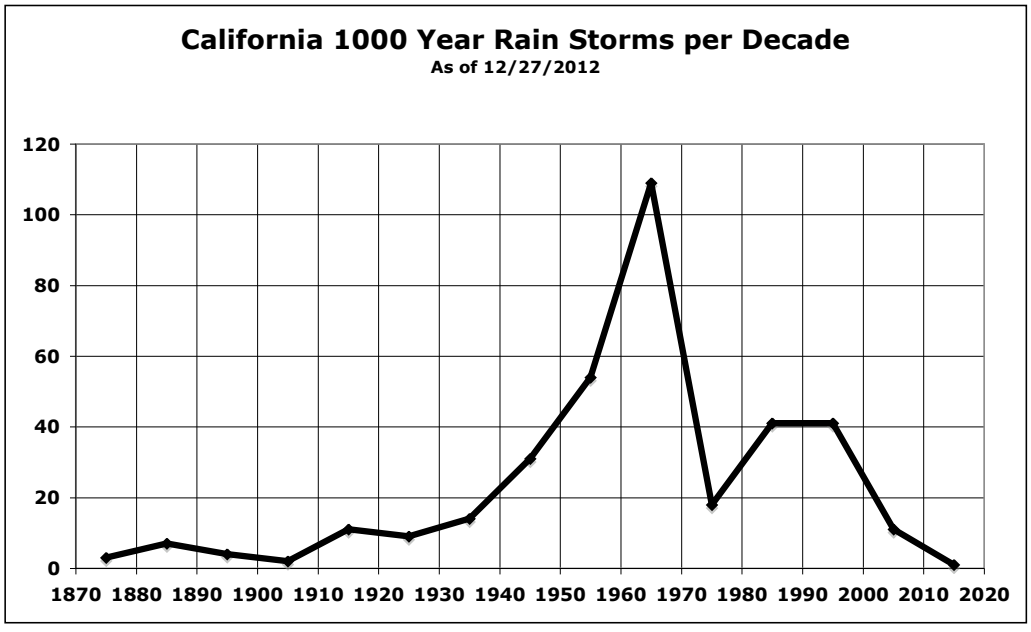
A History of 1000-Year Rainfalls in California

Thousand-year rainstorms have occurred several times in California in the memory of most residents. There have been so many in the short period of the state's recorded history that casual observers question their reality. The key to understanding their frequency is to realize that very intense storms cover very limited areas and California is a very large region. On the average -- there should be one – 1000-year storm each year for each 1000 rain gages -- if the measurements were independent events. The unreality of this example is that storm measurements are not independent; the same storm is frequently measured in many rain gages with highly variable results. The data of this study was originally publishes as "*Rainfall for Drainage Design*" DWR Bulletin 195 in 1976 and has been updated to 2012.

It was found that with rainfall extremes, the coefficients of variation and skewness were geographically distributed. This allowed averaging dimensionless coefficients for each square degree to make estimates of storm frequency from short records when using regional averages of these coefficients rather than the sample statistics.

The one thousand year event is roughly one that is about five standards deviations above the average based on regionally averaged coefficients of variation and skewness. The regions used here are each one-degree quadrangles of longitude and latitude.

The decade 1960-70 had 109 events of 1000-year storms. The decade of 2000 to 2009 has had only 11events of 1000-year storms that may reflect the decline of the number of volunteer climate observer reporting to DWR. The reason for few 1000-year storms from 1870 to 1910 was that there were fewer records and the States Weather Record Archives were lost in the San Francisco Earthquake and Fire of April 18, 1906.

