Estimation of Central Valley Precipitation and Rim Inflows over Water Years 1850-1921

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Introduction and Study Motivation

The goal of this study is the development of a consistent precipitation and streamflow time series for the Sacramento and San Joaquin Valleys, for water years (WY) 1850-1921. Most long-term published analyses of flows in the California's Central Valley focus on data from WY 1922 to the present, because of the availability of a reasonably complete observed stream flow record from this time forward. However, the year 1922, although adequate as a starting point from the data availability perspective, is not representative of baseline, or predevelopment, conditions. This work is intended to support an analysis of flows over time horizons longer than WY 1922-present, led by the University of California at Berkeley, and considers the transition from what may be considered to be near-predevelopment conditions in California, prior to 1850. Over this longer term, 1922 represents a point at which substantial human development-based modification had already occurred in the watershed, with resulting impacts on streamflows, although significant modifications, such as the construction of major storage reservoirs were still to come.

Prior to WY 1922, limited streamflow observations across the state preclude observation based valley-wide estimates of streamflow. In this work, a suite of estimation approaches is used to develop the spatial precipitation across the Central Valley and its contributing watershed and the resulting runoff from the rim watersheds into the valley. Some hydrologic data are available for the pre-1922 period that can be used to develop an estimate of precipitation and streamflows from 1850 through 1921. Specifically, the following sources of information are available: (1) precipitation data are reported at San Francisco and Sacramento beginning in 1850; (2) additional precipitation stations with data from the mid-1870s; (3) streamflow data for a limited number of streams from the 1880's. In addition to the limited amount of historical monthly precipitation data, reconstructed annual precipitation data from tree ring studies (reported to 1977) is incorporated to develop spatial estimates of monthly precipitation across the Sacramento and San Joaquin Valley and the rim watersheds.

Statistical precipitation-runoff relationships for subwatersheds within the Sacramento and San Joaquin watersheds developed from observation-based data (1922-1977) are employed to estimate monthly runoff in the early part of the record (1850-1921).

The resulting data set allows the evaluation of valley flows and Delta outflow to San Francisco Bay through other hydrologic models to understand the transition from pre-1850 conditions to the better-characterized post-1922 period. This memo describes the available streamflow data that can be used directly for a subset of locations, the estimation approaches used for precipitation and streamflow, and provides a link to key electronic deliverables to be used for future work.

Compilation of Historical Streamflow Data for Tributaries to California's Central Valley

The earliest known stream measurements in California were from November 1878 to October 1884 by the State Engineer of California (Hall, 1886). A total of 21 streams in the Central Valley were investigated during this time period to assess the general conditions of the rivers, problems associated with irrigation of the plains, and to help improve navigation on the selected waterbodies (USGS, 1950). The Office of the State Engineer was abolished in 1884 and no further streamflow measurements were taken in California until 1893. The United States Geological Survey (USGS) began work related to streamflow assessment in California in 1894 and established their first gaging station in April 1895 on the Sacramento River. In March 1903, California passed an Act that authorized the State Board of Examiners to enter into contracts with the USGS for the purpose of gaging streams (USGS, 1950). This Act led to the increase of stream-gaging programs in California such that by 1922 stream flow data was being collected throughout the Sacramento and San Joaquin Valleys.

Historical streamflow data from 1850 to 1921 were compiled for the major tributaries flowing into California's Central Valley. Three reports were reviewed to assist in the selection of the streamflow stations containing data in the historical timeframe of interest: Bulletin No. 5, Flows in California Streams Appendix A (Bulletin No. 5) (California Department of Public Works, 1923), Compilation of Records of Surface Waters of the United States through September 1950: Part II-B Pacific Slope Basins in California, Central Valley (USGS, 1950), and the 1957 Joint Hydrology Study: Sacramento River and Sacramento-San Joaquin Delta (California Department Water Resources, 1958). Bulletin No. 5 provides graphical and statistical summaries of historical streamflow data from numerous streamflow stations in California. The 1950 report from the USGS provides raw data tables of mean monthly and annual discharge from hundreds of streamflow monitoring stations in California including the Central Valley. The earliest data reported in the 1957 Joint Hydrology Study was from 1921, which is outside the range of historical streamflow data that was targeted for this study.

After reviewing these reports, a list of potential streamflow stations to be included in the study were identified (Figure 1). One station was selected on each of the major tributaries and on the main stems of the Sacramento and San Joaquin rivers to help characterize streamflows. Stations were selected on the main stems of the Sacramento and San Joaquin rivers to be representative of natural streamflows prior to entering the Central Valley. Stations on the major tributaries to the Sacramento and San Joaquin rivers were selected to characterize flows that are not substantially influenced by anthropogenic activities. For the major tributaries, the closest station on the valley side of the rim boundary with discharge data in the historical timeframe of interest was selected for this analysis. These major tributary stations were also compared with the locations of more recent gaging stations and were found to either overlap or be in close proximity to these newer gaging stations. A total of eight streamflow stations were selected to be included in the study (Table 1). The historical data range shows the range of dates that were identified with historical streamflow data for each site. For some of the stations, this is not a continuous range of measurements, and there may be gaps in this range where data are not available.

Streamflow data from the selected stations were accessed using the USGS's National Water Information System (NWIS) and from historical reports, including USGS Water Supply Papers and the State Engineering Department of California report from 1886 also referred to as the Hall report. NWIS provides online access to electronic water-resources data from approximately 1.5 million sites in the U.S. and surrounding territories. Data from the historical report were in hardcopy format and had to be hand entered into the project database. All of the historical streamflow data collected during the study were organized into an electronic Excel database (provided as Deliverable A). NWIS provided the majority of the streamflow data compiled for this study. USGS Water Supply Papers supplied some limited additional data for three of the selected streamflow stations. USGS Water Supply Papers can be accessed through the USGS's Publication Warehouse in a downloadable pdf format. Bulletin No. 5 provided some additional estimated annual runoff data starting in 1872 for some of the selected streamflow stations. The USGS 1950 report provided some additional monthly mean streamflow data for the Tuolumne River above La Grange and the Stanislaus River near Knights Ferry.

The USGS Water Supply Papers reviewed were identified from the list of references provided by the USGS (1950) and California Department of Public Works (1923). In total, 28 USGS Water Supply Papers related to streamflows in Central Valley tributaries were reviewed for additional streamflow data from the selected locations. Appendix A provides a brief summary of the data available for the selected streamflow stations in each of the USGS papers reviewed. After reviewing the streamflow data contained in the USGS Water Supply Papers, certain limitations to using this data were identified. A major limitation was the difficulty in identifying the station locations included in the papers. There were no latitude and longitude coordinates provided, and many of the streamflow stations were identified using the township and range system or based on landmarks (i.e., bridges, roads, canals, etc.) that no longer exist. Based on these factors, the location of numerous streamflow stations on waterbodies of interest in the USGS Water Supply Papers could not be identified rendering these data unusable.

Another limitation was that data from the USGS papers overlapped (i.e., collected during the same timeframe) with NWIS data or the data provided by the USGS (1950) for selected streamflow locations, but the measurements do not match. When this occurred, the data provided by NWIS or the USGS (1950) were used. Differences between recorded values from the various datasets likely occurred due to the fact that in the 1930s and 1940s the USGS revised numerous streamflow measurements reported in the Water Supply Papers from the early 1900s. The majority of the USGS Water Supply Papers had data from the selected locations that overlapped with NWIS data or the USGS (1950) (see Appendix A). Data were only extracted from the Water Supply Papers if the location provided in the USGS papers could be identified and matched the location of the selected station on the same waterbody, and it did not overlap with the data from NWIS or the USGS (1950) report for that station.

