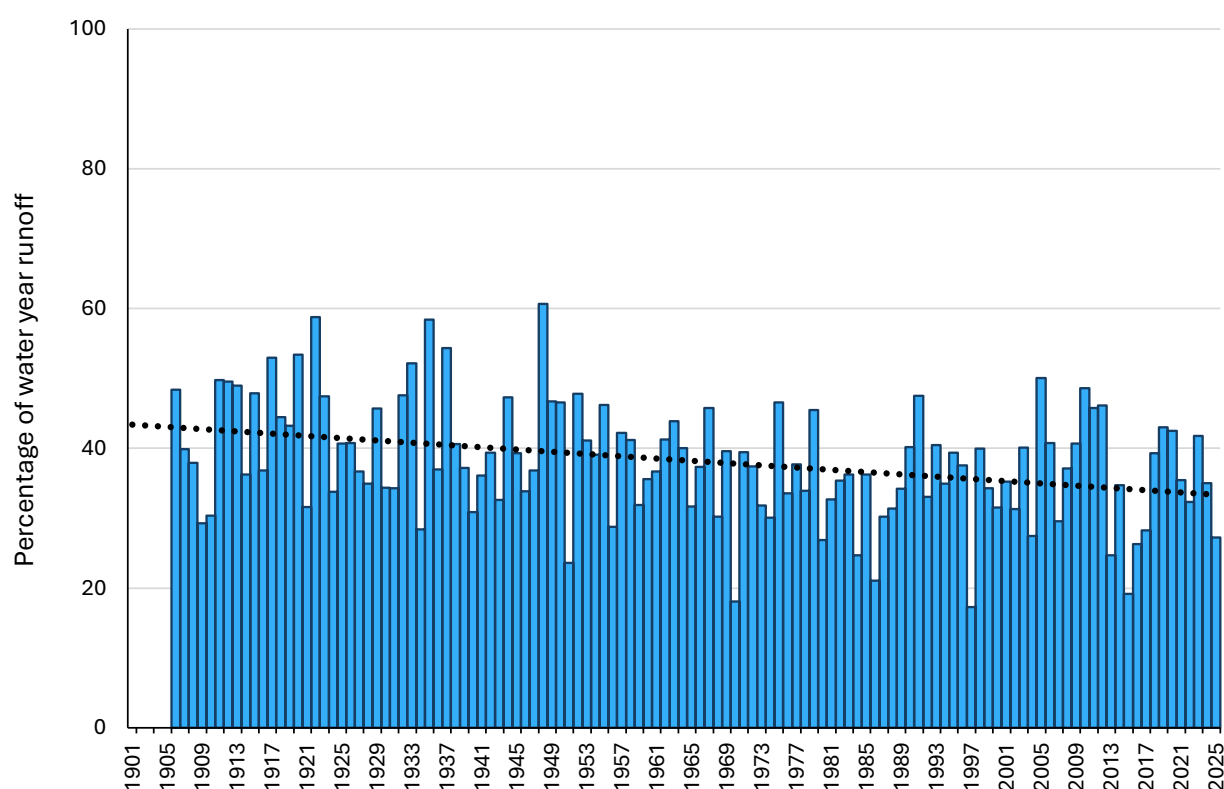


3.13 Snowmelt Runoff

The fraction of spring (between April and July) snowmelt runoff from the Sierra Nevada into the Sacramento River and the San Joaquin River hydrologic regions has generally declined over the past century relative to total runoff for the water year (October 1 through September 30). The declines are about 20 percent in the Sacramento River and about 12 percent in the San Joaquin River.

Figure 3.13.1. Sacramento River Spring Runoff.

