Extreme Precipitation in the American River Basin

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BIOGRAPHICAL SKETCH

Mr. Roos is Chief Hydrologist (part time) with the California Department of Water Resources (DWR) in Sacramento, in its Division of Flood Management. He had 43 years of experience as a water engineer with DWR when he retired from full time service in July 2000. He continues to work part time as a retired annuitant. Prior to retirement, he oversaw work on flood forecasting, hydrology, water supply and snowmelt forecasting, staff meteorology, and related subjects. As Chief Hydrologist, he also provided (and continues to provide) advice on drought, floods, global warming, and weather modification and tries to keep abreast of ongoing water and flood planning studies.

Mr. Roos received a B.S. in Civil Engineering from San Jose State University in 1957 and has been employed by the Department of Water Resources since then. His career began with a series of studies on channels, levees, proposed water transfer works, and water quality in the Sacramento-San Joaquin River Delta. From 1965 through 1978, he worked on various water planning studies and reservoir system operation studies, and evaluated water requirements, supplies, and potential water system developments in the Department's Division of Planning.

In 1979, he began his current assignment in the Division of Flood Management, primarily on flood and water supply forecasting. He was one of the authors of several editions of DWR Bulletin 160, the Department's main water planning document. During the past 10 years, he has had opportunity to share expertise in Israel, northern India, Nigeria, and China.

EXTREME PRECIPITATION IN THE AMERICAN RIVER BASIN

By

Maurice Roos[1]

The American River basin above Folsom Dam covers 1,861 square miles or 1,191,000 acres. At the downstream Fair Oaks gage, just below Nimbus Dam, the drainage area is slightly bigger, 1,888 square miles, which converts to 1,208,000 acres. Rounding to 1.2 million acres is convenient, because that means 1 inch of rain runoff would be 100,000 acre-feet. Therefore, a very large 3-day flood, like that of February 1986 or the 1997 New Year's flood, represents 10 inches of runoff. Not all precipitation turns into runoff; some infiltrates into the soil where it may be returned later as evapotranspiration, or be slowly released as stream base flow, and a small amount may be intercepted by vegetation. In flood work these are normally called losses. In many winter storms, a substantial amount of basin precipitation can go into snowpack accumulation and not contribute to runoff. On the other hand, additional runoff may be generated by a pre-storm snowpack if watershed storm temperatures are above freezing.

The February 1986 flood produced about 23.2 inches of precipitation over 6 days which generated about 1.32 million acre-feet or some 13 inches of runoff (Corps of Engineers, 1987). The estimated maximum 3 day precipitation rate for the 1986 storm was about two-thirds of the 6 day amount at 15.6 inches. This was appreciably more than the estimated 1997 amount which seems to have been 11.7 inches. Basin losses were much higher in 1986 because the watershed started out drier.

Precipitation on the American River basin ranges from about 23 inches near Folsom Dam to over 70 inches in several northeastern and eastern high elevation areas. The basin annual average, from studies by James Goodridge (DWR, 1966), is 55.6 inches; the 1987 Corps of Engineers flood manual shows 53 inches, but that is probably above Fair Oaks gage, based on the same figure being reported in the 1971 Interagency Framework Study for the Fair Oaks gage drainage area. Goodridge (DWR, 1966), calculated the average 1911-1960 American River Folsom Dam natural runoff at 2.55 MAF, which would be 25.6 inches. Subtracting this from the 55.6 inches of average precipitation gave a loss of 30.0 inches, a few inches more than the runoff.

Blue Canyon is an important long term weather station at 5280 feet, one mile high, adjacent to Interstate 80. Its annual average is about 63 inches. (This is 1600 millimeters at an elevation of about 1600 meters, a nice match in the metric system.)

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On average, Blue Canyon is about 10 to 15 percent wetter than the basin as a whole. This difference may be amplified a bit in orographic storm situations.