Only two USGS Water Supply Papers provided additional streamflow data to be used in this study: WSP 51 and WSP 81. WSP 51 provided thirteen daily flow measurements from 6/1900-9/1900 that were not included in NWIS or the USGS, 1950 report for the Yuba River at Smartsville. WSP 81 provided three measurements of daily streamflow from 8/29/1879, 9/18/1900, and 9/6/1901 that were not included in NWIS or the USGS, 1950 report for the Feather River at Oroville. It also provided mean monthly flow data from November 1878 to October 1884 and two daily flow values from 11/27/1895 and 9/10/1900 that were not included in NWIS or the USGS, 1950 report for the Merced River near Merced Falls. This site was later changed to the Merced River at Exchequer, CA. The original source of the mean monthly flow data from 1878-1884 at this site was from an 1886 report produced by William Hall from the State Engineering Department of California. The Hall report also provided data from 1878-1884 for the San Joaquin River below Friant, CA. The name of this location was the San Joaquin River at Hamptonville in the Hall report. The Hall report also provided data for three other rivers of interest: Sacramento River at Collinsville, Tuolumne River at Modesto, and the Stanislaus River at Oakdale. The data from these three locations were not included in the dataset for this report, because these stations were located near the bottom of the valley.

Two of the reports reviewed for historical streamflow data also contained historical precipitation data for a number of weather stations in California including locations in the Central Valley and the surrounding mountain zones. Bulletin No. 5 provided annual precipitation data from 1871-1872 to 1920-1921. Not all of the weather stations included in Bulletin No. 5 had complete records for this timeframe. USGS Water Supply Paper 81 presented monthly precipitation data through 1901-1902. Some of the weather stations included in this report had precipitation data dating as far back as 1849. However, the majority of stations had precipitation records that started in the 1870s or 1880s.

Data Used for Estimating Streamflows through Modeling

The modeling approach relied upon historical precipitation data at selected stations, identification of contributing watersheds for individual streams, and estimates of watershed-average precipitation. The following is a brief summary of these data sources.

Precipitation at Point Locations

Monthly precipitation data at San Francisco were obtained from the National Weather Service (NWS) (http://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca7772), which has a complete record at this station from 1850. These data were supplemented by Sacramento precipitation data from 1850 (NOAA Technical Memorandum NWS WR.266; provided by Maury Roos, personal communication). The NWS source was missing San Francisco data for 1854 which was keyed in from reported values in Hall (1886). Values in the NWS source were consistent with values presented in Hall (1886).

PRISM Data

PRISM (for Parameter-Elevation Regressions on Independent Slopes Model) is a widely used gridded data set for precipitation (http://www.prism.oregonstate.edu/) and a historical 4 km gridded data set for 1895-1980 precipitation was used for this study. Data for the United States were downloaded, and processed to develop monthly estimates of precipitation across the watersheds of interest.

Use of PRISM Data for Estimating Watershed Averaged Precipitation

Watersheds were calculated for all significant streams flowing into the Central Valley using the National Elevation Dataset. Intersecting grid cells in the PRISM data set were identified where more than 50% of a grid square fell within a watershed. The average of all the grid values for a month was computed, and reported as a time series of watershed averaged precipitation for each of the study watersheds. Because of the availability of the underlying information, these time series were computed for 1895-1980.

Tree-Ring Reconstructions of Precipitation

Tree ring records, particularly those from blue oak trees (Quercus douglasii) have been shown to correlate well to a variety of regional climatic variables in California including annual precipitation (Meko et al. 2011), annual stream flow (Meko et al. 2002; Meko, Woodhouse, and Touchan 2014), April 1st snowpack (Belmecheri et al. 2016), and seasonal salinity levels in the San Francisco Bay (Stahle et al. 2013). Widespread distribution of blue oak records dating back to the 1600's across the drainage basins of the Sacramento and San Joaquin Rivers, provides unique information to this specific effort, particularly during the period of limited observation based precipitation records from 1850 to 1895. Two sets of tree ring derived data were obtained for analysis. The first dataset utilized is comprised of 36 blue oak tree site chronologies from around California. Each site is comprised of records from at least 40 living trees in the same area, and the site chronology is an annual time series of representative ring widths (Meko et al. 2011). The second dataset was a spatially distributed (0.5° by 0.5°) reconstruction of annual precipitation from 1571 through 1977 (Diaz and Wahl 2015) based on correlations between observed precipitation and tree ring based river flow reconstructions.

The value of tree rings to reconstruction of annual precipitation over large areas is well established, and future efforts to estimate precipitation and runoff prior to 1850 would necessarily rely heavily on tree ring based information. However, the value to monthly precipitation reconstructions in smaller sub watersheds when regional precipitation observations are available is more limited. First, although the temporal information provided by tree ring records is extensive, the temporal resolution is limited to annual averages. Second, while tree samples are available from point locations, the strongest correlations result from averages of many tree ring records from many locations to basin integrated climatic factors such as annual runoff from large river systems. It is because of this spatial blurring, that the Diaz and Wahl (2015) reconstruction used in this work is based on the correlation of observed precipitation to tree ring based river flow reconstructions rather than a correlation directly to the spatially distributed tree rings.

Unimpaired Flows

The California Department of Water Resources (DWR) has developed a methodology for calculating unimpaired flows in streams by taking out the effects of reservoirs and known diversions/exports. The resulting flows reflect the current watershed characteristics and channel configuration. While they cannot be considered equivalent to natural flows in most cases, in the context of the rim flows from the higher elevation watersheds, unimpaired flows are considered a reasonable representation of natural flows. This assumption is not true in the case of valley floor flows, because of the much more extensive land use change from various natural vegetation types to developed/irrigated land. A set of unimpaired flow data were obtained from MWH Global (Andrew Draper, personal communication) for this analysis.

Modeling Approaches

Precipitation

Traditional rain gage based precipitation observations capture temporal variability of precipitation to a varying degree depending on methodology, but miss the spatial variability of precipitation entirely. As a result, hydrologists have developed numerous methods to use point measurements of precipitation at one or more locations to estimate precipitation at other locations. Where observations at the point of interest do not exist, these methods include weighting methods such as (among others) construction of event specific isohyets (e.g. Hornberger et al. 2014), inverse distance weighting (e.g. ASCE 1996), stochastic interpolation (kriging), and weighted regressions based on physiographic station information such as is used in PRISM (Daly et al. 2008). Where there is available time series information at the location of interest, but the period of record is limited, periods of missing rainfall data can be estimated using data driven methods including most commonly ordinary linear regression (e.g. Haan 1977), but also time series analysis, and generalized linear models (e.g. Hasan and Dunn 2011).

Watershed precipitation during the wet season across the Central Valley was found to be predicted well by a multiple linear regression using the San Francisco, Sacramento, and Diaz and Wahl (2015) tree ring reconstruction. Each month and watershed was fit separately, and the relevant annual tree ring reconstructed precipitation value was used for each month of a water year. To avoid negative precipitation predictions from the raw regression, an extension of linear regression known as a generalized linear model (GLM) was employed.

