Creek in January of 1983 that caused a levee downstream of the Highway 5 Bridge to fail. The storm was centered over the ungaged area between Clear Lake Dam and Rumsey. Following this event, another study was performed. Rainfall and streamflow data from this event were used in calibrating the existing Cache Creek HEC-1 rainfall-runoff model in a 1985 review of Cache Creek hydrology (Reference 3). Model unit hydrographs, losses, and routing parameters were verified or updated. See Reference 3 for a breakdown of subareas and isohyetal patterns used for this storm event. HEC-1 subbasins are shown on Chart 5. The Clear Lake drainage area is further divided into numerous subbasins as shown in Chart 6 (derived from a detailed HEC-1 model created in a prior Corps study).

In 1994, a Reconnaissance Study of the watershed (Reference 5) used the latest HEC-1 model hydrographs as input to a hydraulics model to generate floodplains. In January and March of 1995, two more large storms occurred within the watershed. The March flood caused extensive flooding of land from overtopping of the levees. The two 1995 floods provided additional hydrologic data to use in model calibration, and the hydrology was re-studied after these events (Reference #8). The principal change to the model in the 1995 recalibration was the development of a new unit-hydrograph for a 127 square mile subarea above Rumsey, referred to as "Rumsey Local," or Subarea 805. Although less rainfall data was available for the analysis than was desired, the revised model reproduced the 1983 and 1995 storm hydrographs well at the Rumsey gage. Among the conclusions of the 1995 Study were: 1) the floodplains produced in the 1994 Study did not need revision, 2) the model worked well at the Rumsey gage, and 3) model hydrographs between Rumsey and the Yolo gage needed further analysis, due to the lack of flow data for calibration in this reach. The model reproductions of the three events are shown on Charts 7 - 9.

Although peak and daily flow were produced at the Capay gage (1943 to 1976), hourly hydrograph data is not available. The Yolo gage at the Interstate 5 Bridge has hourly data but does not capture all of the flow during large events, due to channel capacity restrictions farther upstream. Channel capacity is estimated to be between 36,000 to 38,000 cfs for both the channel reach upstream of the levees and for the levees themselves. During large floods, such as occurred in January 1983 and March of 1995, out-of-bank flow farther upstream caused the Yolo gage to record only the flow remaining in the channel. Once the flow leaves the main channel or overtops the levees, it does not return to the creek.

For this feasibility study, a new family of frequency curves for the "without Indian Valley Dam regulation" condition were created for the Rumsey gage. The curves incorporated the latest available data up to water year 1999. Simulations of the 2%, 1%, 0.5%, and 0.2% chance floods were run with the HEC-1 model (modified to remove the affect of Indian Valley regulation). The hydrographs generated at Rumsey were compared to the new frequency curves. Except for the 2% chance event, the peak, 24-, and 72-hour flows produced by the model had a good match with the frequency curves (peak, 1-, and 3-day durations). The peak 24-hour flow in each event hydrograph was about 15% higher than the corresponding 1-day curve value. This is to be expected. Since the USGS measures the daily flow at a gage from midnight to midnight, a portion of the peak 24-hour flow in a hydrograph is often cut off from the computation (especially when the peak occurs in late evening). Over the long run, the difference between the maximum 24-hour flow and the 1-day frequency curve for a given frequency is expected to be around 15%. As mentioned before, the HEC-1 hydrograph for the 2% chance event (1 in 50) had too much volume when compared to the frequency curve. For the 2% chance event, the constant loss rates for two subareas upstream of the Rumsey gage called "Long Valley" and "Local Rumsey" were each increased by 0.02 inches/hr so that the HEC-1 hydrograph and the frequency curves matched for the peak through 3-day durations.

After verifying that the model was producing accurate hydrographs at the Rumsey gage index point, the lower reaches of the model were studied closely. A frequency curve for the Yolo gage was not created, because the gage record is affected by out-of-bank flow upstream. Cache Creek at Road 94B is the most important index point in the HEC-1 model. The Road 94B hydrographs were input into a hydraulic design model for floodplain delineation and alternatives analysis. Road 94B is upstream of the section of Cache Creek in which channel capacity is limited.

The increase in volume between the Rumsey, Capay, and Yolo gage locations was evaluated for observed events in which gage records overlapped. As a result of this analysis, it was determined that HEC-1 generated hydrographs (for all modeled events) had too much volume for the reaches below Rumsey. The analysis included the development of regression equations that predicted the increase in the 1-day and 3-day volume between gages. To reduce volume, two things were done: First, the constant rainfall loss rates for the subareas below Rumsey were increased. Secondly, channel losses were incorporated into the model, which matched those described in the Cache

Creek Basin Standard Project Floods Study (Reference 1). These loss rates are shown in Table 6 of Section 5.7.

There are 8 years of overlapping peak flows between the Rumsey and Capay gages. The attenuation in peak flow from Rumsey to Capay ranges from a 4% to 39% decrease. The average attenuation is a 19% decrease. Further investigation showed that the peak tended to decrease only by a small percentage when the hydrograph shape was 'fat' (well-balanced volume across the various durations). In addition, there was not much attenuation between Rumsey and the Yolo gage in similar situations. Using this information as a guide, the original HEC-1 muskingum "x coefficients" of 0 (zero) were modified to 0.1 to 0.2 for this part of the model.

**5.4 Baseflow.** The baseflow information is unchanged from that presented in the 1979 feasibility report (Reference 3). Baseflow was estimated in the reproductions of the 1964, 1965, and 1970 floods on North Fork Cache Creek near Lower Lake, and Bear Creek near Rumsey. Baseflow was estimated to be equal to the flow at the beginning of the floods, increasing uniformly until it intercepted the extension of the recession limb of the observed hydrographs. Baseflow is difficult to determine accurately for the gages at Rumsey, Capay, and Yolo, as high sustained outflows from Clear Lake and loosing stream reaches obscure the actual baseflow. A loosing reach contributes to the groundwater, while a gaining reach is partially fed by groundwater. In some cases, a stream reach may be seasonally gaining during periods where the groundwater table is high.

**5.5 Unit Hydrograph.** The basic procedure used for developing unit hydrographs in this report is outlined in the Department of the Army's Technical Bulletin 5-550-3, "Flood Prediction Techniques," and in the Corps' Engineering Manual 1110-2-1405, "Flood Hydrograph Analyses and Computations." This procedure involves using the physical dimensions of the basin measured from topographic maps, an estimated average channel and basin hydraulic factor (Manning's "n") obtained by field observation, lag relationships, and summation curves (S-curves) obtained from unit hydrographs developed from reproduction of recorded floods. See References 1, 2, and 4 for additional unit hydrograph information and example unit hydrographs.

**Table 6. Cache Creek Watershed Characteristics**

| Location | D.A. (2) ($mi^2$) | Channel Length (mi) | Lca(3) (mi) | Channel Slope (ft / mi) | $\bar{n}$ |
|---|---|---|---|---|---|
| Bear Cr nr Rumsey | 100 | 31.2 | 13.8 | 72 | 0.06 |
| Cache Cr Local at Diversion Dam(1) | 34 | 11.7 | 7.6 | 243 | 0.06 |
| Cache Cr Local nr Capay(1) | 92 | 24.7 | 11.1 | 101 | 0.06 |
| Cache Cr Local nr Rumsey(1) | 127 | 21.0 | 10.6 | 130 | 0.06 |
| Cache Cr Local nr Yolo(1) | 61 | 24.7 | 16.7 | 63 | 0.06 |
| Cache Cr at Rumsey Bridge | ~960 | -- | -- | -- | -- |
| Cache Cr nr Capay | 1,044 | -- | -- | -- | -- |
| Cache Cr nr Yolo | 1,139 | -- | -- | -- | -- |
| Clear Lk at Lakeport | 528 | -- | -- | --- | |
| Copsey Cr nr Lower Lake | 13.2 | 6.4 | 2.3 | 126 | 0.10 |
| N. Fork Cache Cr at Hough Springs (nr Lower Lake) | 76 | 17.6 | 8.4 | 180 | 0.06 |
| N. Fork Cache Cr - Indian Valley Res. | 121 | 27.0 | 13.8 | 107 | 0.06 |

(1) Channel Length, Lca, and Slope adjusted for Cache Creek subbasins bisected by mainstem Cache Creek, due to hydraulic efficiency of channel.
(2) D.A. = Drainage Area.
(3) Length of channel from basin outlet to centroid of basin.

**5.6 Routing Parameters.** Muskingum routing is the principal channel routing method used in the Cache Creek HEC-1 model. Muskingum coefficients used for Cache Creek below the Grigsby Riffles are based on present channel characteristics and velocities observed during the January 1983 flood. Velocities observed in 1983, ranging from 10 to 16 feet per second, were much higher than previously modeled. Some routings in the upper watershed were not changed from Tatum to Muskingum routing, if the Tatum routing performed well. Where storage effects were significant, Modified Pulls routing was used. Routing parameters for the reaches between the Rumsey gage and Road 94B were modified in this study. The muskingum "x coefficients" were modified to 0.2 instead of the original zero. Muskingum Routing parameters for the basin are shown on Chart 10.

**5.7 Rainfall.** A 96-hour storm was used for the analysis. General rainflood events cause the highest peak flows and volumes in this watershed. In this part of California, intense thunderstorm cells are typically embedded within long duration general storms. These embedded cells can be just as intense as a short duration summer thunderstorm. A stacked rainfall was developed such that the design storm has the same return period for all durations, that is, the 1-, 6-, 24-, 48-, and 96-hour rainfall depths all have the same frequency of occurrence.

Subarea rainfall was developed from 1% chance point rainfall from 19 gages in the region for which depth-frequency relationships were available. The depth-duration-frequency analyses were derived using methods found in Bulletin #195, Rainfall Analysis for Drainage Design, Vol. I & II, Short-Duration and Long-Duration Precipitation Frequency Data, CA Department of Water Resources, Oct. 1976. An isohyetal map of 1% chance point rainfall was developed by plotting the 1%, 96-hour rainfall amounts from the 19 stations on a map, and drawing lines of equal depth between stations.

Different centerings were computed by using depth-area reduction methods found in HMR 58. Using the HEC-1 model, it was determined that centering the storm in the subarea above the Rumsey gage and below Clear Lake and Indian Valley Dam caused the highest peak flows and volumes on Lower Cache Creek. This was the centering chosen for this study. Both rainfall depth and distribution vary by subarea. Cells of intense rainfall will not cover an entire basin (or occur at the same time basin-wide); therefore a different distribution must be used at the storm center than elsewhere on the basin. Depth-area-reduction relationships from the Midcoast California Region were used to develop subarea rainfall distributions. Areal reduction factors are greatest for the short duration rainfall. The rainfall was temporally sequenced according to Sacramento District's Standard Project Storm Criteria. This Standard Project Storm distribution was balanced (reshaped) with the 1% chance, 1-, 6-, 24-, 48-, and 72-hour rainfall for areas of 100 and 1,000 square miles. The distribution and depths for the 100 square mile area was applied to the Rumsey Local subarea (at the storm center), while the 1,000 square mile distribution and depth was applied to the remaining subareas. For 100 square miles, the basin average 1-hour rainfall is 85% of the maximum point rainfall. The 72-hour rainfall for 100 square miles, however, is 95% of the maximum point 72-hour rainfall. Therefore the subarea-wide rainfall distribution is flatter than the point rainfall distribution. For 1,000 square miles, the maximum 1-hour rainfall is 62% of the maximum point rainfall, or flatter still.

For frequency events, basin average precipitation was developed from point 1% chance rainfall depths and depth-area relationships. Point 1% chance rainfall from 19 gages was used to develop isohyets of point rainfall across the watershed. Each subbasin was given an average 96-hour point rainfall depth. In centering the storm over the Rumsey Local subarea, the basin average rainfall for a basin of this size (127 square miles) was determined from the depth-area relationships. That amount of rainfall is then subtracted from the total volume of rainfall for the entire 1,100 square mile watershed, leaving the coincident rainfall volume for the remaining 973 square miles.

Additional subareas totaling 176 square miles, between Clear Lake and Rumsey (below Indian Valley Dam), were added to the Rumsey Local subarea, and coincident rainfall was distributed on these subareas based upon the depth-area relationship for 303 square miles. This process was repeated 2 additional times until all subbasins were given 1% chance rainfall. In this way, the basin average rainfall depth is appropriate for both the local subarea, and the entire watershed. The 2%, 0.5%, and 0.2% chance ninety-six hour rainfall at gages in the region were found to be consistently 92%, 108%, and 119% of the

1% rainfall, respectively. The 2%, 0.5%, and 0.2% chance events were modeled using the 1% chance event distribution and the respective depth for each event.

**5.8 Loss Rates.** Extensive model calibration was performed in the 1985 and 1995 hydrology studies (references 3 and 8). Uniform loss rates for the January 1983 flood reconstitution primarily ranged from 0.15 inches/hr for the Cache Creek Basin above Clear Lake to 0.06 inches/hr in the lower portions of the Cache Creek Basin. An exception was a loss rate of 0.03 inches/hr for the Rumsey Local subbasin. Unusually low loss rates were required to reproduce observed hydrographs at the Rumsey gage. The model reproduced the 1995 events well using the same loss rates developed in 1983. For this feasibility study, loss rates for subbasins upstream of the Rumsey gage remained unchanged (except for the 2% chance event HEC-1 model). For this frequency, the constant rainfall loss rates in the subareas called "Long Valley" and "Local Rumsey" were increased by 0.02 inches/hour in order to get the hydrograph at Rumsey to match the points on the new frequency curve for that location. It is often necessary to change the rainfall loss rates for more frequent events. The largest, historical floods in many of California's watersheds have typically occurred when a large storm system follows after a previously significant rainfall event (which left the soil highly saturated).