Large Storms

Basin rainfall events can be characterized by return periods, that is frequency, for a given length of time such as the peak one day or three day amounts. These estimates are based on the historical record and may not represent the future, especially if global warming changes storm intensities.

Another definition, which used to be employed, is the standard project storm (and standard project flood or SPF). Such a storm is based on the largest storm in the region transposed over the basin of interest, which in our case would be the American River basin. Guidance for transposition was developed by the Corps of Engineers many years ago. I think it is still a good concept but its use has fallen out of practice in deference to statistical treatment and the probable maximum precipitation (PMP) - probable maximum flood (PMF) analysis used for spillway design. Sometimes the SPF is taken as half the PMF. The SPF represents a range of from about a 1 in 200 to a 1 in 400 year event.

The biggest rainfall event believed meteorologically possible on a basin is the probable maximum precipitation or PMP. These synthetic storms are developed now by the procedures in Hydrometeorological Report No. 59, Probable Maximum Precipitation in California (National Oceanic and Atmospheric Administration and the Corps of Engineers, 1999). That report supersedes the earlier HMR No. 36 in 1977. The definition is “theoretically, the greatest depth of precipitation that is physically possible over a given storm area at a particular geographic location at a certain time of the year” (HMR 59, 1999). For the American River basin the largest amounts would be in the December through February period. According to recent work by Robert Collins, of the Corps of Engineers in 2001, the watershed 72 hour PMP could be 29.6 inches, slightly over half the average annual precipitation in the basin.

Comparisons of Past Storms and Floods

Although an intense rainfall event is needed to produce a large flood, the relationship between precipitation and runoff is not direct. Two major factors influence the amount of rain which actually becomes runoff. They are the relative wetness of the watershed at the beginning of the storm and the portion of precipitation going into net snowpack change. Historically there has been a lot of variation in the storm loss rates, that is the difference between basin precipitation and flood runoff at Folsom Dam. A list of the larger flood events of the 20th century from 1905 (the beginning of the measured record at Fair Oaks gage) is as follows:

Water Year	Month	Highest 3-day Runoff Rate
1997	Jan	164,300 cfs
1986	Feb	166,000
1980	Jan	97,800
1965	Dec ‘64	140,300
1963	Jan - Feb	93,900
1963	Oct ‘62	40,000
1956	Dec ‘55	127,400
1951	Nov ‘50	107,500
1938	Dec ‘37	47,500
1928	Mar	98,200
1909	Jan	87,200
1907	Mar	87,800

The above table and this paper focus on the 3-day period as the best volumetric measure of the need for flood management on the American River, including the existing reservoir flood control storage.

The December 1937 flood was included in the list because that storm and flood was an important input in the original formulation and flood control design of Folsom Dam in the late 1940’s. The October 1962 event, known as the Columbus Day storm, was unusual. It generated the highest 3-day rainfall amount although the flood volume was relatively small because the watershed was still very dry from the summer. See the estimates for the various storms on Figure 1, which was developed from estimates of storm percentages at up to 10 precipitation stations, based on a 55.6 inch average annual precipitation basin wide. Results would only change slightly if the actual basin precipitation was a little less, and the relative amounts of the various storms would remain the same. The chart also assumes that the maximum 3-day rates for all American River precipitation stations essentially coincide. If there was a significant lag from one end of the watershed to the other during storm passage, that could slightly lower the maximum amounts by a few percent.