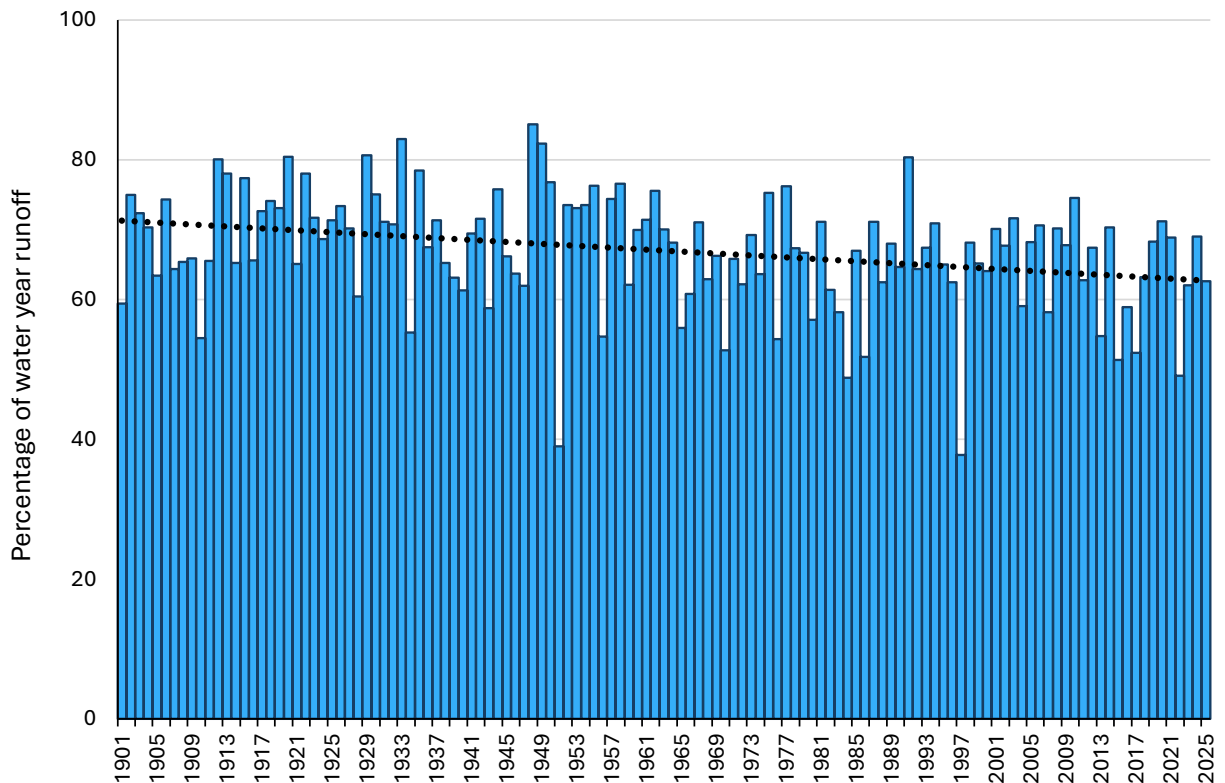


The Sacramento River, California's longest, flows over 400 miles from the Cascades through the Central Valley, joining the San Joaquin to form the Delta before reaching the Pacific. This graph shows April–July runoff as a percentage of total water year runoff.

Source: DWR (2026)



Figure 3.13.2. San Joaquin River Spring Runoff.



The San Joaquin River, California's second longest, begins in the Sierra Nevada, flows 100 miles west, then turns north for 260 miles before joining the Sacramento River. This graph shows April-July runoff as a percentage of total water year runoff.

Source: DWR (2026)

What does the indicator show?

In the spring, snowpack in the Sierra Nevada melts and releases water as runoff. This snowmelt runoff — which typically occurs from April through July — feeds the Sacramento and San Joaquin Rivers, which serve as major sources of water for the state. The proportion of spring (April–July) unimpaired snowmelt runoff flowing into the Sacramento ([Figure 3.13.1](#)) and San Joaquin ([Figure 3.13.2](#)) Rivers has declined by ~20% and ~12% over the last century, respectively, with high year-to-year variability. Unimpaired runoff refers to the amount of water generated from melting snow that flows