An analysis of overlapping flow data for rainfall events at the Rumsey, Capay, and Yolo gages indicated that the model was producing too much volume in the reaches below Rumsey. The analysis included the development of regression equations that predicted the increase in the 1-day and 3-day volume between gages. To study the increase in volume at the Yolo gage, only events in which out-of-bank flow did not occur were studied. To correct the model, two actions were taken: Uniform rainfall loss rates for subbasins below Rumsey were increased from the 1995 Study (originally 0.06 inches/hr., changed to 0.08 to 0.15 in/hr.). Secondly, channel losses (percolation into alluvial aquifers) for the lower reaches were added to the model. The channel loss rates were determined for the Standard Project Flood analysis (Reference 1). The following percolation rates were presented:

**Table 7. Channel loss rates between Rumsey and Yolo**

| Flow Rate ($ft^3$/s per hour) | Seepage ($ft^3$/s per hour) |
|---|---|
| 2000 | 510 |
| 3000 | 670 |
| 5000 | 850 |
| 10,000 | 1220 |
| 20,000 | 1740 |
| 70,000 | 3290 |
| 90,000 | 3780 |

The channel loss rates listed above were incorporated into the HEC-1 model for this study. The channel loss rates were most likely derived from a study done by the

California Department of Water Resources (DWR). For this feasibility study, DWR was contacted for information about streamgage measurements and channel characteristics. DWR employees have been making streamflow measurements on Cache Creek for decades. The reach between Capay and Yolo has been described in another report (Reference 9) as sandy and alluvial in nature. During the warmer months, losses between Rumsey and the Yolo gage may be even higher than those given in table 6. For example, an observation of 1,000 cfs flow at Rumsey and almost zero flow at the Yolo gage has been reported during flow measurements in spring.

To model the various frequency events, only rainfall and loss rates were changed. Large historical floods in this area typically occur during wet periods when the ground has been highly saturated by previous rainfall events. Extremely rare events typically have low loss rates. More frequent events have higher loss rates.

## 6. Flow Frequency

**6.1 Flow Frequency Analysis.** Flow records for Cache Creek at Capay remained unchanged since the gage was discontinued in 1976. Therefore, no new data is available since the graphical peak flow-frequency curve was developed for the 1985 report (Reference 3). Chart 11 shows the original frequency curve for Capay created in the 1985 Study. A new family of frequency curves was generated for Cache Creek at Rumsey (for without Indian Valley Dam regulation) from the latest available flow data. Unregulated flow is produced by taking the incremental "change in storage" at Indian Valley Dam (converted to cfs), routing it to the gage, and adding it to the observed flow. Hourly change in storage is not available at Indian Valley Dam (except for a few large events such as 1997). Since Indian Valley Dam has regulated the watershed since 1974, peak unregulated flow at Rumsey after 1974 could only be calculated for the three floods for which data is available (1983, 1995, and 1997 events). However, these were the three biggest floods since regulation began and therefore the most important values needed for the analysis. Daily change in storage records for Indian Valley Dam are available since regulation began. The Griggsby Riffles (a natural, weir-like structure below Clear Lake) has controlled the rate of release from the dam since 1915. Consequently, Clear Lake Dam regulation was not removed from the "unregulated frequency curve" for Rumsey. The Rumsey frequency curve was used to check the HEC-1 model hydrograph at Rumsey for the "Without Indian Valley Dam" condition.

Measurements of peak flow on lower Cache Creek are difficult, due to the soft alluvial nature of the streambed. During significant flows, the streambed is constantly changing (eroding during the peak and gaining in height from deposition during the recession of the hydrograph). The present site of the Rumsey gage is on the Highway 16 Bridge. DWR employees are unable to make hand measurements when the flow exceeds 20,000 cfs due to overbank flow moving around the bridge. Consequently, an extrapolation of the discharge-rating curve must be done for big floods. DWR officials say that confidence in the estimated peak flow for big floods on Lower Cache Creek is "low."

For the frequency analysis in this study, the peak flow for two events at Rumsey was revised to be different from the official record of the Department of Water Resources.

a. January 26, 1983 Flood. A peak flow of 53,500 cfs at Rumsey was used for the analysis. This was the original estimate for the January 26, 1983 flood. This value was cited in the report "Hydrology Review Report, Cache Creek Basin, California," March 1985, by the U.S. Army Corps of Engineers (Reference 3). A hydrograph with this peak was also used for calibration of the HEC-1 model in the 1985 and 1995 studies conducted by the Corps. It appears that DWR revised the original peak flow estimate at least several years after the event to 74,800 cfs. A peak of 74,800 cfs equates to a 0.25% chance (1 in 400) event on the frequency curve derived in the 1995 Study. DWR officials were contacted to research the reason for the revision. According to DWR employees contacted, Rating Curve #30 was used for the revision. The curve was generated from one measurement taken in 1983 and many measurements taken in 1985 and 1986. The 74,800 cfs peak was derived by extending the rating curve well beyond any measured values. Strangely, the official start date for Rating Table #30 is 01 October 1986, almost 4 years after the 1983 flood. DWR employees spent many hours trying to find documentation on the 1983 event. However, after many days of research, it was determined that more detailed records may have been archived and cannot be easily retrieved. DWR did not know who performed the revision or why it was done. The Capay gage was not in operation at this time. Adding further doubt to the accuracy of the DWR revision is that the peak flow at the USGS operated Yolo gage was lower than the peak for the 1995 and 1997 floods. The 1983 flood did cause a levee to fail, but the failure was downstream of the Yolo gage and the Highway 5 Bridge. For these reasons, the original peak flow estimate of 53,500 cfs was used for the frequency analysis.

b. March 9, 1995 Flood. A peak flow of 52,000 cfs at Rumsey was used for this event. DWR official records give the peak flow for this event as 42,000 cfs. A reconstruction of the event using an HEC-2 and UNET model did not verify DWR's estimate. MBK Engineers in Sacramento provided research on this issue. An HEC-2 model run determined a peak of 48,500 cfs was needed to match a high water mark observed at Road 94B during this event. Furthermore, a UNET Model of the reach determined that it was necessary to have a hydrograph with a peak of 52,000 cfs at the Capay Diversion Dam (routed to Road 94B) to match the high water mark. Overlapping records for the Rumsey and Capay gages have shown that the peak at Capay is usually equal or less than the peak at Rumsey. Therefore, the peak flow of 52,000 cfs that was cited in the 1995 Corps Study was used for the frequency analysis in this study. In the 1995 Study, a hydrograph with a peak flow of 52,000 cfs for the March 9, 1995 storm at Rumsey was used to calibrate the Corps HEC-1 model for Cache Creek.

The historical record length for the Rumsey gage was lengthened by regression with the flow for the Capay gage. The plotting positions of the Rumsey gage flows were changed based upon the regression with Capay. The values derived by regression were not plotted on the frequency curve. Chart 12 shows the resulting frequency curve for "Without Indian Valley Dam" conditions. A regulated frequency curve for Lower Cache Creek was computed from the HEC-1 model hydrographs as described in Section 6.2

**6.2 HEC-1 Model Results.** For each modeled frequency, only the rainfall and loss rates were modified. Except for the 2% chance event model, none of the subareas above Rumsey were modified in the latest HEC-1 model. Therefore, except for the 2% chance event, the HEC-1 model results at Rumsey remain identical to those of the 1995 Reevaluation. The 2% chance event peak flow was decreased by 6% and the 72-hour volume by 15% in order to match the frequency curve. Farther downstream at the Capay gage site, the peak flows for the modeled frequencies (except the 2% chance event) changed only slightly if at all. For the 1%, 0.5%, and 0.2% chance exceedence events at Capay, the 24-hour and 72-hour maximum flow was decreased by an average of 5%. See Table 7 and 8 for the latest flow-frequency results for the Rumsey and Capay gage sites compared to previous studies.

**Table 8. Example Flow- and Volume-Frequency Values at Rumsey**

| STUDY | PEAK Percent Chance Exceedence | | | 72-HOUR Percent Chance Exceedence | | |
|---|---|---|---|---|---|---|
| | **2%** | **1%** | **0.2%** | **2%** | **1%** | **0.2%** |
| 1985 Study(1) | 52,000 | 58,500 | 75,000 | 24,500 | 28,000 | 37,500 |
| Westside Tributaries(2) | 51,500 | 58,000 | 73,500 | 26,000 | 29,000 | 36,500 |
| 1995 Reevaluation | 56,000 | 62,000 | 74,500 | 23,500 | 27,000 | 35,500 |
| 2001 Feasibility Study | 52,000 | 62,000 | 74,500 | 20,500 | 27,000 | 35,000 |

(1) Volume-frequency values are 3-day values from a frequency analysis using mean daily flows, not maximum 72-hour values.
(2) Flow- and Volume-frequency values unpublished at this location.

**Table 9. Example Flow- and Volume-Frequency Values at Capay Gage Site.**

| STUDY | PEAK (Percent Chance Exceedence) | | | 72-HOUR (Percent Chance Exceedence) | | |
|---|---|---|---|---|---|---|
| | **2%** | **1%** | **0.2%** | **2%** | **1%** | **0.2%** |
| 1985 Study(1) | 51,000 | 58,000 | 75,000 | 25,000 | 28,500 | 37,500 |
| Westside Tributaries(2) | 55,500 | 62,000 | 79,000 | 30,500 | 34,000 | 43,000 |
| 1995 Reevaluation | 55,000 | 61,000 | 74,000 | 30,000 | 34,500 | 44,500 |
| 2001 Feasibility Study | 51,500 | 61,500 | 75,000 | 25,500 | 32,500 | 42,500 |

(1) Volume-frequency values are 3-day values from a frequency analysis using mean daily flows, not maximum 72-hour values.
(2) Flow- and Volume-frequency values unpublished at this location.

**Table 10. Flow Frequency Curve for Road 94B**

| | 2% chance exceedence | 1% chance exceedence | 0.5% chance exceedence | 0.2% chance exceedence |
|---|---|---|---|---|
| Peak | 53,000 | 63,500 | 70,000 | 78,500 |
| Peak 24-Hour Flow | 43,500 | 54,500 | 62,000 | 72,500 |
| Peak 72-Hour Flow | 29,500 | 36,500 | 41,500 | 48,000 |

## 7. Risk and Uncertainty Analysis

The Corps of Engineers now uses a Risk and Uncertainty Analysis in its determination of project performance. For the analysis, the hydrologist is asked to provide a frequency curve along with statistics. If no statistics are available for the curve, the hydrologist may provide a "period of record" which describes the uncertainty in the curve. More confidence is given to a longer period of record. The uncertainty described by the period of record is used to create confidence limits for the frequency curve. Since the frequency curve at Road 94B is derived from hydrographs generated by HEC-1, the curve has no statistics. The following discussion describes how the period of record for the frequency curve was derived.

The HEC-1 model hydrographs at Rumsey were verified using a "without Indian Valley Dam regulation" frequency curve for the Rumsey gage. After some adjustment, the output and the frequency curves matched well. The Rumsey gage has 34 years of record (1961 to the present except for some missing years). Another gage called Cache Creek at Capay (1943 to1976) existed 17 miles downstream of Rumsey. This gage has good correlation with the Rumsey gage. Using regression, the Rumsey gage period of record was extended back to 1943 with the March 1995 flood being the largest flood of record (after adjusting the gage record for Indian Dam Regulation).

Prior to 1943, the previous big flood occurred in 1940. A peak flow of 38,700 cfs was recorded at the Yolo gage and a levee broke downstream of the gage causing flooding. This peak flow is close to the 38,000 and 36,400 cfs peak measured for in-channel flow in the 1958 and 1995 events.

During the 1940 event, a gage downstream of the present site of Indian Valley Dam (called North Fork Cache Creek near Lower Lake) recorded a peak flow of 20,000 cfs for its 197 square mile drainage area. At the same time, Clear Lake Dam was releasing approximately 4,500 to 5,000 cfs during the peak of the storm. No gage recorded the flow on Lower Cache Creek for this event (other than the Yolo gage). This leaves over 400 square miles of drainage area that was not measured. Since out-of-bank flow almost certainly occurred upstream of the Yolo gage, there is no available method to determine the actual peak flow that occurred farther upstream. Putah Creek is an adjoining watershed to Cache Creek. The 1940 flood caused the highest peak flow for the gage Putah Creek at Winters (for the unregulated period prior to building of Monticello Dam).

The gage, which has a drainage area of 547 mi2, recorded a peak flow of 81,000 cfs. Therefore, for the purposes of the Risk and Uncertainty Analysis, the period of record was determined to be 60 years of record (water years 1941 to 2000).

