Probable Reasons for Bulletin 120 Forecast Errors in Water Year 2025

Like Water Year (WY) 2024, WY 2025 came in as another relatively average year statewide, however it had a sharp regional divide. The basins north of Interstate 80 saw higher than average precipitation and snow levels with the Central and Southern Sierra seeing totals below average. For precipitation, the Northern Sierra 8-station index was at 112% of average for the water year while the San Joaquin 5-station index and the Tulare 6-station index were at 88% and 90% of average, respectively, for the water year. The automated snow sensor network peaked on April 5th with a statewide total at 102% of the April 1 average; however, the regional differences were similar to the precipitation with the Northern Sierra Nevada at 118% of average on April 1, while the Central Sierra and Southern Sierra were at 92% and 82% of average on April 1, respectively. Despite near or slightly below average statewide precipitation and snowpack for the water year, statewide observed full natural flow over the April through July period came in at only 81% of average with only one basin seeing flows that were above average.

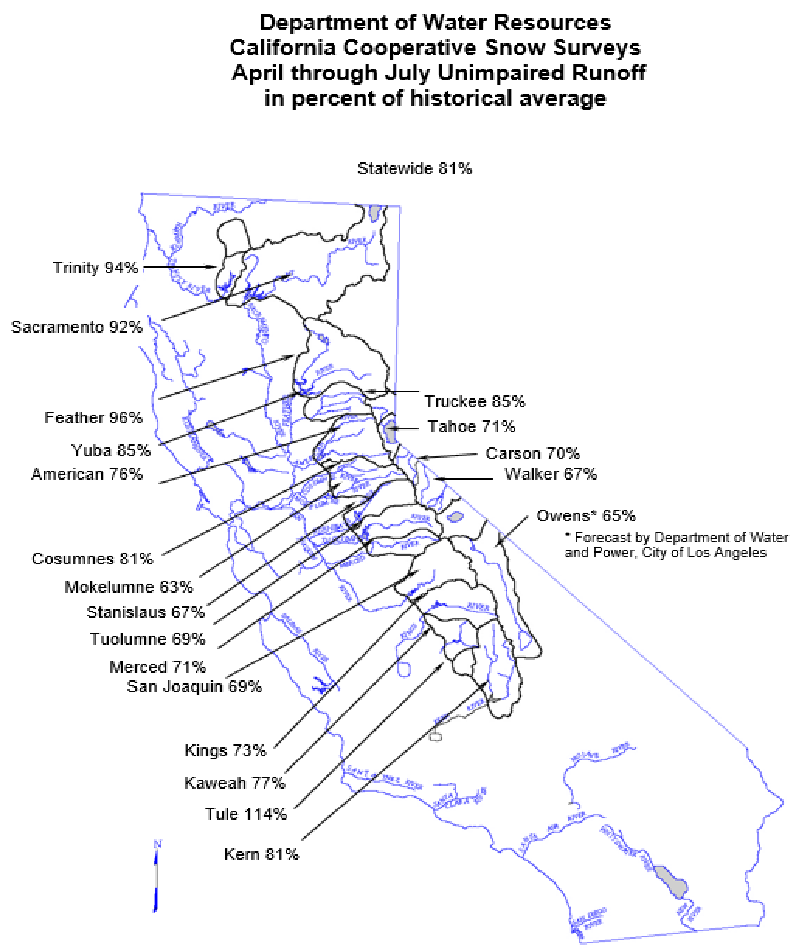

Figure 1: Observed April -July unimpaired runoff for WY 2025 in terms of percent of historical average

Climate and Weather Anomalies

Well Below Average April-July Precipitation

While water year precipitation was near normal, only a few months saw above average precipitation. November, February, and March and December only in the north saw above average precipitation while other months were well below average. This trend was especially pronounced in the April through July runoff period where all three regional precipitation indices (the Northern Sierra 8-station index, the San Joaquin 5-station index and the Tulare 6-station index) had less than 50% of average precipitation accumulation. While most precipitation in the state falls during the December-March period, all runoff models assume median climatology during the forecast period. The lower-than-average precipitation in the spring resulted in lower than forecasted flow.