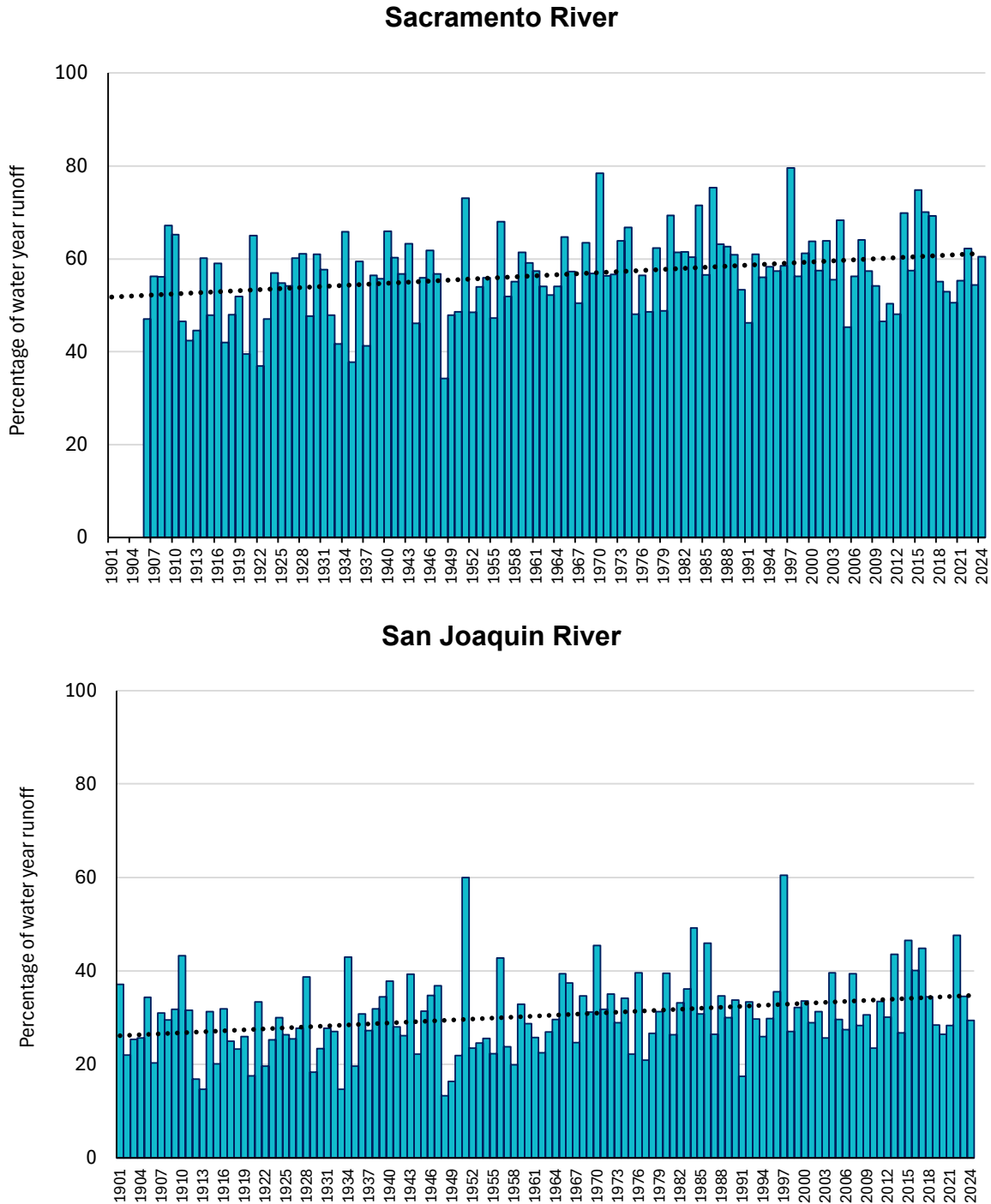
into rivers and streams under natural conditions (i.e., without alterations from reservoirs, water diversions, etc.).

The earlier arrival of warmer temperatures in the spring causes snow to melt earlier in the year, leading to reduced water availability later in the summer and fall. **Figure 3.13.1** and **Figure 3.13.2** show the spring fraction as a percentage of total runoff for the entire water year, which spans from October through the following September.