## 8. Interaction Between Cache Creek and the Yolo Bypass

Cache Creek is a tributary to the Yolo Bypass. The main purpose of this section is to address the concern that proposed alternatives (which involve an improved levee system) could increase the risk of flooding downstream. More specifically, could post-project conditions result in a higher peak stage in the Yolo Bypass as compared to pre-project conditions during a major flood on the Sacramento River? The following paragraphs describe the analysis that was performed to quantify this effect. The impact of the Yolo Bypass on Cache Creek is discussed at the end of this section.

The Yolo Bypass serves as a safety valve for the City of Sacramento when large flows occur on the Sacramento River. High stages on the Sacramento River enable water to spill over a series of weirs that pass water into the Yolo Bypass, thus preventing the Sacramento River from overtopping its levees. See Chart 15. The Yolo Bypass is an extremely wide channel with a capacity of approximately 350,000 cfs at the confluence with Cache Creek. The Yolo Bypass flows north to south towards the Sacramento-San Joaquin River Delta. The bypass is extremely flat. When the Sacramento Weir gates are open (about 8 miles downstream), it can cause a backwater effect and raise the stage in the bypass near Woodland. Flow entering the bypass from Cache Creek would be similar to water entering a reservoir. The water would immediately move both upstream and downstream, quickly attenuating the peak flood wave from Cache Creek. Since contributing volume from Cache Creek (as opposed to peak flow) is the factor that raises the stage in the bypass, the analysis was performed using daily flow (as opposed to hourly values).

Under existing conditions, the Cache Creek levees begin to overtop at 36,000 cfs. In the case of levee failure, channel capacity is further reduced to about 20,000 - 25,000 cfs. Flow in excess of channel capacity spills out onto the floodplain adjacent to the creek. Normally, the overbank flow does not return to the creek and will not enter the bypass. In this Feasibility Study, overbank flow modeled for the 2% chance and 1% chance floods ended up ponding against the landside of the Yolo Bypass levees. Two of the proposed project alternatives involve improved levees that are capable of conveying a higher peak flow to the Cache Creek Settling Basin and ultimately the Yolo Bypass. For the purpose of this analysis (based upon preliminary Risk and Uncertainty calculations), the improved levee capacity is assumed to be 80,000 cfs.

A streamgage called "Yolo Bypass near Woodland (gage i.d. 114530) was chosen for the analysis. The gage is located in the Yolo Bypass on the upstream side of the Interstate 5 Bridge. It is close to the Cache Creek confluence with the bypass. The gage has a period of record of 1939 to present. Chart 15 shows the location of the gage. The ten largest floods of record for the Yolo Bypass near Woodland gage were examined. In all ten events examined, the peak flow on Cache Creek occurred 1 to 3 days prior to the peak flow in the bypass. Lower Cache Creek typically experiences the peak flow of a storm hydrograph within 15 hours of the most intense rainfall. For this analysis, the recorded peak flow at the Cache Creek at Yolo gage could not be used to represent Cache Creek discharges. This is due to limited channel capacity in this reach (36,000 cfs) that has resulted in some water being lost to overbank flow (not measured). The peak instantaneous flow that occurred at the Cache Creek at Rumsey gage or Cache Creek at Capay gage was assumed to be the peak flow that would reach the bypass (no attempt was made to route or attenuate the hydrograph). Historically, significant attenuation often occurs as the hydrograph moves downstream (average of 19% from Rumsey to Capay). Secondly, an even more conservative assumption was made that the peak flow lasted for a full 24-hour period (flat hydrograph). This results in a much higher volume of flow than historically occurred. For a few of the 10 events studied, the maximum peak flow on Cache Creek occurred during a storm which was separate from that which caused the peak in the bypass. In these cases, the maximum peak recorded on Cache Creek for that water year was adopted for use. For each event analyzed, the channel capacity of 36,000 cfs was subtracted from the peak instantaneous flow to derive the 24-hour value to add to the flow recorded in the bypass. This 24-hour flow was added to the recorded daily flow in the bypass on the day in which the peak occurred at the gage called Cache Creek at Yolo (about 6 miles upstream of the Cache Creek Settling Basin). The result of the analysis was that the maximum daily flow recorded in the bypass at the gage near Woodland was never exceeded. In addition, for several of the flood events analyzed, Cache Creek did not experience flows above existing channel capacity (36,000 cfs).

In summary, it is the conclusion of this analysis that the levee alternatives being considered in this Feasibility Study will not cause higher stages in the Yolo Bypass during major floods on the Sacramento River. Furthermore, the largest floods on Cache Creek do not always coincide with the largest events on the Sacramento River. The two largest recorded floods on Cache Creek occurred in January of 1983 and March of 1995 (for unregulated conditions). The January 1983 event did not rank in the top ten events for the Yolo Bypass and the March 1995 event ranked as the 8th largest. The proposed levee alternatives will result in a higher volume of water reaching the bypass over the length of a flood event but should not cause an increase in the peak stage.

The levee alternatives being proposed could increase the frequency of flooding to rice farmers growing crops in the Yolo Bypass. This can occur when a storm centered on Cache Creek causes significantly high flows (above existing channel capacity of 36,000 cfs) and when flows in the Yolo Bypass are minimal. However, these farmers typically plant crops in the spring and harvest in October. Since only large general rainstorms occurring from November through March cause flooding on Lower Cache Creek, impact to the farmers is expected to be minimal.

The Comprehensive Study routed 15 different 1% chance exceedence storm centerings down the Sacramento River and the Yolo Bypass. The maximum stage that occurred among all the centerings was then defined as the official 1% chance stage. The spillway invert of the Cache Creek Settling Basin is 32.5 feet (NVGD 1929). The Comprehensive

Study computed a 1% chance stage in the Yolo Bypass at the Cache Creek confluence as 31.25 feet (NVGD 1929). In addition, the latest FEMA floodmap appears to show the same 1% chance stage at this location. Therefore, a 1% chance exceedence flow in the Yolo Bypass will not prevent flows on Cache Creek from exiting the Settling Basin. The Comprehensive Study 0.5% chance (1 in 200) stage is 33.2 feet (NVGD 1929) therefore this event could overtop the settling basin. The spillway invert is scheduled to be raised another six feet in the year 2017 to compensate for storage loss due to sediment deposition.

## 9. Summary

A 96-hour balanced hyetograph (balanced meaning that the 1-, 6-, 24-, 48- and 96-hour duration rainfall had the same frequency of occurrence) was produced for every subbasin in the HEC-1 model, with the most intense rainfall cell being centered over the subarea that ends at the Rumsey gage (127 square miles). The 1985 Study determined this to be the most critical storm centering for producing the highest flows on Lower Cache Creek. In the 1995 Study, the model was calibrated to three large storms (January 1983, January 1995, and March 1995) using recorded precipitation, reservoir inflow, and streamgage data.

For this study, a family of frequency curves for the Cache Creek at Rumsey Bridge gage (adjusted for without Indian Valley Dam regulation) was produced using the latest flow records available up to the year 2000. The HEC-1 model was run for various frequency events (without Indian Valley Dam) and the hydrographs at Rumsey were compared with the frequency curve. After a few modifications to the 2% chance model, the HEC-1 generated peak, 24-hour, and 72-hour maximum flows for each frequency had a good match with the new frequency curves. In response to concerns voiced in the text of the 1995 Study, "peak attenuation" and "volume change" between the Rumsey, Capay, and Yolo gages was studied in greater detail. Routing parameters and rainfall loss rates were changed to match those observed in historic events. After this was done, Indian Valley Dam regulation was put back into the model and synthetic regulated hydrographs for various frequencies (2%, 1%, 0.5%, and 0.2% chance events) were produced.

Finally, a regulated frequency curve was derived from the HEC-1 model output. Greatest confidence in the model is given to the Rumsey gage index point because of the available flow records. The confidence given to the hydrographs at index points below Rumsey, although less than that at Rumsey, is considered sufficient for a feasibility level study of alternatives and possible future levee design.

## 10. References


1. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Standard Project Floods," May 1974.

2. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Feasibility Report and Environmental Statement for Water Resources Development," February 1979.

3. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Hydrology Review Report," March 1985.

4. U.S. Army Corps of Engineers, Sacramento District, "Cache Creek Basin, California, Feasibility Report and Environmental Statement for Water Resource Development," February 1992.

5. U.S. Army Corps of Engineers, Sacramento District, "Westside Tributaries to Yolo Bypass, California," Draft Reconnaissance Report, June 1994

6. Interagency Advisory Committee on Water Data, "Guidelines for Determining Flood Flow Frequency Analysis Bulletin 17B," revised 1981.

7. U.S. Army Corps of Engineers, Washington D.C., "Risk-Based Analysis for Flood Damage Reduction Studies," EM 1110-2-1619, 1 August 1996.

8. U.S. Army Corps of Engineers, Sacramento District, "Office Report, Hydrology for Cache Creek, Yolo County, California," August 1995.

9. A&M Consultants of California, San Diego, California, "Hydrology Report for Yolo County, California and City of Woodland, California," February 1997.

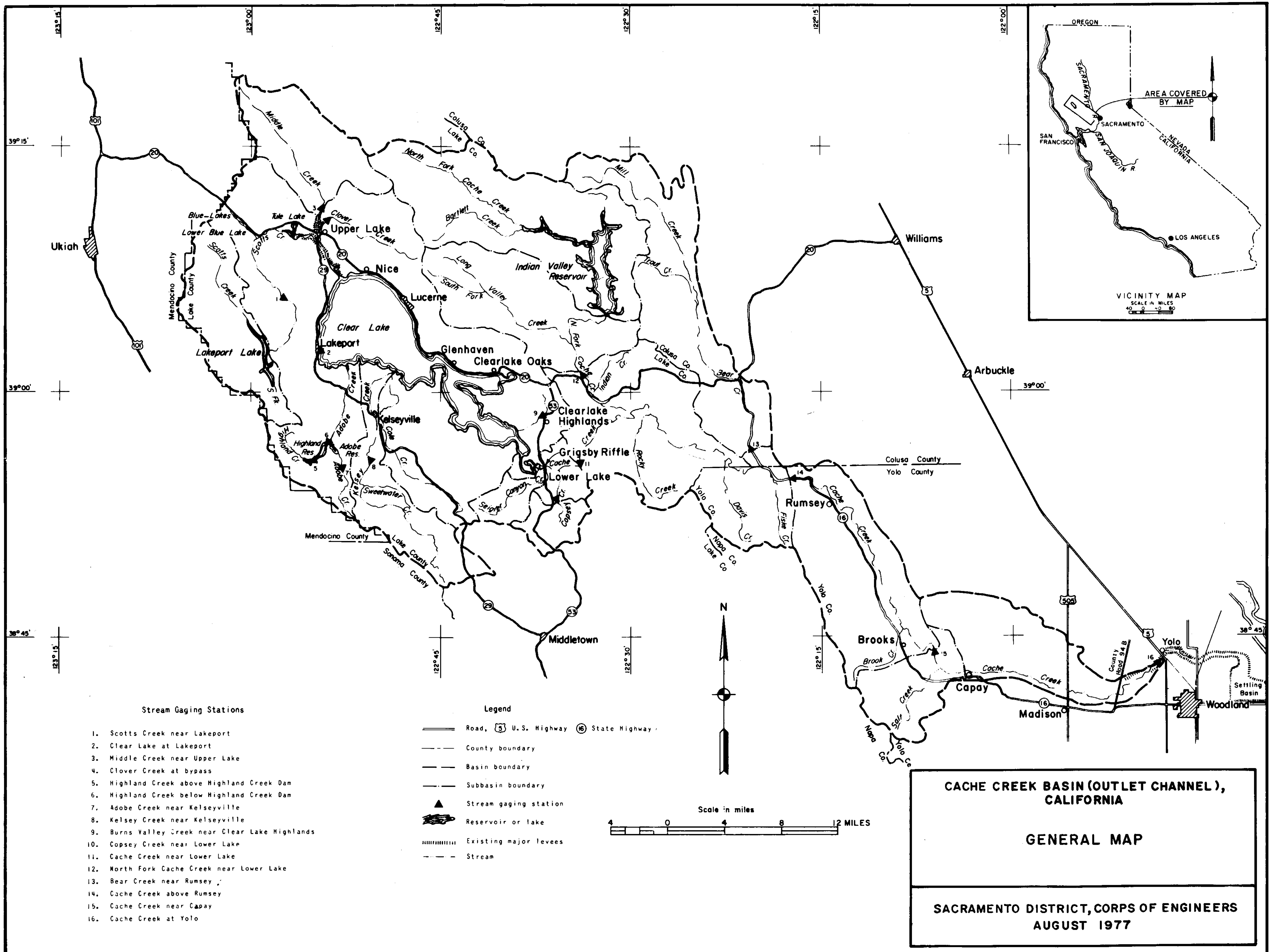
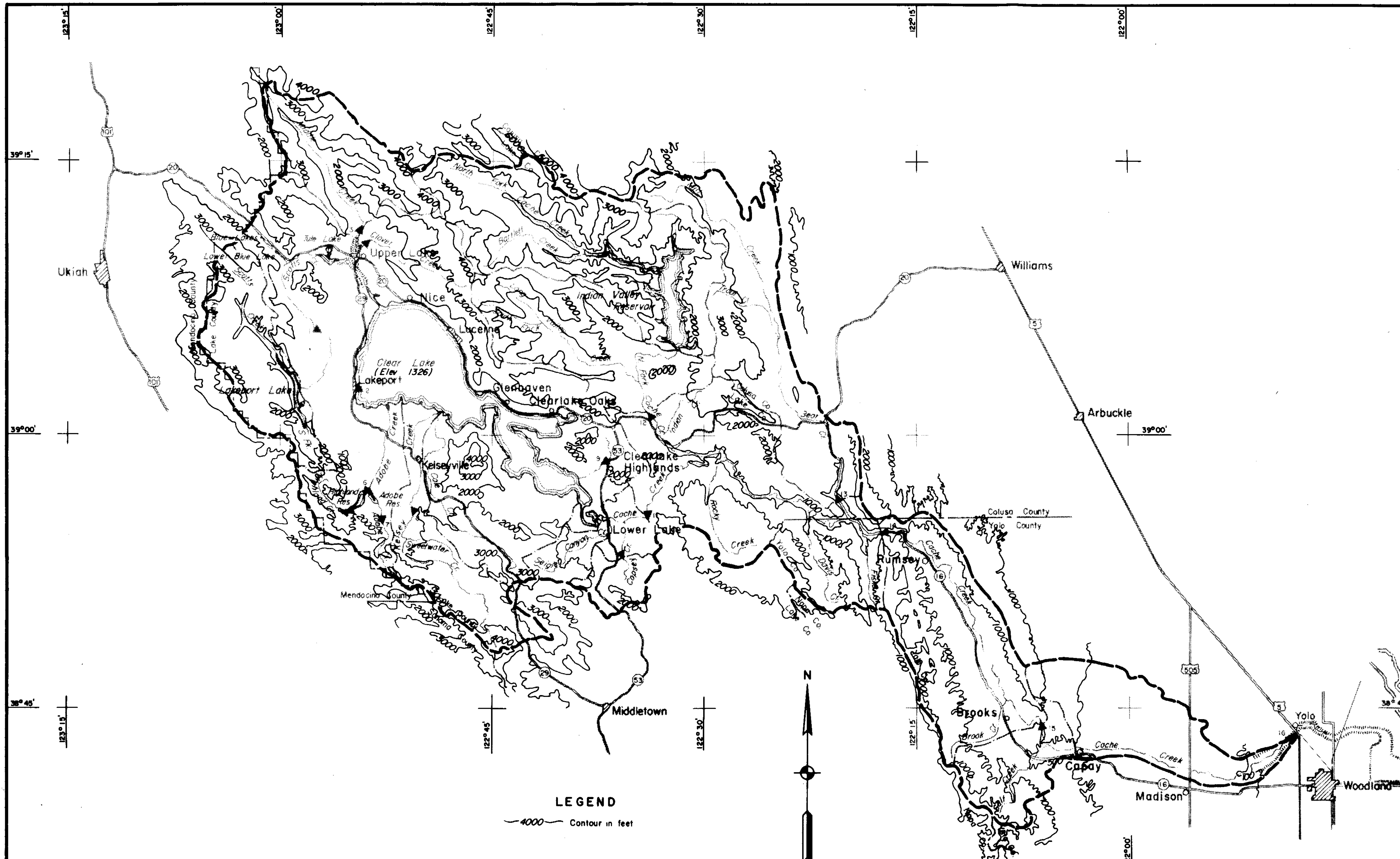