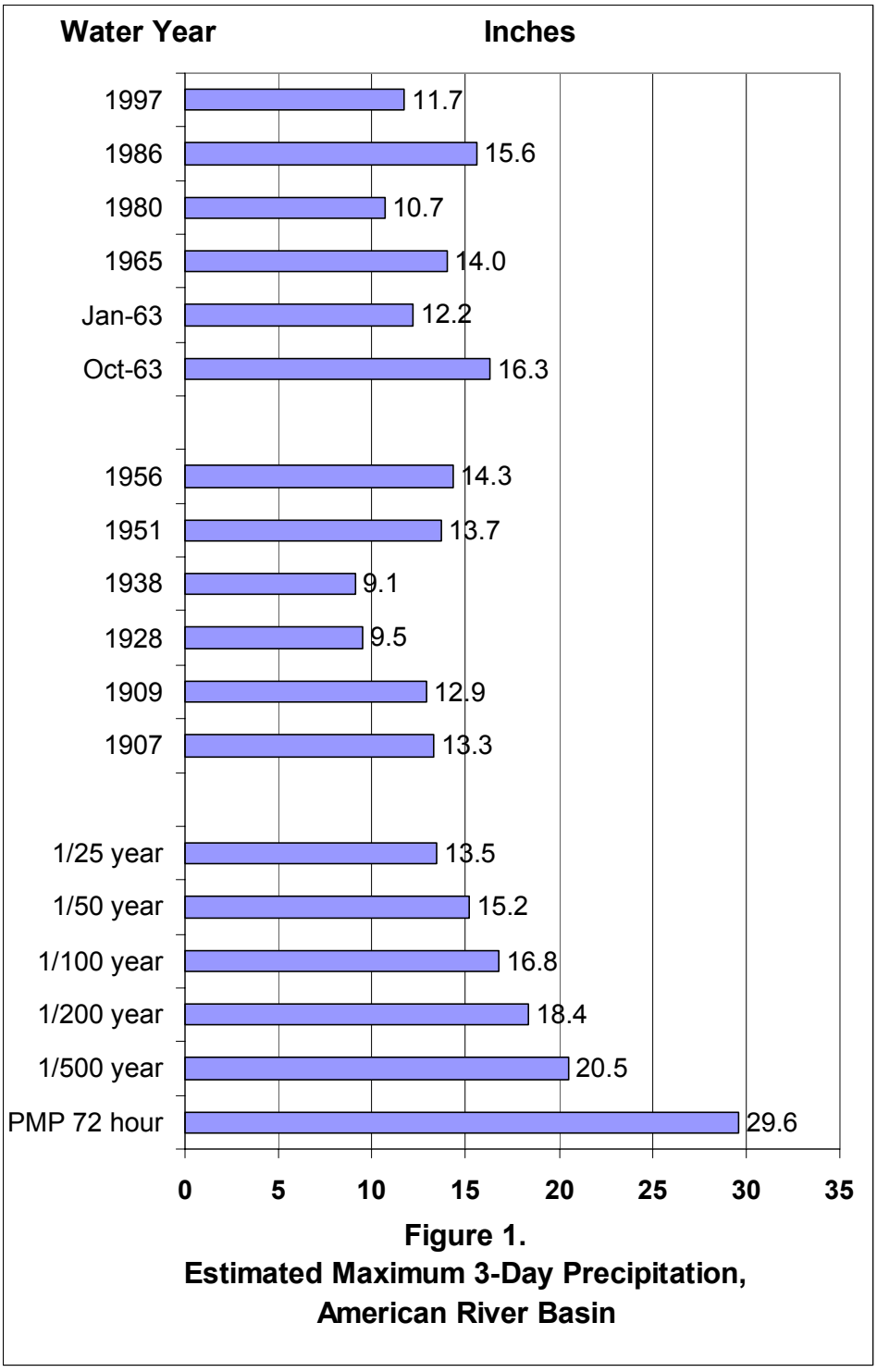

Figure 1.
Estimated Maximum 3-Day Precipitation,
American River Basin

The lower part of Figure 1 shows the estimated annual probabilities of given 3-day precipitation amounts. The 1997 storm produced a peak unregulated inflow 3-day runoff of 164,300 cfs, just a tad below 1986 record amount. But its peak estimated natural runoff was nearly 300,000 cfs and the peak one-day rate was a record 249,000 cfs.