In the Sacramento River, two of the last ten years (2015, 2016, and 2025) ranked among the ten lowest in the percentage of total water year runoff occurring in the spring. In the San Joaquin River, three of the last ten years (2015, 2021, and 2022) also had some of the lowest percentages of total runoff in the spring. The 2015 water year also saw the lowest snowpack on record. Winter runoff was exceptionally high in 2017 due to major storm events in January and February. As a result, the spring runoff contributed a smaller percentage of the total water year runoff, despite its volume being large. As the percentage of spring snowmelt runoff has declined over time, the percentage of winter runoff (October–March) has shown a general increase (**Figure 3.13.3**).



Figure 3.13.3. Sacramento and San Joaquin River Winter Runoff.



The graphs show October-March snowmelt runoff as a percentage of total water year runoff.

Source: DWR (2025)



Average values for the percentage of runoff in the spring are higher for the “snow-dominated” San Joaquin River, compared to the “rain-dominated” Sacramento River – about two-thirds and one-third of the total water year runoff, respectively (DWR, 2021). This difference is explained further in *What factors influence this indicator?*

Why is this indicator important?

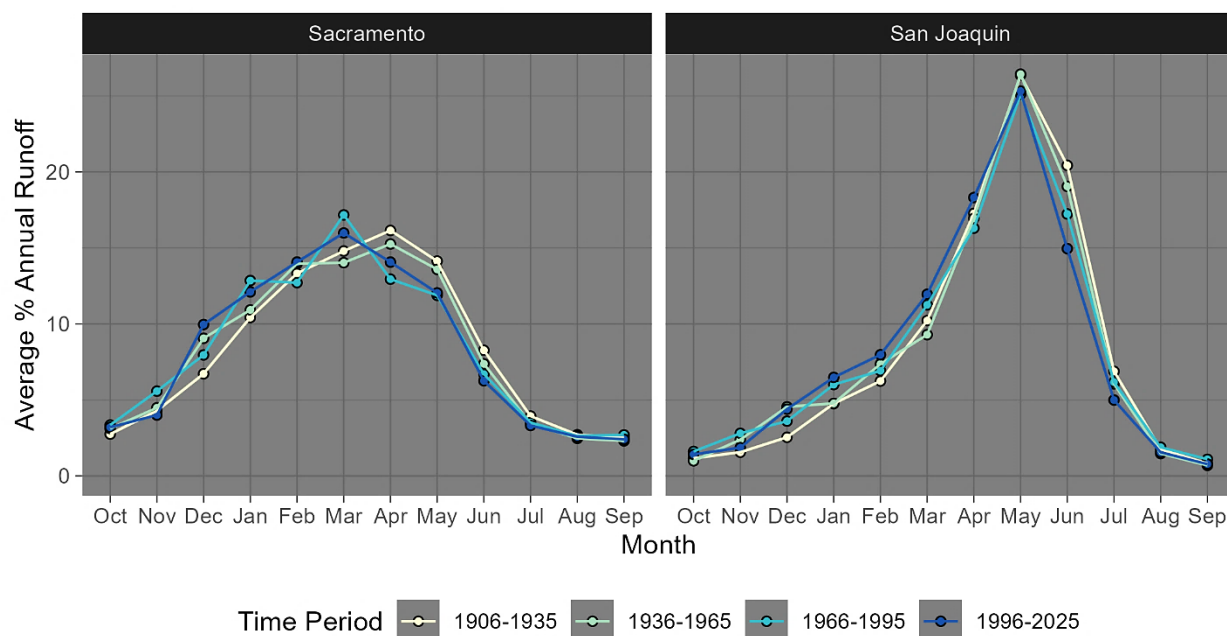
The Sacramento River and the San Joaquin River, the two largest river systems in California, serve as the major sources of water for the state. Snowmelt runoff into streams and rivers supplies water to meet human needs and to support ecosystems. In the Sierra Nevada and southern Cascade Mountains, snow accumulates from October through March, preserving much of California’s water supply in cold storage. As temperatures rise in the spring and there is more daylight and solar radiation, the snowpack melts and releases runoff, typically from April through July.

Spring runoff in these two rivers averages around 14.1 million acre feet (18 billion cubic meters) of water, contributing to about 35% of the usable annual supply for agriculture and urban needs (DWR, 2021; Roos and Anderson, 2006). Spring runoff data, along with related snowpack information, are used for water supply and flood forecasting. (Forecasts of seasonal runoff are published weekly by the [Department of Water Resources in Bulletin 120](#) typically from February through June).