CACHE CREEK BASIN (OUTLET CHANNEL), CALIFORNIA
GENERAL MAP
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
AUGUST 1977
Stream Gaging Stations
1. Scotts Creek near Lakeport
2. Clear Lake at Lakeport
3. Middle Creek near Upper Lake
4. Clover Creek at bypass
5. Highland Creek above Highland Creek Dam
6. Highland Creek below Highland Creek Dam
7. Adobe Creek near Kelseyville
8. Kelsey Creek near Kelseyville
9. Burns Valley Creek near Clear Lake Highlands
10. Copsey Creek near Lower Lake
11. Cache Creek near Lower Lake
12. North Fork Cache Creek near Lower Lake
13. Bear Creek near Rumsey
14. Cache Creek above Rumsey
15. Cache Creek near Capay
16. Cache Creek at Yolo
Legend
Road, U.S. Highway, State Highway
County boundary
Basin boundary
Subbasin boundary
Stream gaging station
Reservoir or lake
Existing major levees
Stream
Scale in miles
4 0 4 8 12 MILES
VICINITY MAP
SCALE IN MILES
OREGON
NEVADA
CALIFORNIA
AREA COVERED BY MAP
SACRAMENTO
SAN FRANCISCO
SAN JOAQUIN R
LOS ANGELES
Ukiah
Upper Lake
Nice
Lucerne
Clear Lake
Lakeport
Glenhaven
Clearlake Oaks
Clearlake Highlands
Grigsby Riffle
Lower Lake
Kelseyville
Middletown
Williams
Arbuckle
Rumsey
Brooks
Capay
Madison
Woodland
Yolo
Indian Valley Reservoir
Blue Lakes
Tule Lake
Lakeport Lake
Highland Res.
Adobe Res.
Settling Basin
Mendocino County
Lake County
Sonoma County
Colusa County
Yolo County
Colusa Co.
Lake Co.
Yolo Co.
Napa Co.
North Fork Cache Creek
Bartlett Creek
Long Valley Creek
South Fork
Middle Creek
Scotts Creek
Clover Creek
Kelsey Creek
Adobe Creek
Cole Cr.
Sweetwater Cr.
Seigler Canyon Cr.
Copsey Cr.
Cache Creek
Rocky Creek
Davis Cr.
Fiske Cr.
Bear Cr.
Trout Cr.
Mill Creek
Indian Cr.
Brook Cr.
Salt Creek
County Road 94B
39° 15'
39° 00'
38° 45'
123° 15'
123° 00'
122° 45'
122° 30'
122° 15'
122° 00'
N

Chart 1.




CACHE CREEK BASIN
CALIFORNIA

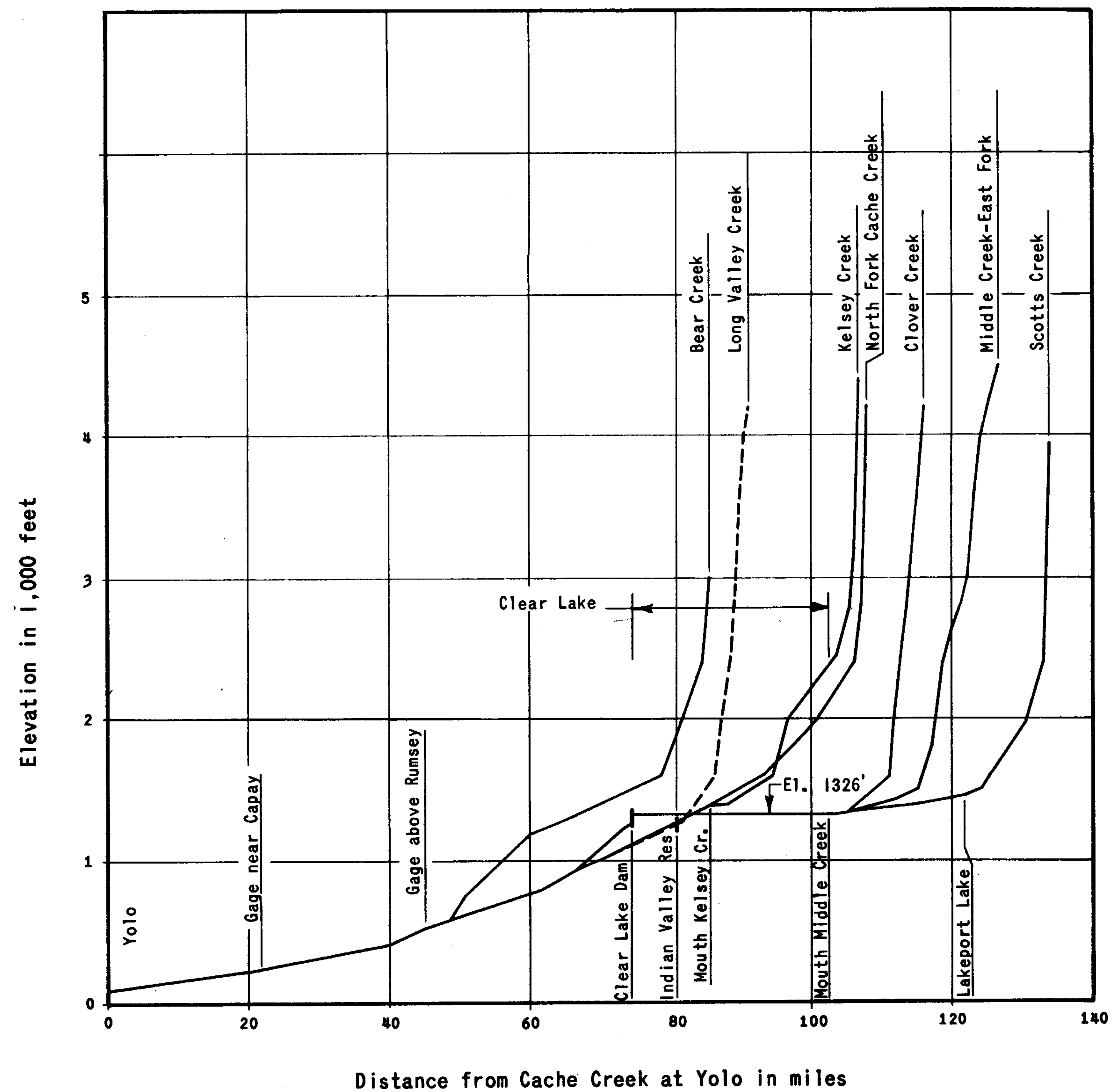
## TOPOGRAPHY MAP

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: P. W.
Drawn: L. H. C.

Date: FEBRUARY 1974

Chart 2.




CACHE CREEK BASIN
CALIFORNIA

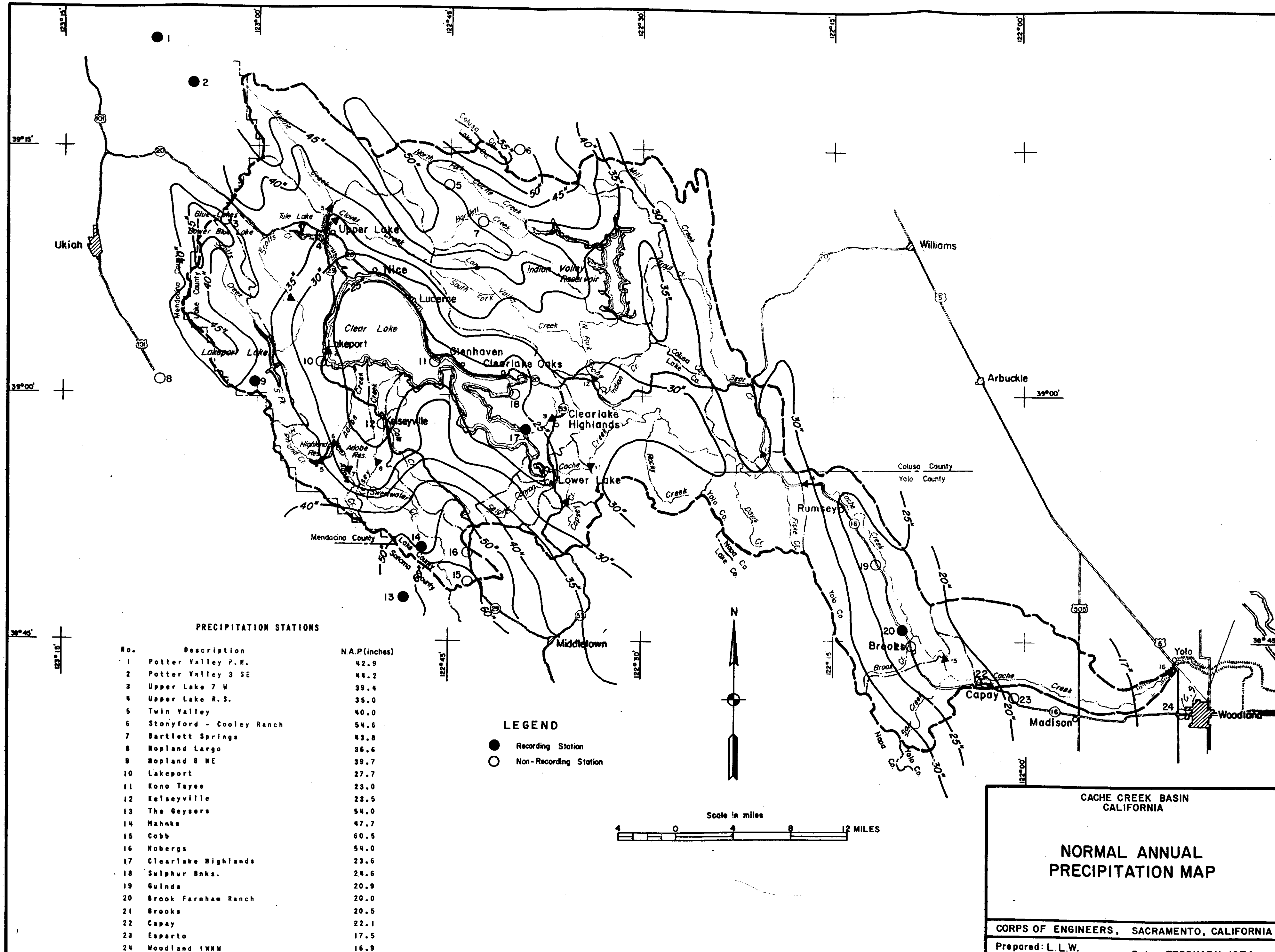
STREAM PROFILES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: P.W.
Drawn: L.H.C.