GLMs allow a nonlinear transformation (the link function) to be applied to the underlying regression and assumptions for the distribution of residuals to be non-Gaussian. Hasan and Dunn (2011) found the Tweedie family of distributions to be useful for modeling monthly rainfall with GLMs. The Tweedie family encompasses several familiar distributions (e.g., normal, gamma, and Poisson distributions) as particular values of its index parameter. One advantageous property of this family is that it can represent distributions with support over all real numbers, the positive real numbers, or the positive real numbers and zero. The data developed for this analysis have some exact zero values in the dry season and are otherwise positive. The Tweedie family of distributions allows consistent modelling of all data under one framework.

We updated our precipitation linear regressions to GLMs by estimating the Tweedie family index parameter appropriate for each month and each watershed by maximum likelihood. This was done with the `tweedie` package in R, which allows various methods of estimating the Tweedie densities that are not representable in closed form (Dunn and Smyth, 2001 and 2008). Then the regression is fit using the `glm` function in R with using Tweedie distribution corresponding to the estimated index parameter.

Streamflow

Rainfall-runoff relationships are driven by physical processes with characteristic times on the order of minutes to hours, and thus, where data permits, physically based modeling of rainfall-runoff typically utilizes daily or sub-daily time-steps (e.g. Beven 2012). Where data is limited to monthly or annual averages, rainfall-runoff models are often constructed based on empirical relationships described by single or multi-variate linear regressions between rainfall estimates (previous and current), temperature, and previous runoff as predictors of runoff in a given period (e.g. Bonné 1971). Haan (1977) describes such models based on the assumption of a linear relationship between variables as “possibly the most common … used in hydrology”. Where a linear relationship between monthly or annual timestep rainfall and runoff does not adequately capture observed watershed behavior, more complex statistical methods including generalized linear models and non-linear models (e.g. Machado et al. 2011; Hasan and Dunn 2011), or physically based models (e.g. Arnell 1992; Xu and Singh 1998; Remesan, Bellerby, and Frostick 2014) may yield better results. Additional model complexity does not necessarily translate to improved model performance (Jakeman and Hornberger 1993), and researchers must weigh the development costs of additional model complexity against uncertain potential benefits.

Multiple linear regression of all monthly PRISM precipitation values from water year start predicted watershed unimpaired flow values reasonably well. For example, December flow would be predicted using October, November, and December precipitation. This approach is also conceptually appealing because it is consistent with the physical process of precipitation accumulating as snowpack over the beginning part of the water year and then melting and entering the valley as streamflow. For predicting October streamflow September precipitation of the previous water year is included as a predictor.

Incorporating a nonlinear relationship in the model further improved predictions. The initial linear model within the GLM framework was refined with a power link function, where the power is estimated as part of fitting the model. A power greater than one represents a superlinear relationship between observations and the predictors, and a power less than one yields a sublinear relationship. The model is parameterized in a Bayesian framework to incorporate constraints on the power parameter of the link function via a prior distribution. This allows mitigation of the effects of a small number of outlier points from very wet years resulting in a large estimate for the power parameter and consequent overestimates of flows during the hindcast period. Fitting was performed using Stan, a computer program implementing Bayesian inference though Markov Chain Monte Carlo.

Some smaller watersheds had minimal flow in the summer and early fall in most water years, and these small flows are not particularly well correlated with the preceding months' precipitation. A model based on the long-term average each year had comparable predictive accuracy to the GLM in these cases, and the simpler model is selected when this is the case.

Results

Results from this analysis include estimates of monthly precipitation across the Central Valley at the Hydrologic Unit Code-10 (HUC-10) level from 1850-1894 and estimates of monthly streamflow from the watersheds defined in Table 2 from 1850-1921. These data are provided as electronic files for input for valley-wide modeling. For the Berkeley modeling effort, it is assumed that precipitation data from 1895 onwards and streamflow data from 1922 onwards will be obtained through PRISM and from DWR's existing streamflow database.

Model performance is compared using the quality of the fits (reported as R^2), and the Nash-Sutcliffe efficiency (NSE) coefficient, a commonly used approach to assess the predictive power of hydrological models (Nash and Sutcliffe, 1970). Scores for both performance measures approaching 1 are favorable, with a value of 1 indicating a perfect match between a model and observations. For a subset of streams for which pre-1921 observed streamflow data exist, modeled values can also be compared to the historical data.

As a first step, model fits for precipitation are compared for each of the HUC-10 watersheds identified as part of the valley floor (Lissa MacVean, personal communication) (Table 2). In general, the modeling framework utilizing the San Francisco and Sacramento observed monthly precipitation and the tree-ring reconstructed annual precipitation, is a good predictor of the HUC-10 watershed-average monthly PRISM precipitation for 1895-1977, with most R^2 and NSE values exceeding 0.8, and many exceeding 0.9. This information is also shown on a monthly level on scatter plots (Figure 3), demonstrating a good match between modeled and PRISM values, in most months with meaningful precipitation (November through April). Precipitation in the driest months is not well predicted by this modeling framework, and is not considered a significant weakness of the approach: the dry month contributions to total annual precipitation are minimal. Further, rainfall in the higher elevations in the summer months are spatially more challenging to monitor and related to processes different than winter precipitation and convective in nature (Lundquist et al., 2009).

Modeled precipitation is also compared to watershed-average precipitation for the rim watersheds in Table 3. Modeled fit of precipitation in rim watershed stations. The target is the watershed-average precipitation (calculated from PRISM), predicted using San Francisco and Sacramento observed data and annual tree ring reconstructued precipitation. As with the valley floor watersheds, the precipitation modeling framework is a good predictor of the watershed-average monthly PRISM precipitation for 1895-1977, with most R^2 and NSE values exceeding 0.8, and many exceeding 0.9, with strong fits in months with most of the rainfall. A scatterplot associated with these fits is shown on a monthly level in Figure 4. As with the valley precipitation, the November through April primary rainfall period is well represented by the model.

The runoff-model was developed using PRISM watershed-average precipitation and used for comparing the modeled and actual runoff for the WY 1922-1981 period (Figure 5). As an alternative, which must be used when no observed data for precipitation are available, the modeled precipitation for WY 1922-1977 was used for computing the runoff, thus incorporating the error in the precipitation estimate (Figure 6). The fits associated with the runoff model with exact PRISM watershed-average inputs provides a strong prediction across most watersheds in both the Sacramento and San Joaquin basins (Table 4), providing support for the use of the modeling methodology. When the model is run using estimated precipitation, the fits are poorer (Table 5), as might be expected because of the error in the precipitation estimate.

Samples of time series data are provided for two basins (the American and Yuba Rivers), with all time series plotted in appendices summarized in the Deliverables section. The time series of annual precipitation is shown in Figure 7 for the American River, including a hindcast back to 1850. The runoff prediction is provided using two approaches, using the exact PRISM data (available from 1895 onwards) and using estimated precipitation data (Figure 8). Consistent with the tabular summaries, the model agreement is better when the PRISM information is utilized. These plots also compare other sources of data from the pre-1922 period for comparison: the NWIS data from USGS and the data from Hall (1886). There is agreement with the pre-1922 data, although not as good post-1922 data, and the model values appear to be lower for high flow years. Results from the Yuba River watershed are compared in a similar manner in Figure 9 and Figure 10.