Inaccurate Weather Forecasts (February Storm)

The Department of Water Resources (DWR) has transitioned to ingesting 6-day Quantitative Precipitation Forecasts (QPF) produced by the National Weather Service (NWS) into the Bulletin 120 (B120) forecast procedures. The use of QPF replaces the use of seasonal climatology in the near term. This allows DWR to update seasonal water supply forecasts with the most current short-term weather forecasts, which may have considerable impacts on runoff. While this inclusion has improved forecast performance, there is still improvement to be made in weather models to the point that they can cause errors when ingested in runoff forecasts. During the water year, multiple forecasts failed to verify during the year. This means that precipitation totals that were forecast did not end up occurring. While the addition of QPF into the forecasting procedures does increase accuracy of forecast, it is inevitable that some forecasts will not verify which results in increased forecast error for that particular runoff forecast. For example, during an early February storm event, the forecast precipitation data was over forecasted in areas in the Central and Southern Sierra Nevada while conditions were under forecasted in the Northern Sierra. The over and under prediction of precipitation from the weather forecasts resulted in inaccurate snowpack estimates used in the B120 forecast procedure. This resulted in an over forecast of snowmelt runoff during the month of February. While in this particular event, the overestimate was caught by DWR's forecasters and corrected by the subsequent runoff forecast, there is still caution and due diligence that must be exercised when using QPF in the B120. QPF that does not verify with the actual accumulated precipitation leads to errors in runoff forecasts.

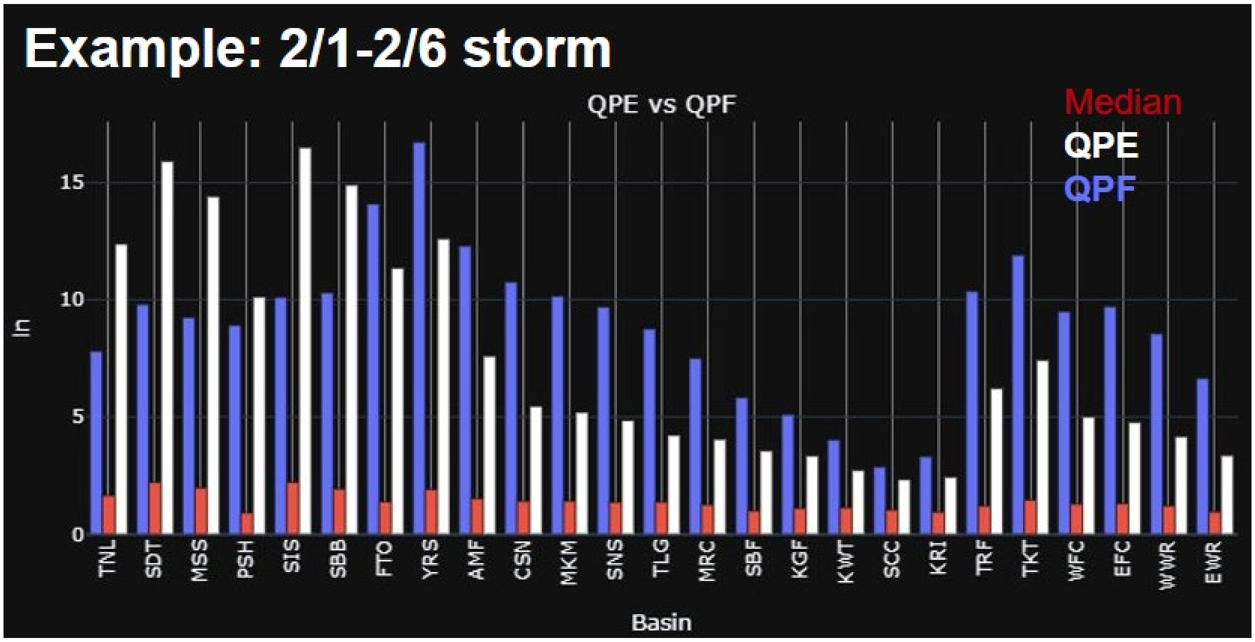

Figure 2: Example of QPE vs QPF verification for a storm on February 1-6, 2025. Values are summed across the 6-day window and averaged across stations in each basin.