Much of the state’s flood protection and water supply infrastructure was optimized for historical conditions to capture high volumes during winter storms to prevent flooding. In the spring, as much streamflow as possible is captured and stored in reservoirs to be delivered for multiple uses during the drier summer and fall months. Changes to spring runoff patterns, such as the timing of peak monthly runoff, can strain the current water management system, requiring adjustments in water storage and flood strategies. In the last 60 years, peak runoff in the Sacramento River has shifted earlier by a month (March instead of April), compared to earlier years in the record (1906-1965); no such shift is seen in the San Joaquin River (**Figure 3.13.4**). Sacramento River watersheds are located at lower elevations and thus more vulnerable to changes in snowpack than the snow-dominated San Joaquin River watersheds.



Figure 3.13.4. Monthly Average Runoff as Percent of Annual (1906-2025).



A comparison between historical and current 30-year averages of the fraction of total water year runoff that occurs each month shows peak runoff occurring earlier in recent years in the Sacramento River, while the San Joaquin River is largely unchanged.

Source: DWR (2025), analysis by Christine Albano

The earlier onset of spring runoff generally results in less available water in warmer months for domestic and agricultural uses, hydroelectric power production, recreation and other uses. This results in lower soil moisture, which could stress vegetation, leading to tree deaths and increasing wildfire risk. Changes in the amount and timing of snowmelt runoff can alter streamflow and impair cold-water habitats, particularly for salmonid fishes (Halofsky, 2021; Roos, 2000). Runoff during rain-on-snow events – when rain falls on existing snowpack – has been associated with mass erosion of slopes, damage to riparian zones, and downstream flooding (Li et al., 2019). Warming temperatures increased runoff during the large storms of February 2017 by about 30% (Huang et al., 2018).



Tribal Connection 3.13.1

Earlier and more concentrated snowmelt runoff is also occurring east of the Sierra Nevada. A Tribal member from the Big Pine Paiute Tribe of the Owens Valley notes that this snowmelt runoff is less easily absorbed by drought-impacted land. *“In addition to wildfire and drought, the region has also faced climate extremes in the form of heavy snowmelt and runoff. In 2023, a season of significant snowfall in the Sierra Nevada was followed by a rapid and intense melt, forcing the community to prepare for possible flooding. This was not a new concern—Big Pine and the surrounding areas have experienced flash flooding before, particularly when the land becomes too saturated to absorb additional water. Historically, water flowing off the mountains during the spring melt was absorbed by the valley’s meadows, wetlands, and creeks, but with shifts in precipitation timing, land development, and soil health, the ability of the land to buffer these events has weakened. Much of the land where one of our Tribal groups traditionally lived lies directly in a floodplain, placing areas of cultural and ancestral importance at continued risk. These patterns further underscore how the challenges we now face are not isolated or seasonal—they are cumulative, intersecting, and deeply tied to both climate and the long-term legacy of altered land management”* (Big Pine Paiute Tribe, 2026).

What factors influence this indicator?

Snowmelt is directly influenced by the amount of precipitation that falls as snow. The amount of water stored in the snow is known as the snow water equivalent and is highly variable from year to year. Lower water volumes of spring snowmelt runoff compared to the rest of the water year (**Figure 3.13.3**) indicate warmer winter temperatures or early onset of warm springtime temperatures. With warmer winter temperatures, a greater proportion of precipitation occurs as rain, and snow falls and accumulates less at lower elevations than in the past. Higher elevations of the snow line mean reduced snowpack and runoff in the spring.

Increased winter snowmelt was found to be highly sensitive to temperature, as indicated by long-term trends in temperature and snowmelt data at a significant percentage of



snow monitoring stations across western North America (Musselman et al., 2021). In the Sierra Nevada, the peak snow mass and snowmelt shifted earlier over the past 30 years, as daily maximum temperatures increased in March and April (Kapnick and Hall, 2010). Years of “snow drought”—defined as anomalously low snow-water content due to either a lack of winter precipitation (dry snow drought) or lack of snow accumulation despite normal winter precipitation (wet snow drought; Harpold et al. 2017; also see the *Snow-Water Content* chapter)—between 1951 and 2017 originated and evolved in various ways in the northern Sierra Nevada (Hatchett and McEvoy, 2018), including from extreme early season precipitation, frequent rain-on-snow events, lower fractions of precipitation falling as snow, and midwinter peak runoff events. These conditions are generally associated with earlier snowmelt runoff.