Discussion

This work has shown that reasonably accurate, monthly average, watershed scale precipitation reconstructions can be created statistically for the Sacramento and San Joaquin basins based on point precipitation observations in San Francisco and Sacramento, augmented with tree ring information. This approach has allowed a continuous, monthly average precipitation record to be developed for the Sacramento and San Joaquin basins from 1850 to the present. Similarly simple statistical relationships between rainfall and runoff are also remarkably descriptive of watershed response to precipitation in the rim watersheds of these basins, and as such a continuous, monthly estimate of unimpaired flows from these basins is also now available. This data set will likely be sufficient for most hydrologic studies of the Sacramento and San Joaquin back to 1850. The precipitation reconstruction could be extended back further in time using tree ring records alone, but there is not likely much room for improvement to the existing 1850-1894 time series with more complicated methods. On the other hand, although the streamflow reconstructions are very good, it is possible that more complicated watershed modeling methods might improve these estimates to some degree. For example, modeling of flows in the rim watersheds is being performed by the California Department of Water Resources (2016, draft) using the Soil Water Assessment Tool (or SWAT, a distributed watershed model). The DWR work has modeled daily flow, and the quality of the fits reported to date are not better than what are finding. This is not a direct comparison, because we are using monthly flows, where we might anticipate better model performance. However, the relative complexity of the distributed watershed model should be noted; the data requirements are much larger, and in most cases such information will not be available for the 19th century. As an example, the SWAT model for the Feather River used 64 sub-basins, each with precipitation data derived from PRISM. The cost-benefit of additional work will depend on the nature of the questions being asked with the data. Potentially, analyses looking to the future—in contrast to the hindcast modeling developed here—will benefit from the detailed watershed modeling in SWAT or an alternative tool, where adequate data exist for setting up and running the model.

Another area that may be examined further is the prediction of flows in wet years which may be of interest in flooding-related studies. The comparison with the pre-1922 data and the under-prediction of large annual flows is not easily explained, and may be related to changes in the watershed, changes in the stream channel morphology, and to the fundamental quality of the data. Because the 19th century data collection was discontinued, it is not easy to determine shifts that may have occurred because of changes in location or the methodology for reporting flow volumes. Detailed examination of the causes of this variation was beyond the scope of the present work, but the limited available observations and model comparisons are intriguing and may be considered in future work.

Deliverables:

Electronic file compiling pre-WY-1922 streamflow data at stations representative of rim watershed inputs to the Sacramento and San Joaquin Valleys (California Central Valley Tributary Streamflows Pre WY 1922.xls).

Electronic file with estimated precipitation data for individual valley watersheds at the HUC-10 level and the rim watersheds, and streamflow estimates for the rim watersheds (Precipitation and Streamflow Estimates by Watershed.xls)

Time series plots of precipitation at the rim watersheds (Appendix B. pdf)

Time series plots of streamflow in the rim watersheds using PRISM values of precipitation (Appendix C.pdf)

Time series plots of streamflow in the rim watersheds using estimated values of precipitation (Appendix D.pdf)

Scanned copies of relevant USGS water supply papers identified as potential data sources in this report are also uploaded (Appendix E. Pdfs of USGS Water Supply Papers.zip).

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Table 1
Selected Historical Streamflow Stations

Station Name	USGS Station ID	Latitude	Longitude	Historical Data Range
San Joaquin River below Friant, CA	11251000	36^{0}59'04"	119^{0}43'24"	11/1/1878- 9/30/1921
Merced River at Exchequer, CA (downstream of Lake McClure)	11270000	37^{0}34'55"	120^{0}16'45"	1/1/1879 - 9/30/1921
Tuolumne River above La Grange Dam near La Grange, CA (below Don Pedro Res.)	11288000	37^{0}42'35"	120^{0}24'45"	9/1/1895 - 9/30/1921
Stanislaus River near Knights Ferry, CA	11300000	37^{0}52'30"	120^{0}36'20"	1/1/1904 - 9/30/1921
Sacramento River above Bend Bridge near Red Bluff, CA	11377100	40^{0}17'19"	122^{0}11'08"	10/1/1891 - 9/30/1921
Feather River at Ororville, CA	11407000	39^{0}31'18"	121^{0}32'48"	8/29/1879 - 9/30/1921
Yuba River at Smartsville, CA	11419000	39^{0}13'25"	121^{0}17'33"	6/28/1900 - 9/30/1921
American River at Fair Oaks, CA	11446500	38^{0}38'08"	121^{0}13'36"	10/1/1904 - 9/30/1921

Table 2. Modeled fit of precipitation at valley floor watersheds, reported at the HUC-10 level. The target is the watershed-average precipitation (calculated from PRISM), predicted using San Francisco and Sacramento observed data and annual tree ring reconstructued precipitation.

HUC10	R^2	Nash-Sutcliffe Efficiency	N	Period
1804000113	0.81	0.80	993	1895-1977
1804000120	0.81	0.81	993	1895-1977
1804000108	0.80	0.80	993	1895-1977
1804000109	0.84	0.84	993	1895-1977
1804000114	0.87	0.87	993	1895-1977
1804000116	0.85	0.85	993	1895-1977
1804000117	0.86	0.86	993	1895-1977
1804000118	0.88	0.87	993	1895-1977
1804000705	0.83	0.83	993	1895-1977
1804000119	0.89	0.89	993	1895-1977
1804000121	0.86	0.86	993	1895-1977
1804000107	0.86	0.86	993	1895-1977
1804000808	0.89	0.88	993	1895-1977
1804000202	0.88	0.88	993	1895-1977
1802015903	0.94	0.94	993	1895-1977
1802016306	0.97	0.97	993	1895-1977
1802016307	0.97	0.97	993	1895-1977
1804000111	0.88	0.88	993	1895-1977
1804000115	0.86	0.86	993	1895-1977
1804000204	0.90	0.89	993	1895-1977
1804000302	0.91	0.91	993	1895-1977
1804000303	0.95	0.95	993	1895-1977
1804000306	0.91	0.91	993	1895-1977
1804000307	0.96	0.96	993	1895-1977
1804000308	0.95	0.95	993	1895-1977
1804000309	0.95	0.95	993	1895-1977
1804000807	0.89	0.88	993	1895-1977
1804000913	0.91	0.91	993	1895-1977
1804000914	0.90	0.90	993	1895-1977
1804001007	0.91	0.91	993	1895-1977
1804005103	0.92	0.92	993	1895-1977
1804005104	0.94	0.94	993	1895-1977
1804000205	0.92	0.92	993	1895-1977
1802011102	0.96	0.96	993	1895-1977
1802015606	0.87	0.86	993	1895-1977

HUC10	R^2	Nash-Sutcliffe Efficiency	N	Period
1802015803	0.91	0.91	993	1895-1977
1802015502	0.85	0.85	993	1895-1977
1802015503	0.86	0.86	993	1895-1977
1802015504	0.85	0.85	993	1895-1977
1802011101	0.96	0.95	993	1895-1977
1802011103	0.97	0.97	993	1895-1977
1804001209	0.96	0.96	993	1895-1977
1804001307	0.96	0.96	993	1895-1977
1804005101	0.93	0.93	993	1895-1977
1804005102	0.93	0.93	993	1895-1977
1802010401	0.87	0.86	993	1895-1977
1802010403	0.87	0.87	993	1895-1977
1802010405	0.87	0.87	993	1895-1977
1802012603	0.92	0.92	993	1895-1977
1802012604	0.93	0.93	993	1895-1977
1802012907	0.92	0.92	993	1895-1977
1802015207	0.86	0.85	993	1895-1977
1802015208	0.84	0.84	993	1895-1977
1802015601	0.86	0.85	993	1895-1977
1802015602	0.88	0.87	993	1895-1977
1802015701	0.88	0.88	993	1895-1977
1802015704	0.89	0.89	993	1895-1977
1802015705	0.86	0.86	993	1895-1977
1802015706	0.90	0.90	993	1895-1977
1802015802	0.91	0.91	993	1895-1977
1802015901	0.92	0.92	993	1895-1977
1802015902	0.92	0.92	993	1895-1977
1802016101	0.95	0.95	993	1895-1977
1802016102	0.95	0.95	993	1895-1977
1804001103	0.94	0.94	993	1895-1977
1804001206	0.92	0.91	993	1895-1977
1804001305	0.95	0.95	993	1895-1977
1804001306	0.94	0.94	993	1895-1977
1802010402	0.87	0.86	993	1895-1977
1802010404	0.90	0.89	993	1895-1977
1802010406	0.90	0.90	993	1895-1977
1802010407	0.93	0.93	993	1895-1977
1802010408	0.92	0.92	993	1895-1977