DWR is working with its research partners and the NWS to expand the reliable use of alternative QPF products that include up to ten days. Concurrently, DWR and its research partners continue to evaluate the reliability of different precipitation forecast products as well as transition probability factors that blend forecasted precipitation with median climatology. Additionally, DWR forecasters are working with partners to establish site-specific transition probabilities informed by historical performance trends and forecast uncertainty. This method would result in improving runoff forecast performance by increasing confidence in the blended QPF product at each specific station.

Difficulties in Delineating Precipitation Between Rain and Snow

When precipitation falls between the date when manual snow course measurements are taken and the forecast date, the current B120 forecast procedure assumes it all falls as snow and corrects the measurement using estimates from observation-based gridded Quantitative Precipitation Estimates (QPE). Like QPF, the inclusion of QPE has increased the performance of B120 forecasts. However, the current assumption that both the QPE and QPF fall as snow when calculating model snow estimates for the B120 forecasts is not always accurate. For example, during the early February storm event previously mentioned, large precipitation totals were forecasted to occur during the time between when snow course measurements were made and when the B120 forecast was issued. Weather forecasts during that period indicated that these storms would be warmer than usual and would have an unusually high snow line; thus, the assumption that all falling precipitation was snow was incorrect. DWR forecasters used available information from snow pillow observations and gridded snow datasets to estimate how much snow had already accumulated at each course since the measurement date. While this method has been used with relative success for years, these are still estimates which have to be corrected in subsequent forecasts with updated snow observations after the storm passes. Depending on how wet the storm system is and how much rain versus snow falls on the watershed, this method introduces error into the first of month B120 forecasts.

DWR, with the assistance of its partners, has worked on methods to partition amounts of forecasted precipitation into rain versus snow, thus creating a Quantitative Snow Forecast (QSF) that can be applied to future events. This will use the forecasted dewpoint and wet-bulb temperature to more accurately determine near-term forecasted snow volumes to apply to each station and in turn result in more accurate runoff forecasts.

Snow State Uncertainty

DWR uses in-situ observations of snowpack from snow sensors or courses to model snow states for the B120 forecasts, but it also monitors the state of the snowpack by tracking gridded model-based products from partners. Inconsistencies between observations and gridded estimates introduced some uncertainty during the forecasting process. For example, DWR forecasters regularly compare data in the neighboring Kings and San Joaquin watersheds. Both basins are of similar sizes and geography, with snow and flow estimates that can be larger in one basin versus the other depending on the year. This year provided difficulties in comparing the snowpack data between the Kings River and San Joaquin River as multiple methodologies produced conflicting snow information.

Snow states as of April 1:

	DWR Snow Course Index		ASO (3/25, 3/23)	M3W iSnobal	ASO WRF-Hydro	SWANN	Snow-17
	High	Low					
San Joaquin	90.4	69.6	882 TAF	940 TAF	897 TAF	1055 TAF	1149 TAF
Kings	88.8	63.9	1013 TAF	1019 TAF	964 TAF	1068 TAF	1121 TAF

Figure 3: Snow states for the San Joaquin and Kings basins on April 1, 2025 as estimated by the DWR measurement-based indices, and basin-wide volumes from 5 gridded datasets. The pink color highlights which basin had the larger estimate.

The chart above shows snow estimates in each basin from internal DWR methods and external sources. The DWR indexes (divided into high and low elevation areas of each watershed), composed of measured snow courses against their historical average, suggested a deeper snowpack in the San Joaquin River on April 1. DWR's indexes agreed with the National Weather Services (NWS) California Nevada River Forecasting Center (CNRFC) Snow-17 model. Other estimates produced by the Airborne Snow Observatories Inc (ASO) WRF-Hydro model and the University of Arizona's SWANN dataset indicated that the Kings River had higher snow volumes. This discrepancy led DWR forecasters to believe that the San Joaquin snowpack was deeper than it actually was. This ultimately led to an over forecast of the San Joaquin River April-July runoff, resulting in the large error (10% over observed) in the final June forecast.