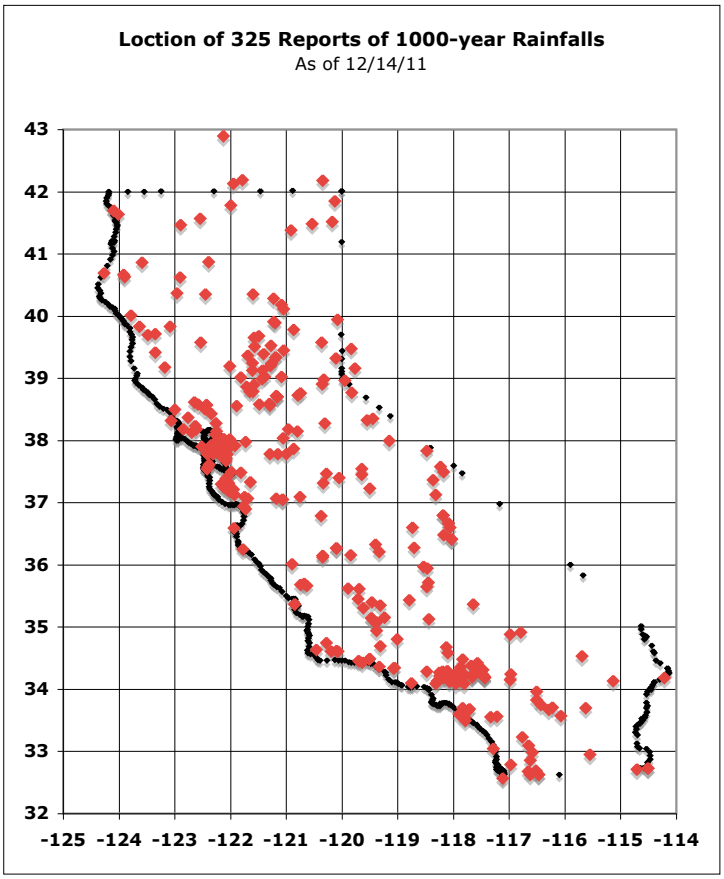


The largest California storms can be evaluated based on the number of stations reporting highest ever damage. There are ways of defining the worst ever storm. The billion dollar storms of recent record occurred in 1954(1,337), 1962(1,483), 1964(1,231), 1969(1,464), 1982(1,209), 1986(1,239), 1995(1,281) and 1997(2,064). This study is clearly biased in that the 2002-dollar values been taken from various published sources.

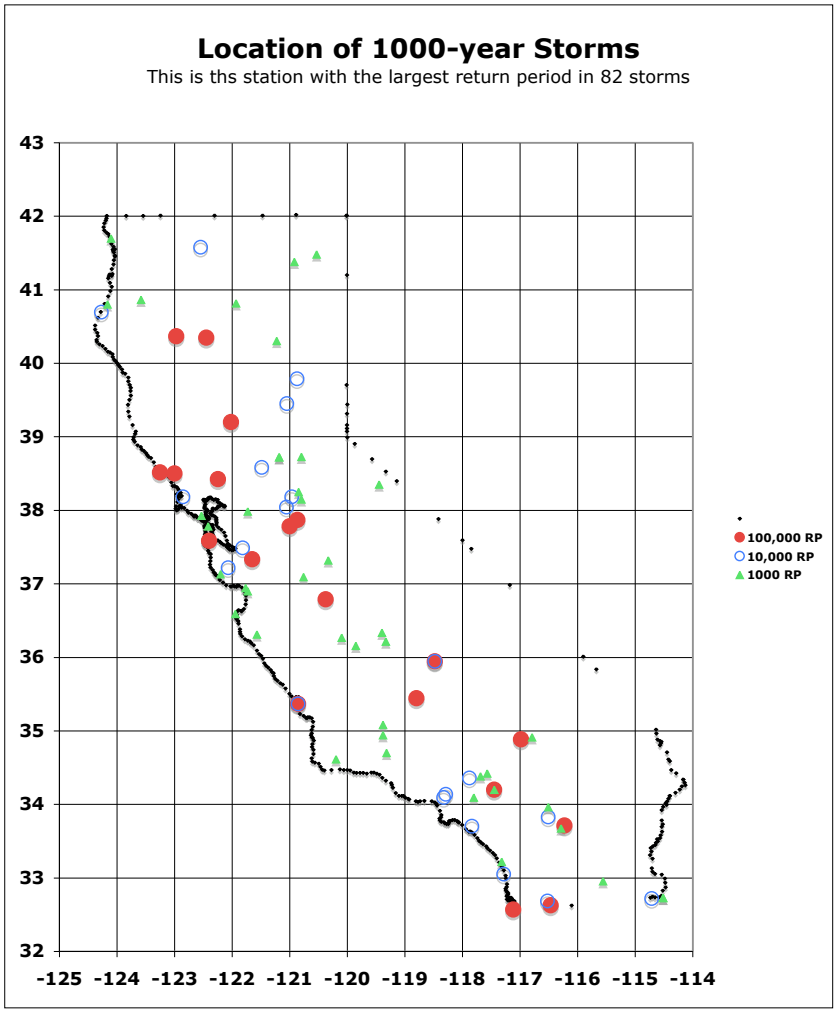
The largest storms of California based on the number of lives lost would be the New Years storm of 1934 when 96 lives were lost.