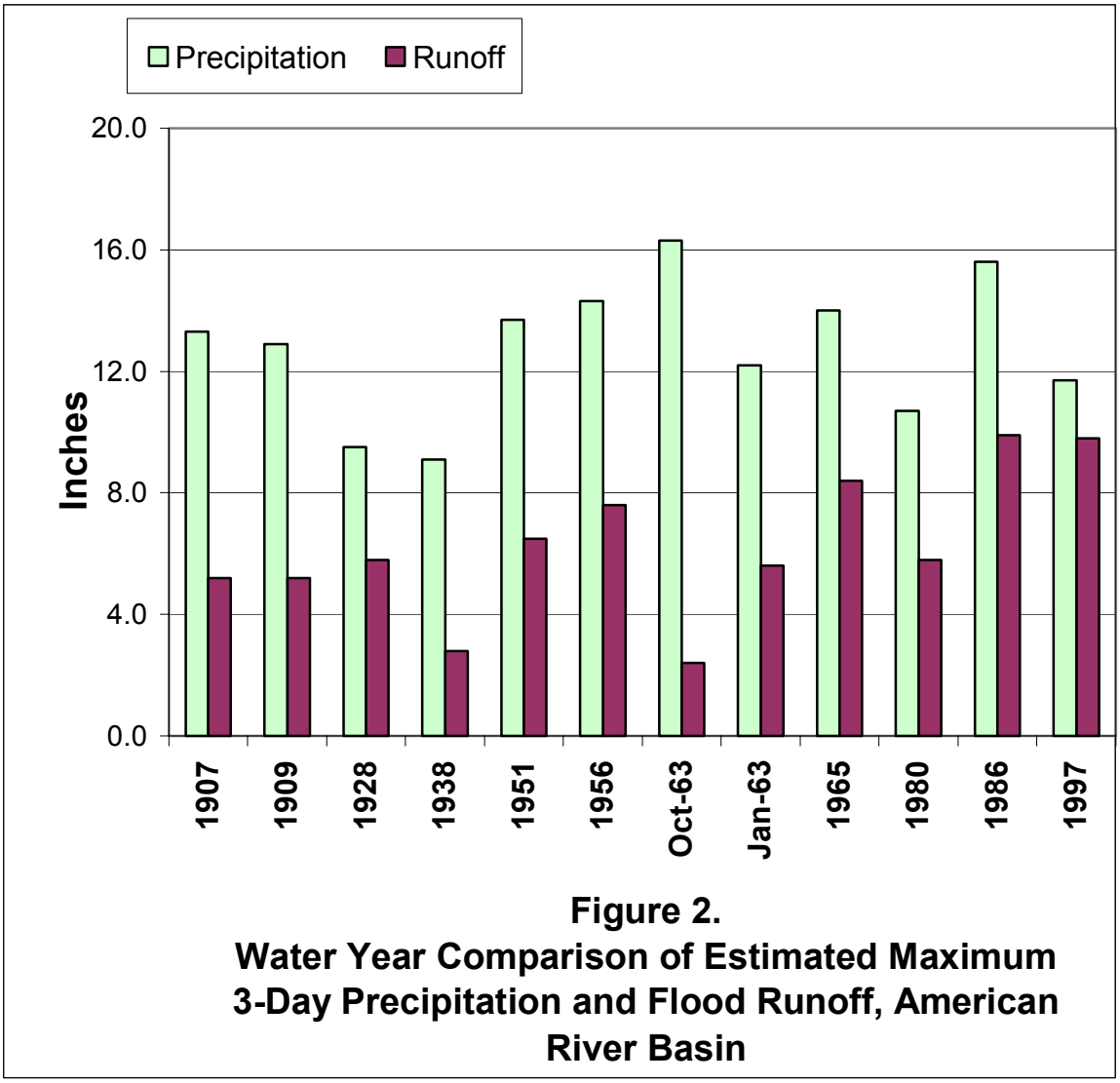

Figure 2.
Water Year Comparison of Estimated Maximum 3-Day Precipitation and Flood Runoff, American River Basin