In the future, DWR will rely more heavily on ASO spatially distributed snow observations to check whether the snow course index accurately reflects snow volumes and snow distribution patterns present in the basins. As more ASO observations become available, DWR will be able to test the predictability and representativeness of certain snow course locations and determine if measurements captured in certain areas accurately reflect the spatial distribution in the watershed. More ASO observations will also allow DWR to understand seasonal and subseasonal variability in the snowpack which has a significant influence on the timing and scale of snowmelt runoff volumes.

Landscape and Climate Change Impacts

Fire Impacts to Soils and Vegetation

Two of the watersheds that were under forecasted in WY2024 continued to be under forecasted in WY2025. Both the Consumnes and the Tule Rivers were heavily impacted by large wildfires during the previous drought. Wildfires impact runoff by creating hydrophobic soil conditions that prevent infiltration as well as killing large swaths of vegetation that would otherwise use large quantities of water. Even when accounting for previous years' errors, DWR forecasters continued to underestimate the continued impact of fire on the two basins. While the differences in the Consumnes River observed flow were mild compared to its neighboring basins of the American River and Mokelumne River, the Tule River flow was considerably larger (114% of average versus 77% and 81% of average for the Kaweah River and Kern River, respectively). DWR adjusted the forecasts for the Cosumnes and Tule Rivers higher as the forecast season continued to reflect larger than expected runoff but still under forecast both rivers

Looking forward to WY 2026, it is expected that the recent Garnet Fire will impact runoff generation in the Kings watershed. DWR conducted snow-free lidar survey of the affected area in fall 2025 to record and track landscape changes and update model states in the ASO WRF-Hydro model used by DWR.

DWR continues to partner with UC Davis and ASO Inc. to conduct studies on landscape changes in the Sierra Nevada with special attention on wildfire impacts. The goal of these studies is to inform how to adjust hydrologic runoff models to more accurately forecast runoff after large scale wildfires occur in a watershed.

Data Collection Gaps

Uncertainty in Federal Assistance on Snow Measurements

DWR has almost 260 snow courses across the Southern Cascades and Sierra Nevada. DWR depends on partner agencies to maintain and measure a large portion of these snow courses, but many of these partners are agencies in the federal government including the National Park Service (NPS), the US Forest Service (USFS) and the Natural Resource Conservation Service (NRCS). These federal agencies measure and assist in maintenance of over 40% of the total number of snow courses including several difficult to access wilderness sites. These federal agencies are also responsible for approving and issuing special use permits that allow for helicopter flights into remote snow courses as well as the maintenance, repair, and upgrade of hydrometeorological stations (such as snow pillows and precipitation gauges). In May, several of the lower elevation snow courses in the San Joaquin basin were not measured by the USFS due to staff reductions or furloughs. Had these courses been measured the snow volumes would have been estimated more accurately and the resulting forecast would have been more accurate. So far in 2025, federal funding and policy changes have resulted in layoffs and early retirements across all federal agencies that collect snow data for DWR. During WY2025, DWR was able to work with its local watershed partners in limited cases to ensure that snow course measurements were made at snow courses usually measured by federal agencies. It remains unclear how much of an impact the reduced federal workforce will have on snow course measurements in WY2026 or beyond. Nonetheless, missing snow course data is a significant source of forecast error.

DWR can use alternative data including snow sensors and modeled localized snowpack estimates derived from ASO data in place of measured courses. However, using this data would require additional model training and verification, and the data itself is limited in historical record compared to manual course measurements that have decades of consistent measurements. If federal agencies are unable to measure snow courses reliably in the future, DWR will need to seek additional resources to fund contractors or additional DWR staff to measure these snow courses.