HUC10	R^2	Nash-Sutcliffe Efficiency	N	Period
1802010409	0.93	0.93	993	1895-1977
1802010410	0.95	0.95	997	1895-1981
1802010411	0.94	0.94	993	1895-1977
1802010412	0.90	0.89	993	1895-1977
1802011506	0.87	0.86	993	1895-1977
1802011607	0.96	0.96	993	1895-1977
1802012605	0.95	0.95	993	1895-1977
1802015605	0.87	0.86	993	1895-1977
1802015703	0.86	0.86	993	1895-1977
1802015707	0.88	0.87	993	1895-1977
1802015804	0.93	0.93	993	1895-1977
1802015904	0.94	0.94	993	1895-1977
1802015905	0.94	0.94	993	1895-1977
1802016103	0.96	0.96	993	1895-1977
1802016104	0.98	0.98	993	1895-1977
1802016205	0.95	0.95	993	1895-1977
1802016301	0.96	0.96	993	1895-1977
1802016302	0.96	0.96	993	1895-1977
1802016303	0.97	0.97	993	1895-1977
1802016304	0.97	0.97	993	1895-1977
1802016305	0.96	0.96	993	1895-1977
1804000304	0.95	0.95	993	1895-1977
1804000305	0.94	0.94	993	1895-1977
1804001210	0.97	0.97	993	1895-1977
1804001211	0.96	0.96	993	1895-1977
1804001308	0.97	0.97	993	1895-1977
1802000312	0.78	0.78	993	1895-1977
1802000313	0.79	0.79	993	1895-1977
1802000405	0.77	0.77	993	1895-1977
1802015101	0.81	0.80	993	1895-1977
1802015102	0.82	0.81	993	1895-1977
1802015103	0.80	0.79	993	1895-1977
1802015104	0.81	0.81	993	1895-1977
1802015303	0.84	0.84	993	1895-1977
1802015404	0.82	0.81	993	1895-1977
1802015405	0.84	0.84	993	1895-1977
1802015501	0.85	0.85	993	1895-1977
1802015702	0.84	0.84	993	1895-1977

HUC10	R^2	Nash-Sutcliffe Efficiency	N	Period
1802012602	0.90	0.90	993	1895-1977
1802012806	0.90	0.90	993	1895-1977
1802000310	0.78	0.78	993	1895-1977
1802000311	0.77	0.76	993	1895-1977
1802015301	0.80	0.80	993	1895-1977
1802015302	0.81	0.81	993	1895-1977
1802015603	0.81	0.81	993	1895-1977

Table 3. Modeled fit of precipitation in rim watershed stations. The target is the watershed-average precipitation (calculated from PRISM), predicted using San Francisco and Sacramento observed data and annual tree ring reconstructued precipitation.

Watershed	R^2	Nash-Sutcliffe Efficiency	N	Period
American River	0.83	0.82	993	1895-1977
Antelope Creek	0.84	0.84	993	1895-1977
Battle Creek	0.81	0.80	993	1895-1977
Bear River	0.89	0.89	993	1895-1977
Bear Creek	0.87	0.86	993	1895-1977
Big Chico Creek	0.89	0.89	993	1895-1977
Butte and Little Chico Creeks	0.85	0.85	993	1895-1977
Cache Creek	0.90	0.90	993	1895-1977
Calaveras River	0.90	0.90	993	1895-1977
Chowchilla River	0.85	0.85	993	1895-1977
Cosumnes River	0.88	0.88	993	1895-1977
Cow Creek	0.81	0.80	993	1895-1977
Deadman and Dutchman Creeks	0.86	0.85	993	1895-1977
Deer Creek	0.84	0.83	993	1895-1977
Dry and Sutter Creeks	0.91	0.91	993	1895-1977
Elder Creek	0.87	0.86	993	1895-1977
Feather River	0.85	0.85	993	1895-1977
Fresno River	0.85	0.85	993	1895-1977
Merced River	0.85	0.85	993	1895-1977
Mill Creek	0.81	0.81	993	1895-1977
Mokelumne River	0.86	0.86	993	1895-1977
Putah Creek	0.91	0.91	993	1895-1977
Sacramento River	0.73	0.68	993	1895-1977
San Joaquin River	0.83	0.83	993	1895-1977
Seven Mile and Paynes Creeks	0.85	0.84	993	1895-1977
Stanislaus River	0.86	0.86	993	1895-1977
Stony Creek	0.89	0.89	993	1895-1977
Thomes Creek	0.85	0.85	993	1895-1977
Tuolumne River	0.85	0.85	993	1895-1977
Yuba River	0.86	0.86	993	1895-1977

Table 4 Modeled fit of runoff in rim watershed stations using the PRISM values of precipitation.

Watershed	R^2	Nash-Sutcliffe Efficiency	N	Period
American River	0.87	0.87	711	1922-1981
Antelope Creek	0.90	0.90	711	1922-1981
Battle Creek	0.87	0.87	711	1922-1981
Bear River	0.94	0.94	711	1922-1981
Bear Creek	0.90	0.90	711	1922-1981
Big Chico Creek	0.87	0.87	711	1922-1981
Butte and Little Chico Creeks	0.91	0.91	711	1922-1981
Cache Creek	0.94	0.94	711	1922-1981
Calaveras River	0.93	0.93	711	1922-1981
Chowchilla River	0.92	0.91	711	1922-1981
Cosumnes River	0.91	0.91	711	1922-1981
Cow Creek	0.93	0.93	711	1922-1981
Deadman and Dutchman Creeks	0.89	0.88	711	1922-1981
Deer Creek	0.89	0.89	711	1922-1981
Dry and Sutter Creeks	0.91	0.91	711	1922-1981
Elder Creek	0.85	0.85	711	1922-1981
Feather River	0.83	0.83	711	1922-1981
Fresno River	0.92	0.92	711	1922-1981
Merced River	0.93	0.93	711	1922-1981
Mill Creek	0.88	0.88	711	1922-1981
Mokelumne River	0.89	0.88	711	1922-1981
Putah Creek	0.96	0.96	711	1922-1981
Sacramento River	0.92	0.92	711	1922-1981
San Joaquin River	0.93	0.93	711	1922-1981
Seven Mile and Paynes Creeks	0.90	0.90	711	1922-1981
Stanislaus River	0.90	0.90	711	1922-1981
Stony Creek	0.93	0.93	711	1922-1981
Thomes Creek	0.80	0.80	711	1922-1981
Tuolumne River	0.93	0.92	711	1922-1981
Yuba River	0.86	0.86	711	1922-1981

Table 5 Fit evaluation of runoff in rim watershed stations using the estimated values of precipitation. The precipitation input to the runoff model is based on San Francisco and Sacramento observed data and annual tree ring reconstructued precipitation. Fits not as good as in Table 4, because of the incoportation of error in the precipitation estimate.