The largest storms of California based on the number of station reporting highest ever rainfall the January-February storm of 1969 when 328 stations. Notable also was the Columbus Day storm of 1962 when 224 stations reported highest ever rain and the February storm of 1986 when 233 stations reported the largest ever rainfall.

The storm of January 23 1943 had 101 reports of 10 inches of rain in one day.
It was concluded that in general an average of $1 million in flood damage occurs with each rain station reporting a highest ever rainfall. See Worst Storms.xls.



It is apparent that the frequency of large storms in related to the density of observations. The locations of stations reporting 1000-year storms are shown here:

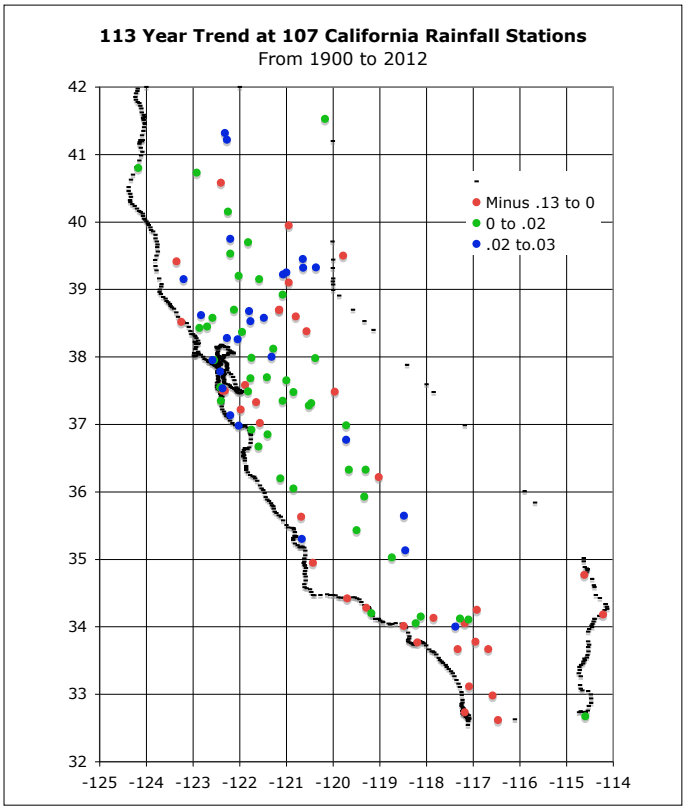


This shows the highest rain of 1000-ter storms

In this study maps of thirty large storms are plotted at the same map scale to illustrate the local nature of extreme storm. As an example the great storm of the San Francisco Bay area of January 4, 1982 covered a relatively small region but had 1000-year rainfalls at 15 stations.