Date: FEBRUARY 1974

Chart 3.




**PRECIPITATION STATIONS**

| No. | Description | N.A.P.(inches) |
|---|---|---|
| 1 | Potter Valley P.H. | 42.9 |
| 2 | Potter Valley 3 SE | 44.2 |
| 3 | Upper Lake 7 W | 39.4 |
| 4 | Upper Lake R.S. | 35.0 |
| 5 | Twin Valley | 40.0 |
| 6 | Stonyford - Cooley Ranch | 54.6 |
| 7 | Bartlett Springs | 43.8 |
| 8 | Hopland Largo | 36.6 |
| 9 | Hopland 8 NE | 39.7 |
| 10 | Lakeport | 27.7 |
| 11 | Kono Tayee | 23.0 |
| 12 | Kelseyville | 23.5 |
| 13 | The Geysers | 54.0 |
| 14 | Hahnke | 47.7 |
| 15 | Cobb | 60.5 |
| 16 | Hobergs | 54.0 |
| 17 | Clearlake Highlands | 23.6 |
| 18 | Sulphur Bnks. | 24.6 |
| 19 | Guinda | 20.9 |
| 20 | Brook Farnham Ranch | 20.0 |
| 21 | Brooks | 20.5 |
| 22 | Capay | 22.1 |
| 23 | Esparto | 17.5 |
| 24 | Woodland 1WNW | 16.9 |

CACHE CREEK BASIN
CALIFORNIA

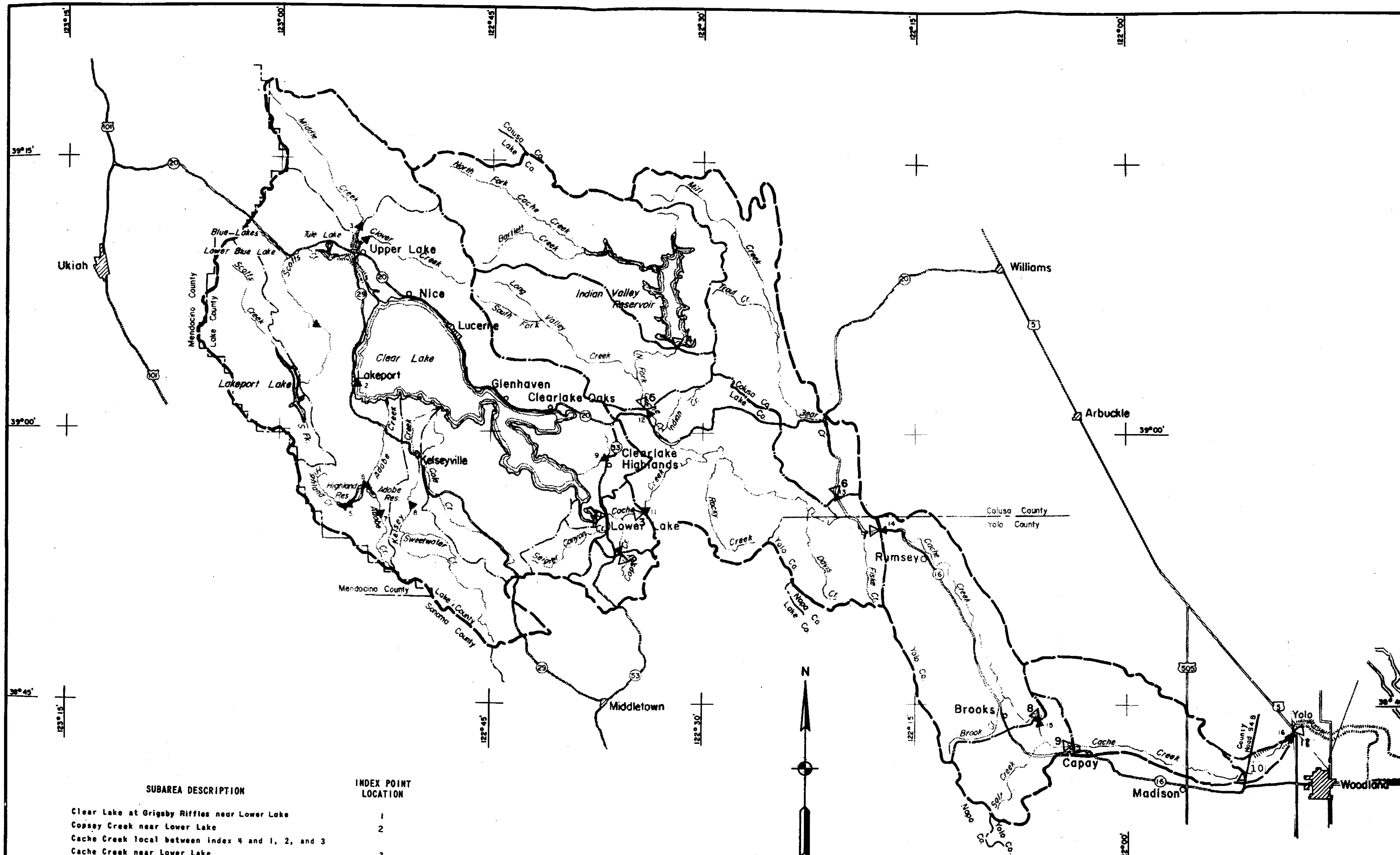
## NORMAL ANNUAL PRECIPITATION MAP

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: L. L. W.
Drawn: L. H. C.

Date: FEBRUARY 1974

Chart 4.




| SUBAREA DESCRIPTION | INDEX POINT LOCATION |
|---|---|
| Clear Lake at Grigsby Riffles near Lower Lake | 1 |
| Copsey Creek near Lower Lake | 2 |
| Cache Creek local between index 4 and 1, 2, and 3 | |
| Cache Creek near Lower Lake | 3 |
| North Fork Cache Creek at Indian Valley Reservoir | 4 |
| North Fork Cache Creek local between 4 and 3 | |
| North Fork Cache Creek near Lower Lake | 5 |
| Bear Creek near Rumsey | 6 |
| Cache Creek local between index 6 and 5, 4, and 3 | |
| Cache Creek above Rumsey | 7 |
| Cache Creek local between index 7 and 6 | |
| Cache Creek near Capay | 8 |
| Cache Creek local between index 8 and 7 | 9 |
| Cache Creek local between index 9 and 8 | |
| Cache Creek at Road 94B | 10 |
| Cache Creek at Yolo* | 11 |

*(levees prevent local runoff from entering creek)

Scale in miles: 4 0 4 8 12 MILES

NOTE: For legend see CHART I

CACHE CREEK BASIN
CALIFORNIA

## SUBAREA MAP

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: P. W.
Drawn: L. H. C.
Date: FEBRUARY 1974

Chart 5.

CACHE CREEK HEC-1 SUB-BASINS MAP

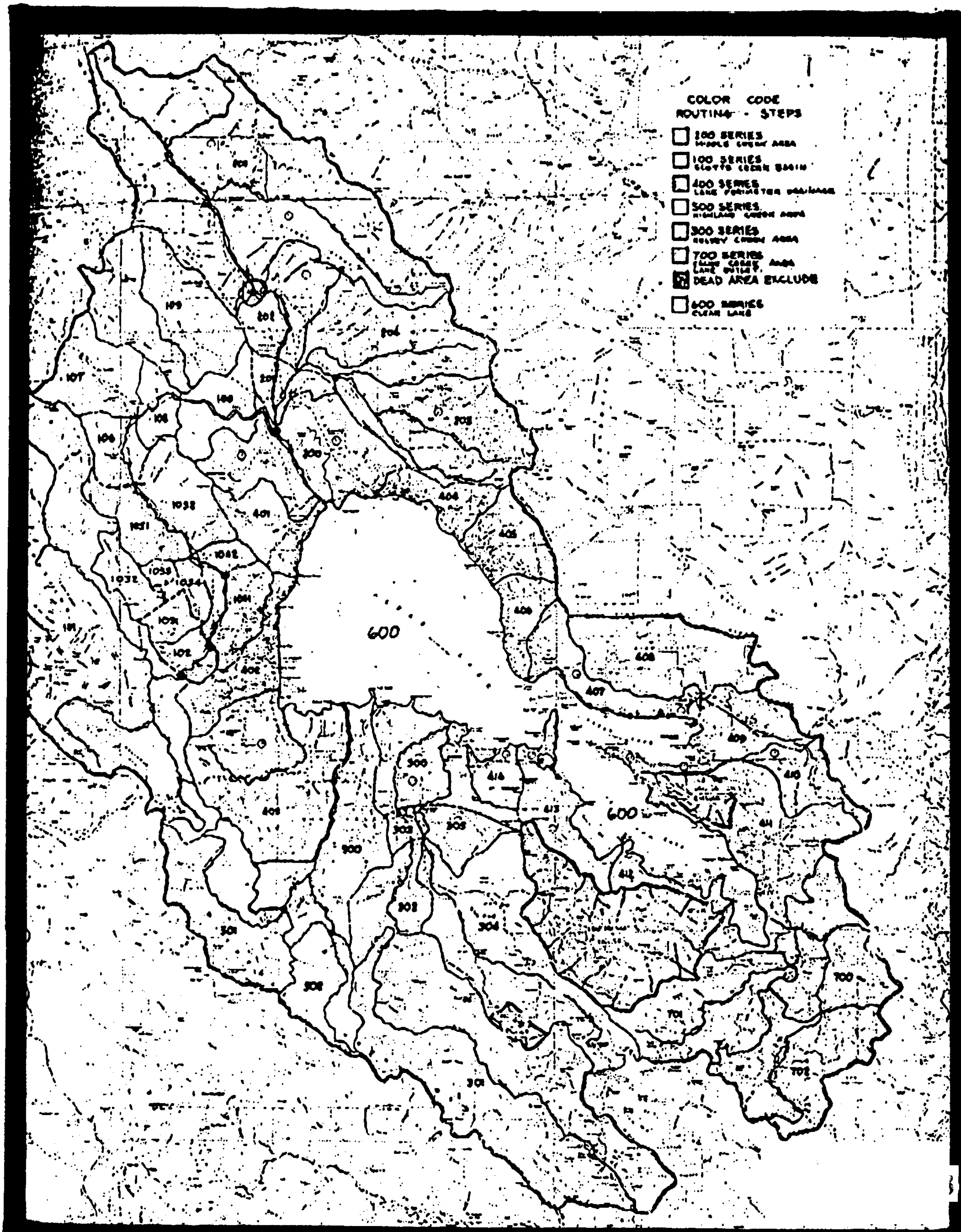



Chart 6.