Watershed	R^2	Nash-Sutcliffe Efficiency	N	Period
American River	0.75	0.75	672	1922-1977
Antelope Creek	0.74	0.74	672	1922-1977
Battle Creek	0.71	0.70	672	1922-1977
Bear River	0.83	0.82	672	1922-1977
Bear Creek	0.68	0.66	672	1922-1977
Big Chico Creek	0.78	0.77	672	1922-1977
Butte and Little Chico Creeks	0.77	0.77	672	1922-1977
Cache Creek	0.78	0.77	672	1922-1977
Calaveras River	0.80	0.79	672	1922-1977
Chowchilla River	0.72	0.71	672	1922-1977
Cosumnes River	0.78	0.77	672	1922-1977
Cow Creek	0.78	0.78	672	1922-1977
Deadman and Dutchman Creeks	0.72	0.71	672	1922-1977
Deer Creek	0.73	0.72	672	1922-1977
Dry and Sutter Creeks	0.78	0.78	672	1922-1977
Elder Creek	0.69	0.68	672	1922-1977
Feather River	0.69	0.69	672	1922-1977
Fresno River	0.73	0.72	672	1922-1977
Merced River	0.82	0.82	672	1922-1977
Mill Creek	0.71	0.71	672	1922-1977
Mokelumne River	0.81	0.81	672	1922-1977
Putah Creek	0.84	0.84	672	1922-1977
Sacramento River	0.76	0.76	672	1922-1977
San Joaquin River	0.85	0.85	672	1922-1977
Seven Mile and Paynes Creeks	0.77	0.77	672	1922-1977
Stanislaus River	0.82	0.81	672	1922-1977
Stony Creek	0.76	0.76	672	1922-1977
Thomes Creek	0.64	0.63	672	1922-1977
Tuolumne River	0.84	0.83	672	1922-1977
Yuba River	0.72	0.72	672	1922-1977

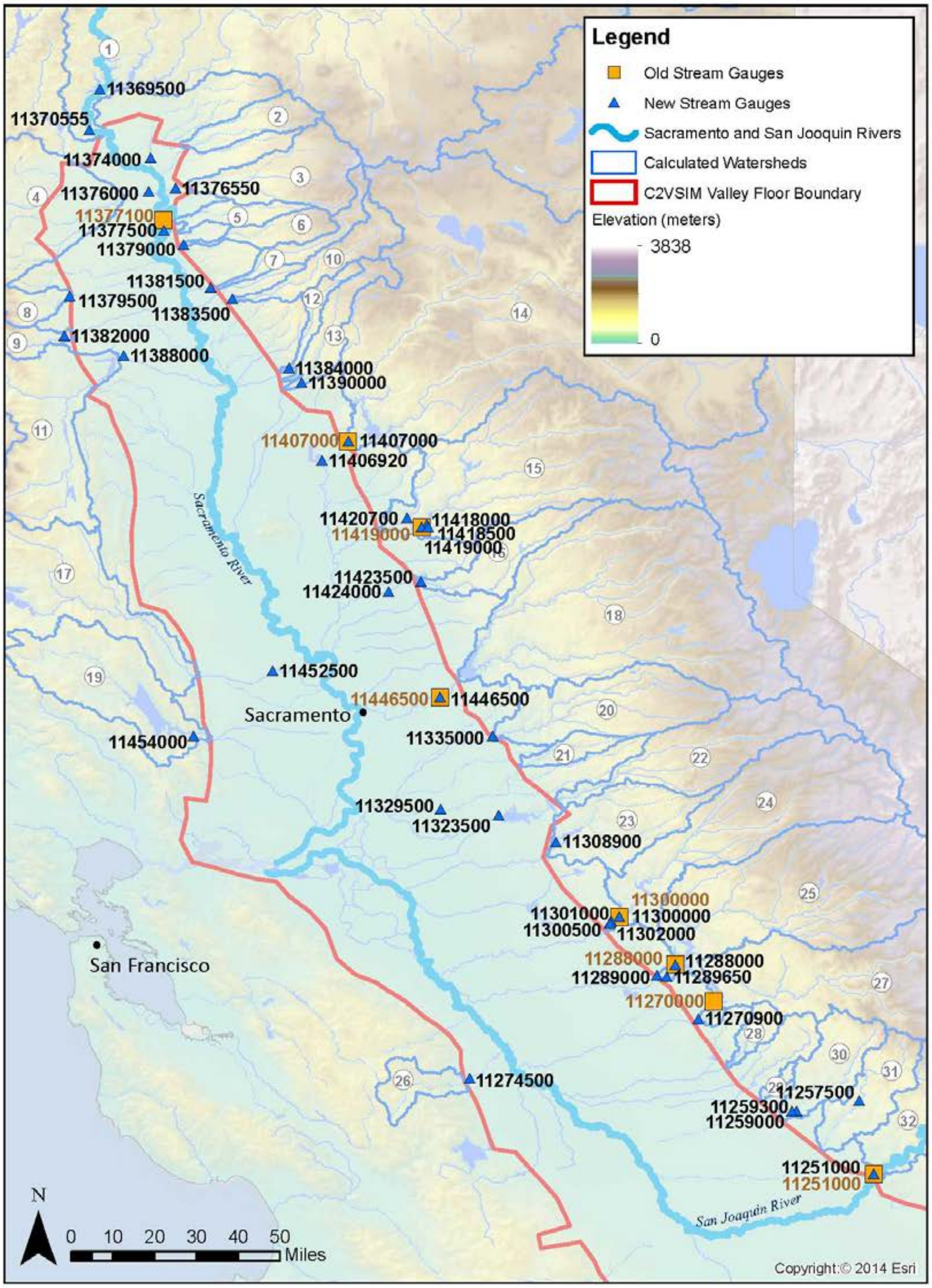


Figure 1 Mapping of historical and modern stations for developing database of pre-WY 1922 inflows.