A clear view of severe rainstorms is clouded by vast array of rain records. Three rain records have come down to which are fairly continuous from 1850. This study compares records of large storms that have occurred since rainfall measurements were commonly made in about 1862. This was the first storm where measurements exceed 1,000 years or where enough stations report the highest ever rainfalls. Storm maps are included in the Storm folder on the DVD.

The 113-year rainfall trends for California are in general for dryer south coastal weather and wetter inland weather in northern California; as a result flood protection works once thought to be adequate are rendered less adequate by the heavier rainfalls in the interior drainage basins. Sacramento is near sea level and the flood threat inspired Leon Hunsaker to write a book called "*Lake Sacramento*" in November 2005.



One way of visualizing the California's rainfall pattern is to consider the return period of five inches in one day. In the more humid mountainous areas, five inches in one day is the expected every other year at Blue Canyon but five inches in one day a 1000-year event at Sacramento. In the arid portion of the State five inches in one day is a rare event that occurs less frequent than once in a thousand years.

California has a remarkably variable rainfall. The average annual rainfall for the State is estimated to be 23 inches per year. The range in average annual rainfall is from a high of 148.86 at Ship Mountain in the Smith River basin in the northwest to a low of 1.65 inches per year at El CentroAnother remarkable thing about rainfall variability in California is that the variability of the most recent 50 years from 1950 to 2000 was far greater than the previous 50 years. This resulted in a smaller than expected level of protection from Folsom Dam on the American River.

The maximum total rainfall for a single water-year in California was 256 inches. This occurred at Camp Sixin the Smith River Basin for the 1982 water year. There are reports (Schmidli 1981) of stations going for a whole year with no rain.

Another aspect of California's rainfall distribution that reflects on this study is the distribution of the number of rainy days per year. The Northern part of the state has far more rainy days per year than in a location in the South with an equal average annual rainfall.

The basic picture of a 1000-year rainfall in California is when 20 percent of the average annual rainfall occurs in one day in the relatively humid northwest corner of the State. Over 120 percent of the average annual rainfall occurs in one day in the arid Southeast corner of the State. Actually a 1000-year event for Brookings, Oregon is 15 percent of the mean annual rainfall in one day and at Yuma, Arizona it is 165 percent.

This study is an over-view of records of all daily total rainfall measurements that were readily available in California. They were compiled to study spillway safety and culvert sizing. It required examining all available precipitation records and evaluating the frequency of flood producing rainfalls for the areas affecting the projects. There are areas in the rain gage network where the records are not yet analyzed as well as regions of no gages.

This study is based on 145,000 station years of daily rainfall observations from 4100 daily rain gages. This translates to 34 million daily observations, so it should come as no surprise that the largest rainfall event reported here is 13.4 standard deviations above the mean and has a return period of over 10 million years. This was 16.10 inches at Campo in San Diego County on August 12, 1891.

The Campo record is one of over 1000 records in California that have been operated by the National Weather Service since it was founded in 1891 (Darter 1942). The National Weather Service rain-gage network was the backbone of water and flood control planning for the state and nation. Mainly volunteer weather observers have operated it since the beginning. California has over 100 additional agencies keep networks of rain gages to supplement the National Weather Service network that is too sparse for detailed planning studies.

It is hoped that future automated rain data collection platforms can maintain the historic continuity with this vast reservoir of knowledge. Sharing historic data on rainfall is an important objective. Attorneys and those who need to know the relative significance of historic rainfall events will find this study useful. Their needs are one of the objects of the study of rainfall extremes.

A characteristic of many of the cyclonic storms of this study is the buildup of robust weather systems on the windward ocean facing slopes, from which they then spill over on to the "rain shadow zone" on the leeward side of the mountains. There are many examples of large return periods in the "rain shadow" with greater rain depths and lesser return periods on the windward slopes. An out standing example is the February 10, 1978 storm on the Southern San Joaquin Valley; as well as the Sierra Valley portion of the February 1986 storm. Other examples include

the Antioch storm of September 1918, the Calaveras Dam Storm of November 18, 1950 and the Richmond Storm of January 4, 1982.