The characteristics of a watershed affect changes in runoff. As previously mentioned, due to being located at lower elevations, the Sacramento River watersheds are more vulnerable to reduced snowpack than the San Joaquin River watersheds. A study of projected changes in runoff in the 21st century found that the rain-dominated Sacramento watersheds will experience earlier and increased amounts of peak runoff; in contrast, in the snow-dominated San Joaquin watersheds, runoff peak timing and amounts are projected to remain relatively unchanged (He et al., 2019; He et al., 2021).

Technical Considerations

Data characteristics

Runoff for the Sacramento River system is the sum of the estimated unimpaired runoff of the Sacramento River and its major tributaries, the Feather, Yuba, and American Rivers. “Unimpaired” runoff refers to the amounts of water produced in a stream unaltered by upstream diversions, storage, or by export or import of water to or from other basins.

The California Cooperative Snow Surveys Program of the California Department of Water Resources (DWR) collects snow water data. Runoff forecasts are made systematically, based on historical relationships between the volume of April through July runoff and the measured snow water content, precipitation, and runoff in the preceding months (Roos, 1992).



Related snowpack information is used to predict how much spring runoff to expect for water supply purposes. Each spring, approximately 50 agencies, including the United States Departments of Agriculture and Interior, pool their efforts in collecting snow data at about 260 snow courses throughout California. A snow course is a transect along which snow depth and water equivalent observations are made, usually at ten points. The snow courses are located throughout the state from the Kern River in the south to Surprise Valley in the north. Courses range in elevation from 4,350 feet in the Mokelumne River Basin to 11,450 feet in the San Joaquin River Basin.

Since the relationships of runoff to precipitation, snow, and other hydrologic variables are natural, it is preferable to work with unimpaired runoff. To get unimpaired runoff, measured flow amounts have to be adjusted to remove the effect of infrastructure or water management operations such as reservoirs, diversions, or imports (Roos, 1992). The water supply forecasting procedures are based on multiple linear regression equations, which relate snow, precipitation, and previous runoff terms to April-July unimpaired runoff. Major rivers in the forecasting program include the Trinity, Pit, McCloud, Sacramento, Feather, Yuba, American, Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, Kaweah, Tule, Kern, Truckee, East and West Carson, East and West Walker, and Owens.

A Basin Characterization Model was used to determine historical and current 30-year averages of the fraction of total water year runoff that occurs each month in the Sacramento River and San Joaquin River. The Basin Characterization Model is a 270-meter resolution gridded model that uses weather variables from the PRISM dataset and information on terrain, geology, soil, and land cover to simulate monthly snowpack, soil moisture, runoff, and recharge dynamics across the state of California from 1896 to present. It does not account for water management and land use disturbances so is intended as an approximation of natural hydrologic conditions. Data are available from the US Geological Survey at: <https://www.usgs.gov/data/basin-characterization-model-a-monthly-regional-water-balance-software-package-bcmv8-data>



Strengths and limitations of the data

River runoff data have been collected for over a century for many monitoring sites. Stream flow data exist for most of the major Sierra Nevada watersheds because of California's dependence on their spring runoff for water resources and the need for flood forecasting. The April to July unimpaired flow information represents spring rainfall, snowmelt, as adjusted for upstream reservoir storage calculated depletions, and diversions into or out from the river basin. Raw data are collected through water flow monitoring procedures and used, along with other variables, in a model to calculate the unimpaired runoff of each watershed.

Instrumentation and measurement methods have generally improved over time, strengthening the reliability of monitoring data. However, some monitoring sites have been relocated short distances, and variations in streambed shape can affect the accuracy of flow measurements. Most foothill sites, though, have relatively stable streambeds that minimize this limitation.

OEHHA acknowledges the expert contribution of the following to this report:



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