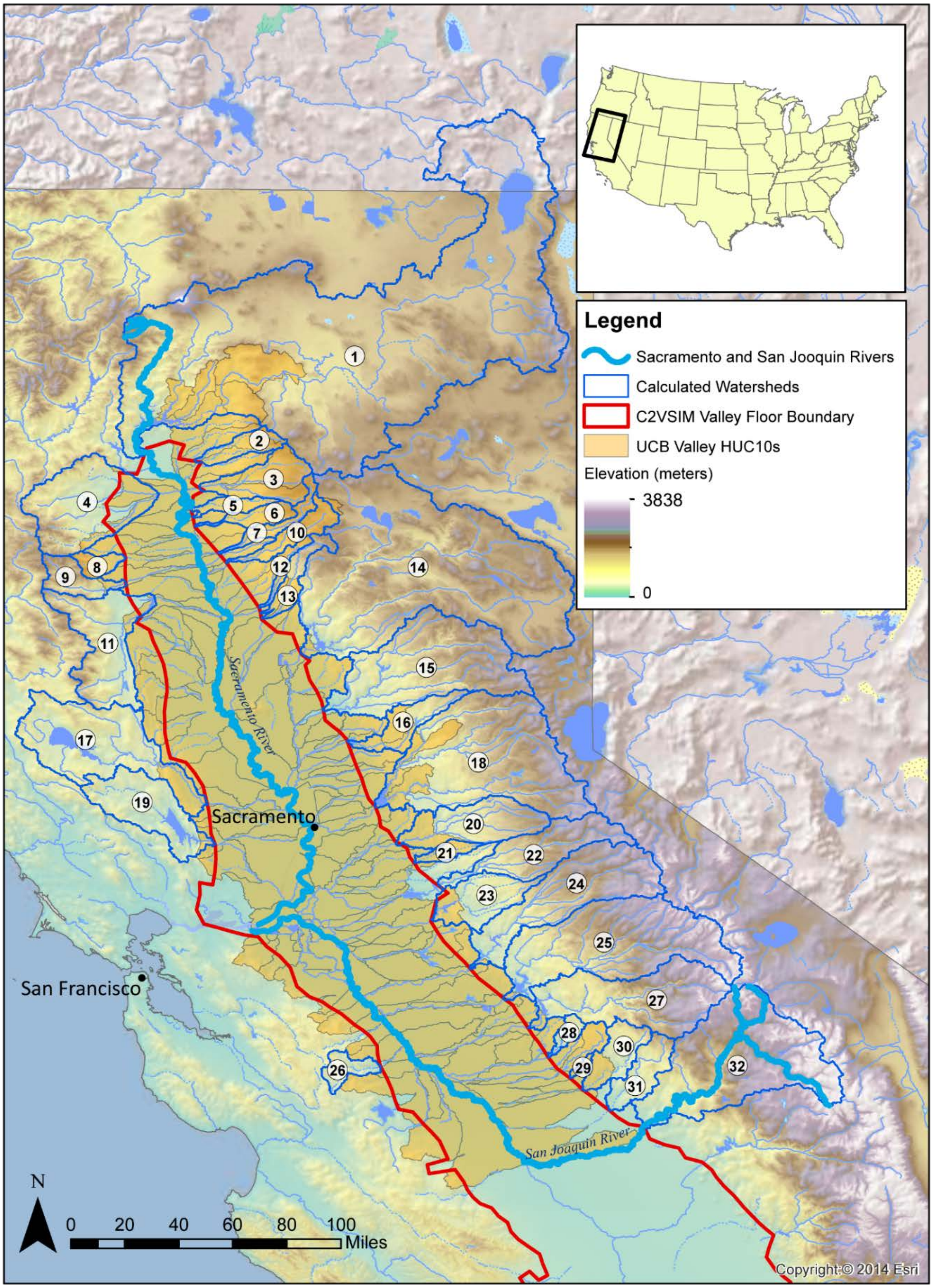


Figure 2 Definition of watersheds used for estimating inflows into the Central Valley. Each contributing watershed was calculated using the National Elevation Dataset.

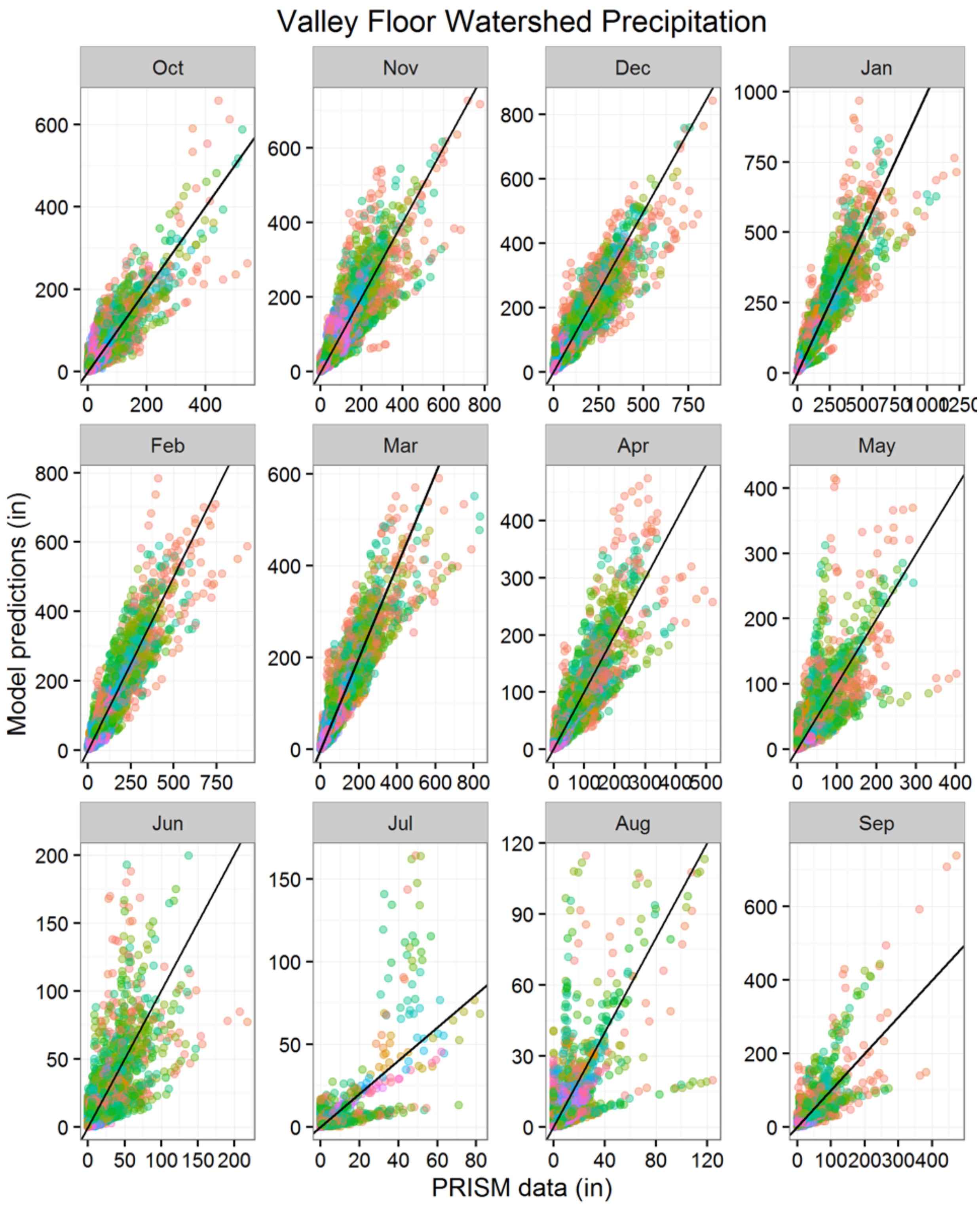


Figure 3 *Evaluation of PRISM precipitation and modeled precipitation in the HUC-10 valley floor watersheds using observed data from San Francisco and Sacramento and reconstructed annual precipitation from tree rings (Diaz and Wahl, 2014). Black lines represent the 1:1 line. Multiple watersheds are shown in different colors for illustration and are not meant to differentiate on these plots. The fits associated with individual watersheds are reported in Table 3.*