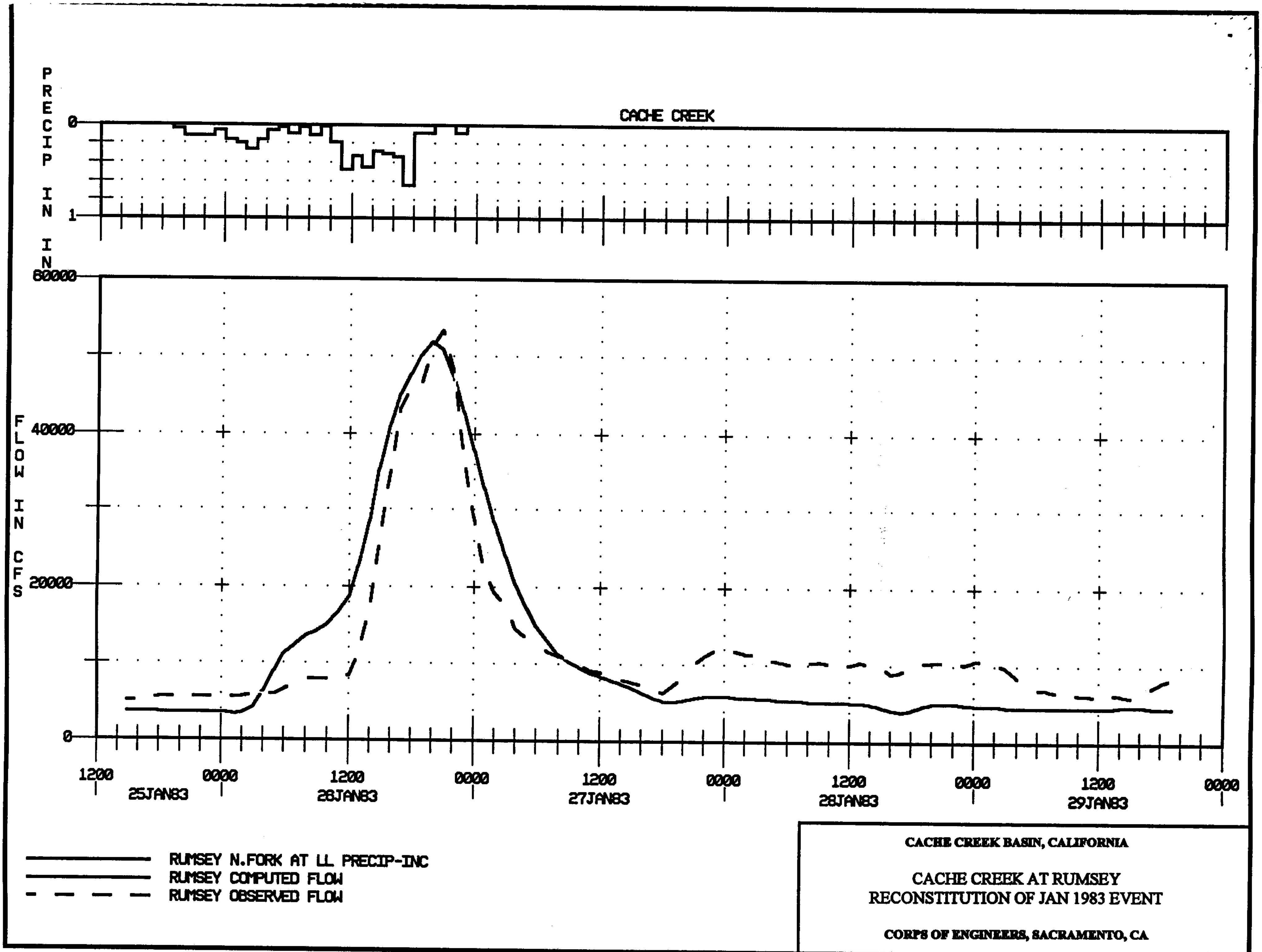
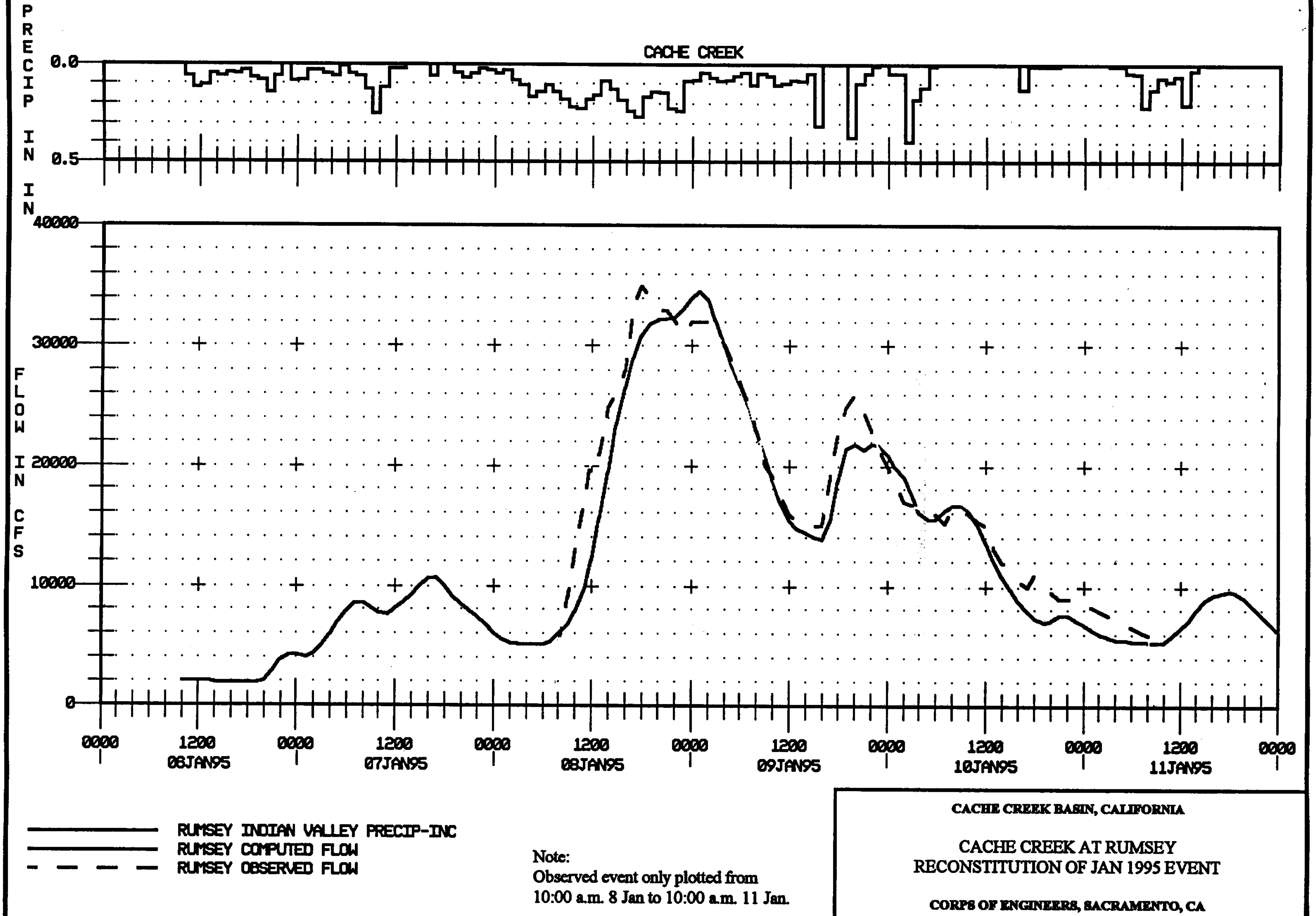

PRECIP IN IN
0
1
CACHE CREEK
FLOW IN CFS
60000
40000
20000
0
1200
25JAN83
0000
1200
26JAN83
0000
1200
27JAN83
0000
1200
28JAN83
0000
1200
29JAN83
0000
RUMSEY N.FORK AT LL PRECIP-INC
RUMSEY COMPUTED FLOW
RUMSEY OBSERVED FLOW
CACHE CREEK BASIN, CALIFORNIA
CACHE CREEK AT RUMSEY
RECONSTITUTION OF JAN 1983 EVENT
CORPS OF ENGINEERS, SACRAMENTO, CA

Chart 7.




Note:
Observed event only plotted from 10:00 a.m. 8 Jan to 10:00 a.m. 11 Jan.

**CACHE CREEK BASIN, CALIFORNIA**

CACHE CREEK AT RUMSEY
RECONSTITUTION OF JAN 1995 EVENT

**CORPS OF ENGINEERS, SACRAMENTO, CA**

Chart 8.

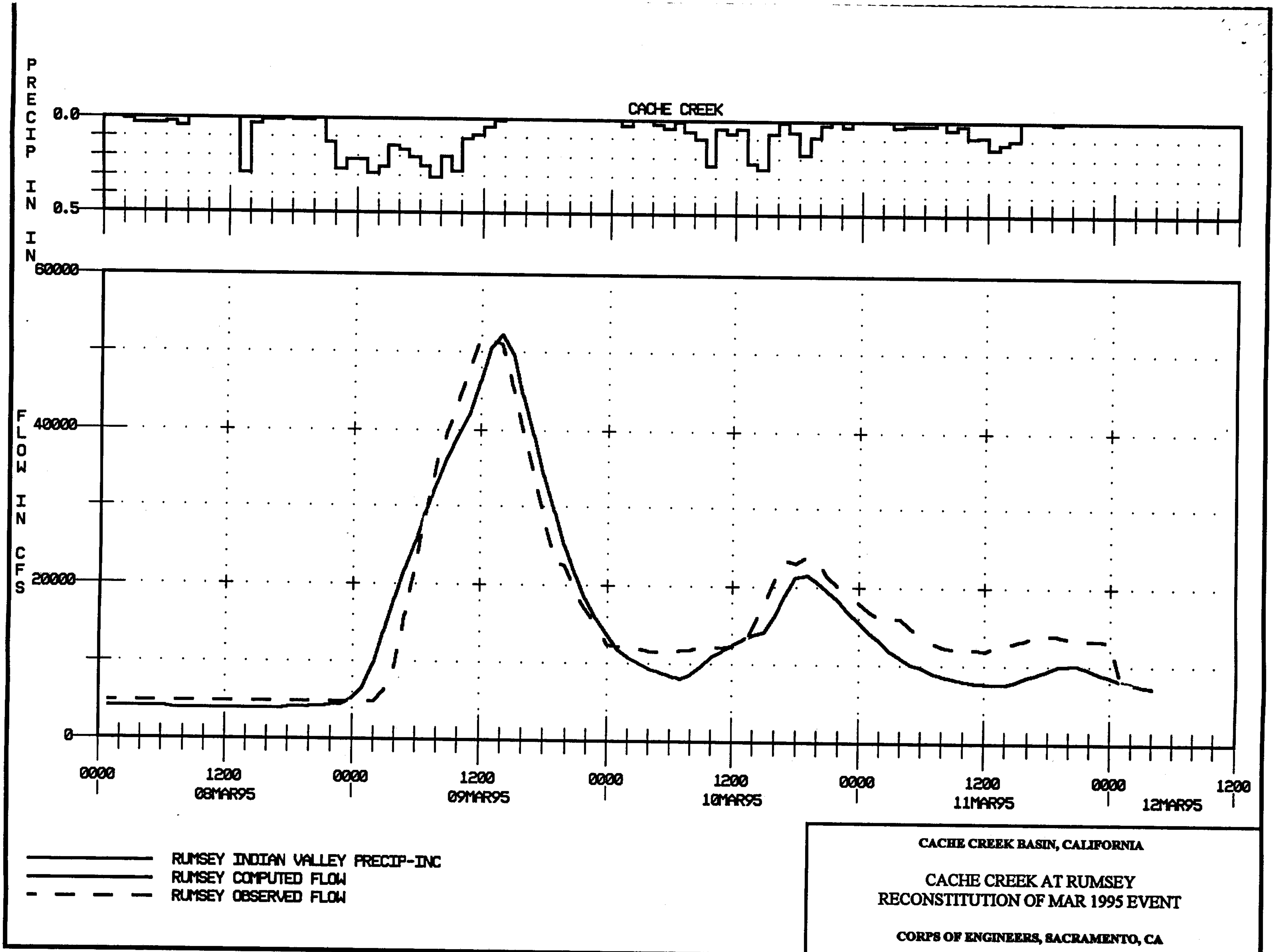
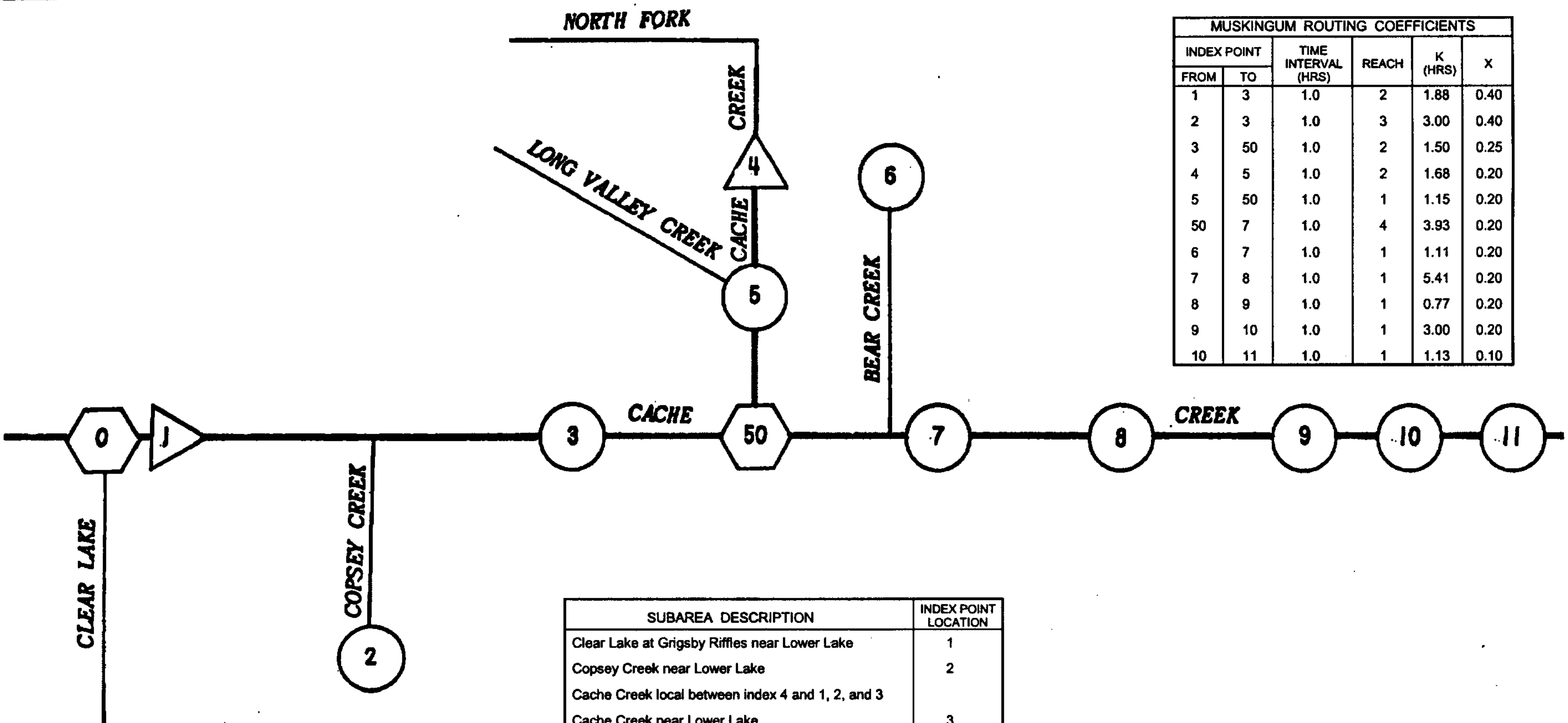