The estimated 3-day precipitation input to the 1997 storm was three fourths of that in the February 1986 storm and not much more than a 1 in 10 year event (which would be 11.3 inches). Figure 2 gives a comparison of basin precipitation and runoff amounts, both expressed in inches. The 1997 loss rates (difference between precipitation and runoff) are the lowest of any of the 12 events. This is because of the extremely wet December, already twice normal, prior to the New Year's storm. It is sobering to think what might have happened if an approximately 1 in 60 year storm like February 1986 had occurred with about 4 inches more rainfall in 1997. That would have generated another 400,000 acre-feet.

Earlier Floods

The measured flow record on the American River extends back to 1905. But there were many floods in the preceding half century and before. Floods for the

1878 – 1909 period on the lower Sacramento River have been chronicled by Dr. John Thompson (November 1996). There were large floods in February 1878, in early 1881, December 1889 and in March 1890, late December 1892 and early January 1893 and again in March 1893, early March 1902, and a bigger flood in late February and early March of 1904. The 1500 foot Edwards levee break in 1904 south of downtown Sacramento deeply inundated practically everything south of Y Street where there was a levee then. This was the flood which led to installation of a stream gaging measurement network to get a better quantitative estimate of the actual flood flows. The new gages were ready in 1907 and 1909 for even bigger floods. It is a composite of 1907 and 1909 which furnished the basis for design of the Sacramento River Flood Control Project. The story during these years is a continual succession of ever higher Sacramento River at I Street stages before some levee broke to stop the rise. The 1890 floods were indirectly responsible for the pear orchards of today in the Sacramento River Delta. Prior to that flood, many acres of peaches, apricots, cherries and plums, as well as pears were grown. As a result of flooding and water logging in 1890 only the pears survived; most of the other orchard trees perished and the farmers took to growing pears along the river.

What about the 1862 flood? This was apparently the grand daddy of all flood events when much of the Central Valley was an inland sea. Quantitative estimates are lacking, and we can not relate the peak stages reported to either flow or 3-day rates with confidence. It is my opinion that the flood was slightly bigger, perhaps 10 percent more than the 1997 event. That water year was a soaker with three large rain on snow events. One recorded measurement was 72 inches in Sonora between November 11 and January 14 which increased to 102 inches by January 31. The peak 3-day rainfall amount in January at Nevada City was 14.7 inches, comparable with the 1997 storm value of 15.15 inches at the same station.

One other precipitation event deserves mention - an extreme local precipitation event from a severe thunderstorm which dumped 4.41 inches in one hour in June 1982 on an automatic remote rain gage on Forni Ridge at 7600 feet elevation just north of Highway 50. That sets the one hour record so far for California. Over 3 inches fell in 18 minutes and caused a flash flood which came down to the highway.

I should mention the April 1880 Sacramento City storm. It produced 1.99 inches in 2 hours and 7.24 inches in the peak 24 hours. The maximum day was April 20th at 5.28 inches, the 2 day April 20 and 21 total was 8.37 inches and the 3 day April 19 – 21 amount was 8.81 inches. The month was 14.20 inches compared to 2.75 this last April which we thought was wet. The 3-day amount, 8.81 inches, is nearly half the normal annual average of around 18 inches. By contrast, the wettest 3-day period on the American River watershed, in October 1962, was 29 percent of the annual average with February 1986 not far behind. The 1880 storm apparently did not produce a large river flood. It did not seem to be a strongly orographic storm and mountain precipitation was largely in the form of snow.

What can one say to conclude? I think the key element is that we need to look out whenever the mountain watersheds get extremely wet, as happened in 1997, when a rainstorm not much over a 1 in 10 year 3-day event produced a whopping flood. The same situation occurred in 1862 when a couple of heavy antecedent storms in December primed the watershed for the biggest flood in January after snowfall to relatively low elevations.

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