CACHE CREEK
PRECIP IN IN
0.0
0.5
FLOW IN CFS
60000
40000
20000
0
0000
1200
08MAR95
0000
1200
09MAR95
0000
1200
10MAR95
0000
1200
11MAR95
0000
1200
12MAR95
RUMSEY INDIAN VALLEY PRECIP-INC
RUMSEY COMPUTED FLOW
RUMSEY OBSERVED FLOW
CACHE CREEK BASIN, CALIFORNIA
CACHE CREEK AT RUMSEY
RECONSTITUTION OF MAR 1995 EVENT
CORPS OF ENGINEERS, SACRAMENTO, CA

Chart 9.




| MUSKINGUM ROUTING COEFFICIENTS | | | | | |
|---|---|---|---|---|---|
| INDEX POINT | | TIME INTERVAL (HRS) | REACH | K (HRS) | X |
| FROM | TO | | | | |
| 1 | 3 | 1.0 | 2 | 1.88 | 0.40 |
| 2 | 3 | 1.0 | 3 | 3.00 | 0.40 |
| 3 | 50 | 1.0 | 2 | 1.50 | 0.25 |
| 4 | 5 | 1.0 | 2 | 1.68 | 0.20 |
| 5 | 50 | 1.0 | 1 | 1.15 | 0.20 |
| 50 | 7 | 1.0 | 4 | 3.93 | 0.20 |
| 6 | 7 | 1.0 | 1 | 1.11 | 0.20 |
| 7 | 8 | 1.0 | 1 | 5.41 | 0.20 |
| 8 | 9 | 1.0 | 1 | 0.77 | 0.20 |
| 9 | 10 | 1.0 | 1 | 3.00 | 0.20 |
| 10 | 11 | 1.0 | 1 | 1.13 | 0.10 |

| SUBAREA DESCRIPTION | INDEX POINT LOCATION |
|---|---|
| Clear Lake at Grigsby Riffles near Lower Lake | 1 |
| Copsey Creek near Lower Lake | 2 |
| Cache Creek local between index 4 and 1, 2, and 3 | |
| Cache Creek near Lower Lake | 3 |
| North Fork Cache Creek at Indian Valley Reservoir | 4 |
| North Fork Cache Creek local between index 4 and 5 | |
| North Fork Cache Creek near Lower Lake | 5 |
| Cache Creek at junction with North Fork Cache Creek | 50 |
| Bear Creek near Rumsey | 6 |
| Cache Creek local between index 6 and 5, 4, and 3 | |
| Cache Creek above Rumsey | 7 |
| Cache Creek local between index 7 and 6 | |
| Cache Creek near Capay | 8 |
| Cache Creek at Capay Diversion Dam | 9 |
| Cache Creek local between index 9 and 8 | |
| Cache Creek at Road 94B | 10 |
| Cache Creek local between index 10 and 9 | |
| Cache Creek at Yolo | 11 |

**LEGEND:**

Subarea – (2)

Reservoir – ▷1

Routing Point – ⬡

LOWER CACHE CREEK FEASIBILITY STUDY
CALIFORNIA

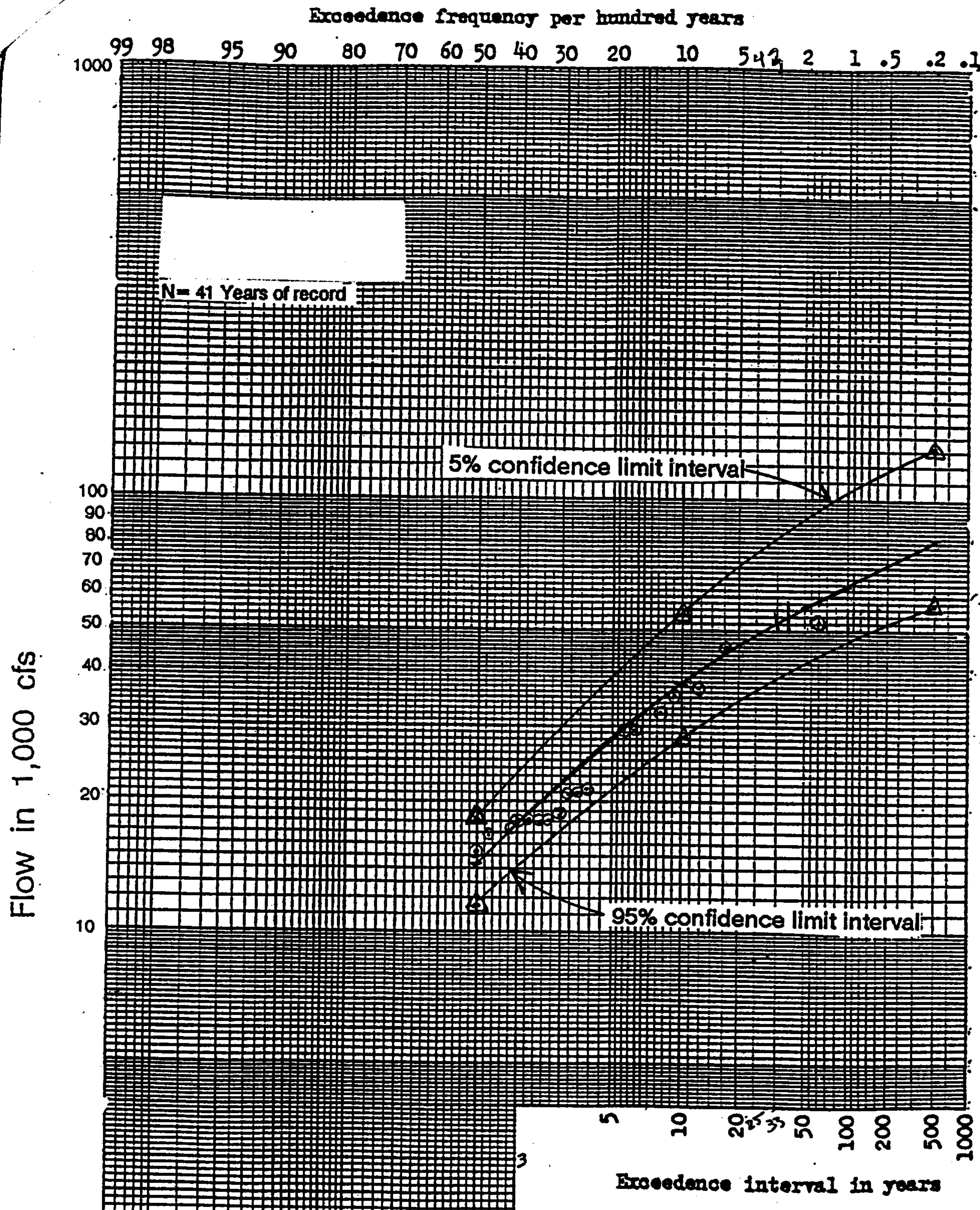
# ROUTING DIAGRAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J. H.
Drawn: J. M.

Date: SEPT 2001

CHART 10




Westside Tributaries, California

## CACHE CREEK AT CAPAY PEAK FLOW FREQUENCY CURVE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared by: G.C.M. Date: AUG 1994

Drawn by: G.C.M. Rev. August 1994

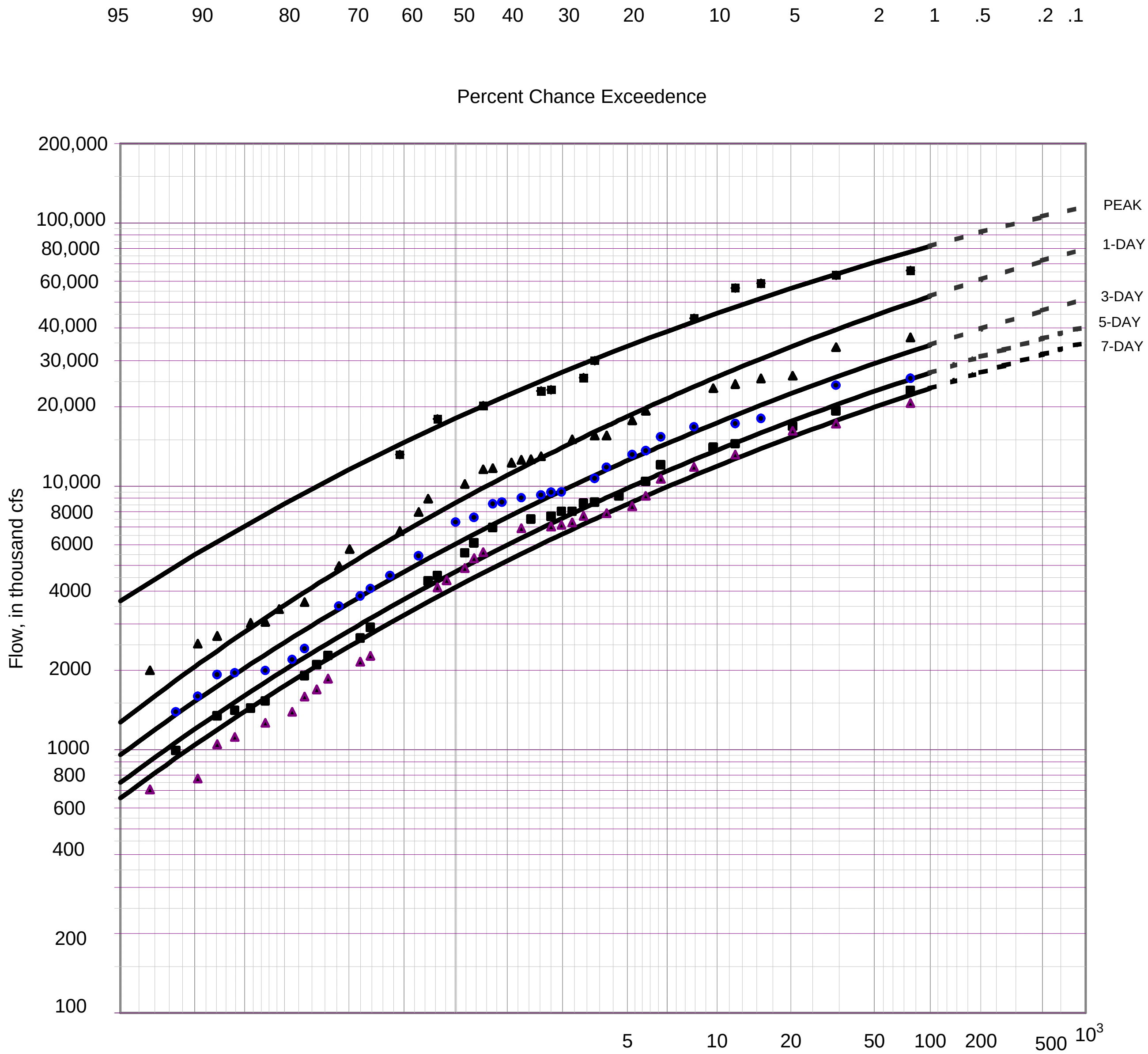
Notes: 1

1. Due to regulation of flow at Indian Valley Reservoir the curve is graphically drawn.
2. Period of record is 1943-1984.
3. Total contributary drainage area is 1019 square miles.
4. Sample statistics were computed for utilization in a risk and uncertainty analysis.

CHART 5

FROM HYDROLOGY FOR WESTSIDE TRIBUTARIES, CALIFORNIA, JUNE 1994

Chart 11.




CURVE STATISTICS:

| | Mean | Std Dev | Skew |
|---|---|---|---|
| Peak | 4.223 | 0.355 | -0.60 |
| 1-Day | 3.895 | 0.426 | -0.60 |
| 3-Day | 3.741 | 0.410 | -0.60 |
| 5-Day | 3.636 | 0.410 | -0.60 |
| 7-Day | 3.576 | 0.410 | -0.60 |

Notes: 1. Computed probability.
2. Cache Creek at Rumsey period of record is WY1961 - 1999, 33 years of record.
3. Curve statistics derived from correlation with Capay gage.
4. Indian Valley Dam regulation removed from gage records.

**CACHE CREEK, CA**

**2000 FEASIBILITY STUDY**

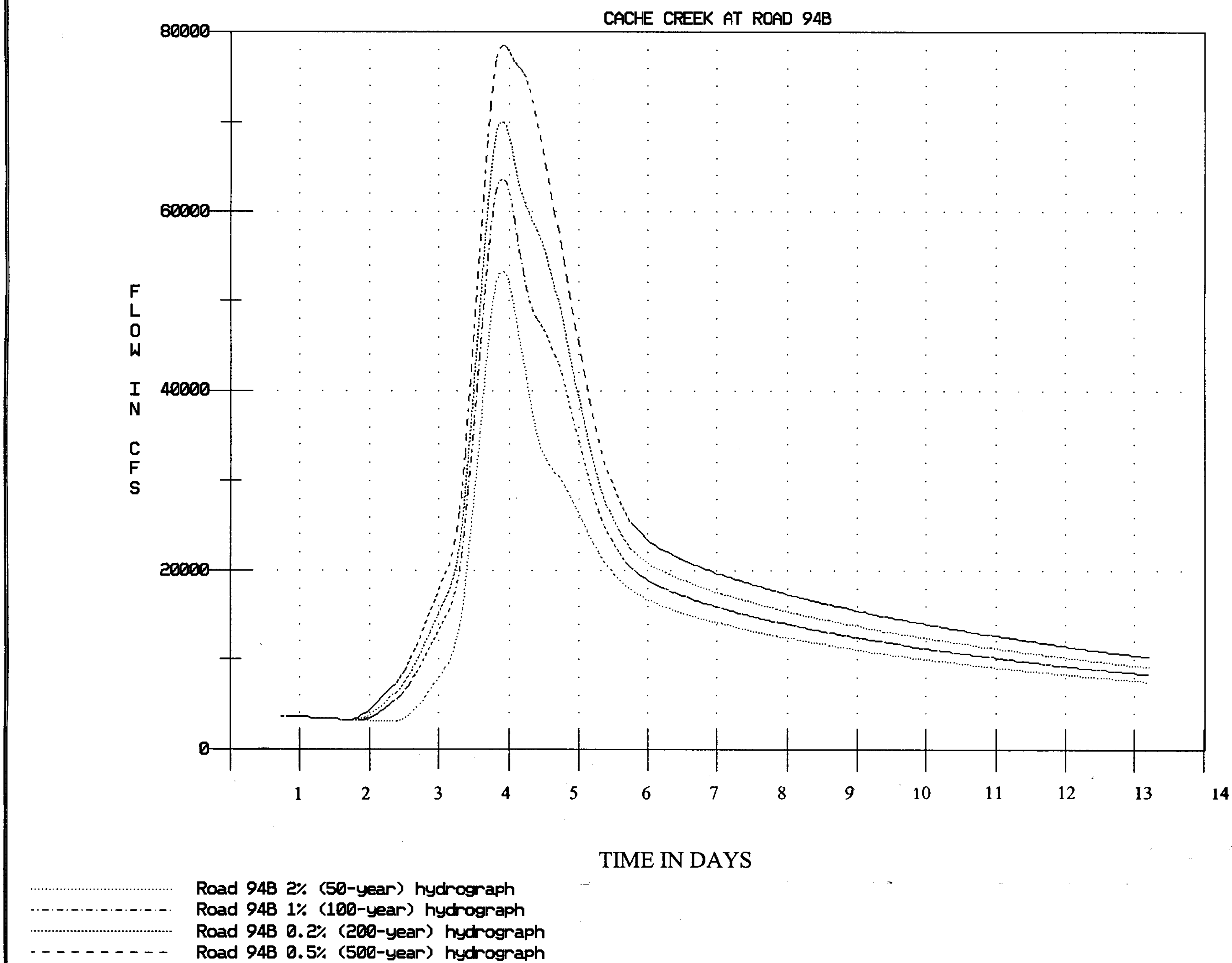
**PEAK RAINFLOOD FREQUENCY CURVE**

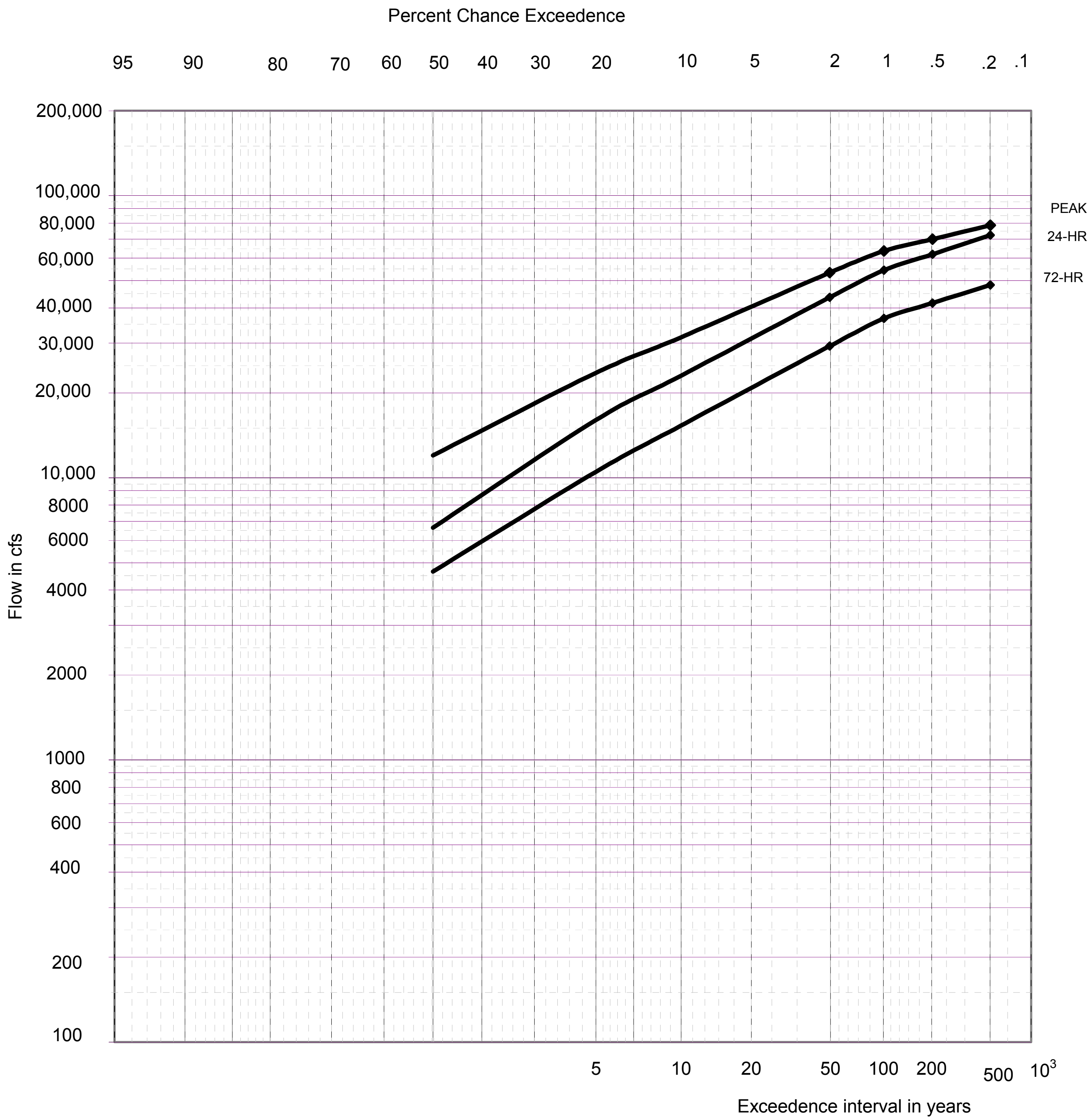
**CACHE CREEK AT RUMSEY**
**WITH NO INDIAN VALLEY DAM**

**U.S. ARMY CORPS OF ENGINEERS**
**SACRAMENTO DISTRICT**

Prepared by JMH

**CHART 12**


CACHE CREEK AT ROAD 94B
80000
60000
40000
20000
0
FLOW IN CFS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME IN DAYS
Road 94B 2% (50-year) hydrograph
Road 94B 1% (100-year) hydrograph
Road 94B 0.2% (200-year) hydrograph
Road 94B 0.5% (500-year) hydrograph




Notes:

1) Computed Probability
2) 2%, 1%, 0.5% and 0.2% chance exceedance events generated by HEC-1 model output

Prepared by JMH

**LOWER CACHE CREEK, CA**

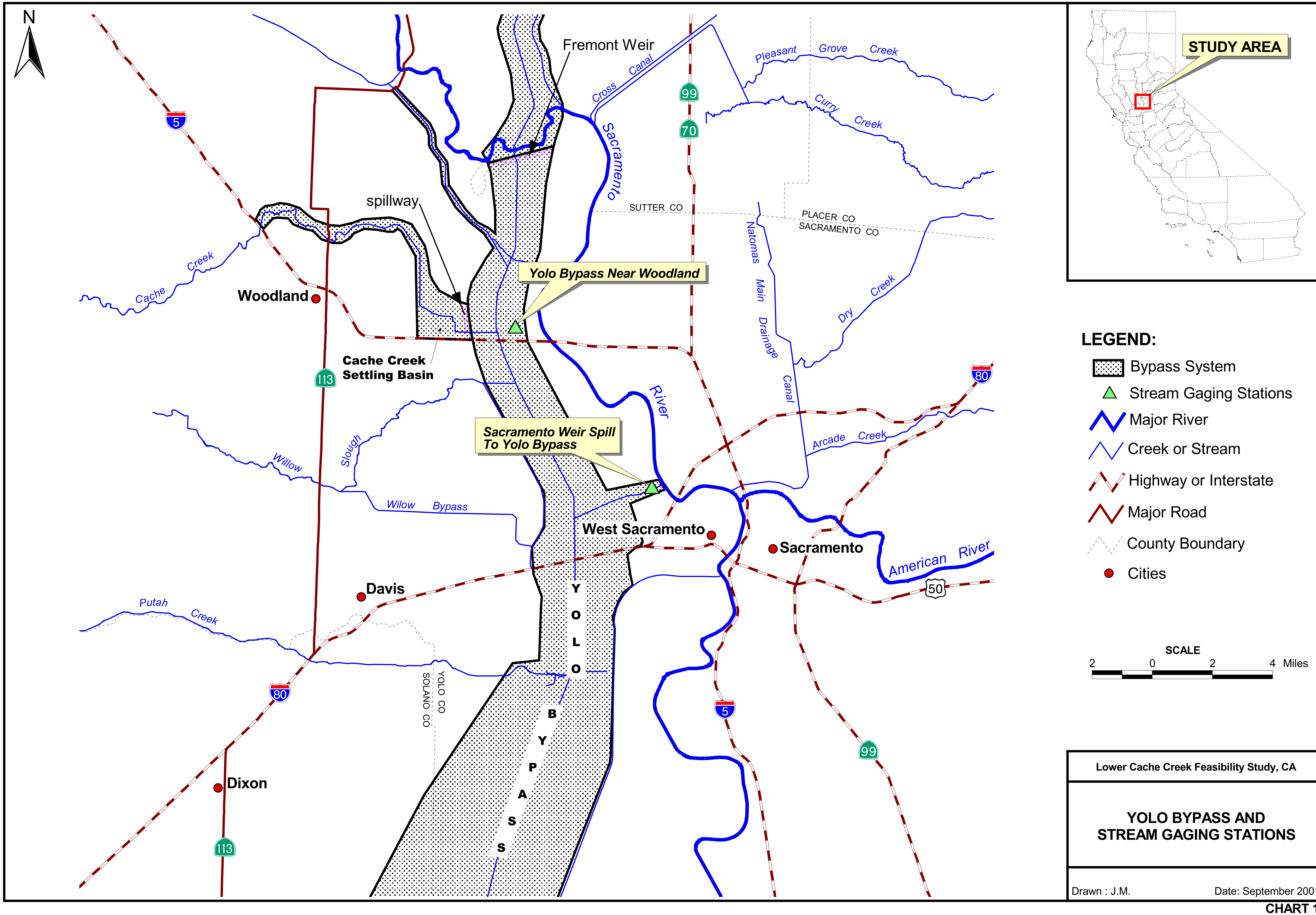
**2000 FEASIBILITY STUDY**

**PEAK RAINFLOOD FREQUENCY CURVE**

**CACHE CREEK AT ROAD 94B**
**EXISTING CONDITIONS**

**U.S. ARMY CORPS OF ENGINEERS**
**SACRAMENTO DISTRICT**

**CHART 14**


N
Fremont Weir
Cross Canal
Pleasant Grove Creek
Curry Creek
Sacramento
SUTTER CO
PLACER CO
SACRAMENTO CO
spillway
Cache Creek
Woodland
Yolo Bypass Near Woodland
Natomas Main Drainage Canal
Dry Creek
Cache Creek Settling Basin
River
Sacramento Weir Spill To Yolo Bypass
Willow Slough
Wilow Bypass
Arcade Creek
West Sacramento
Sacramento
American River
Davis
Putah Creek
YOLO CO
SOLANO CO
YOLO BYPASS
Dixon
STUDY AREA
LEGEND:
Bypass System
Stream Gaging Stations
Major River
Creek or Stream
Highway or Interstate
Major Road
County Boundary
Cities
SCALE
2 0 2 4 Miles
Lower Cache Creek Feasibility Study, CA
YOLO BYPASS AND STREAM GAGING STATIONS
Drawn : J.M.
Date: September 2001
CHART 15