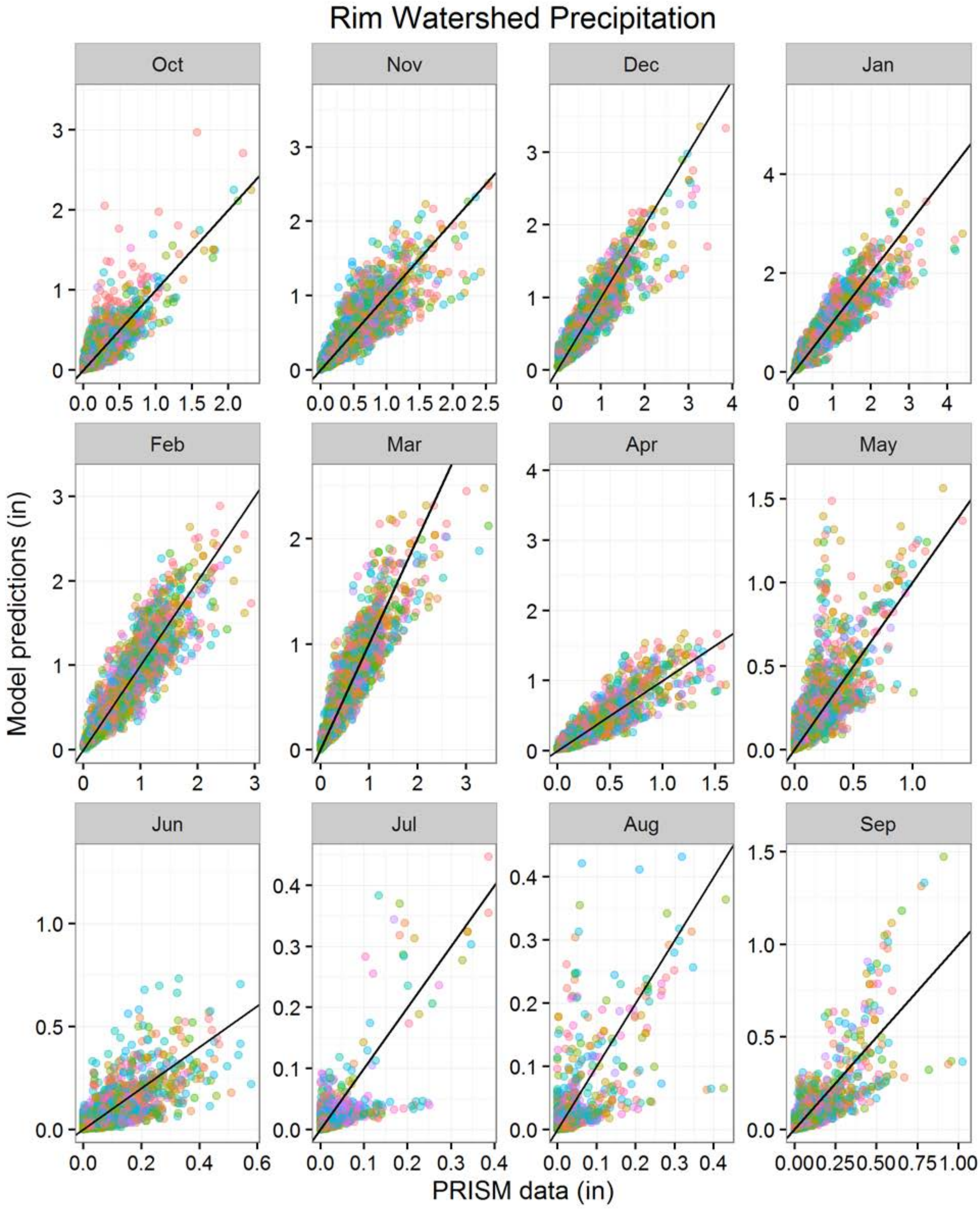


Figure 4 Evaluation of PRISM precipitation and modeled precipitation in the rim watersheds using observed data from San Francisco and Sacramento and reconstructed annual precipitation from tree rings (Diaz and Wahl, 2014). Black lines represent the 1:1 line. Multiple watersheds are shown in different colors for illustration and are not meant to differentiated on these plots. The fits associated with individual watersheds are reported in Table 3.

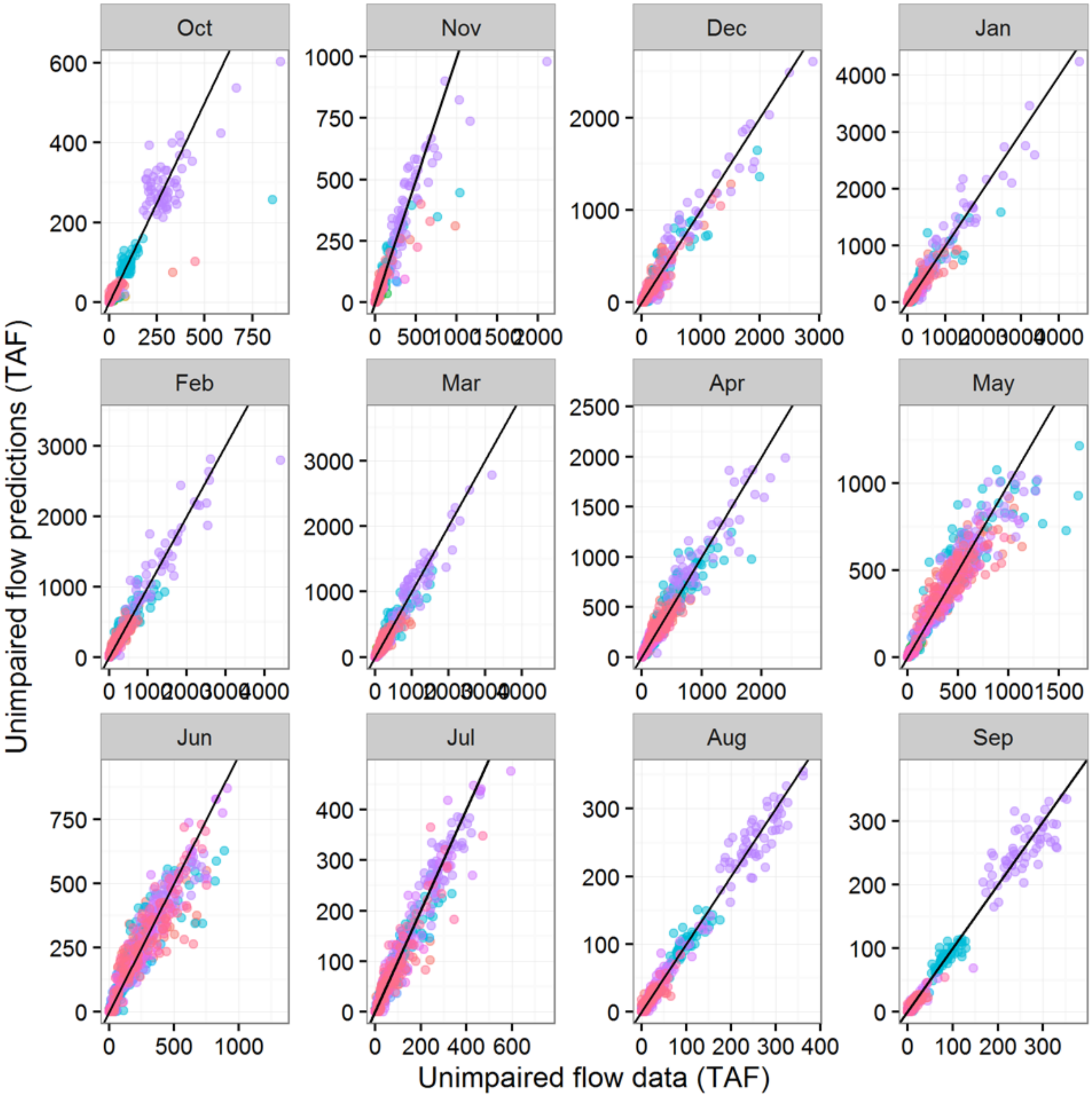


Figure 5 Evaluation of unimpaired flow (DWR and MWH estimates) and modeled unimpaired flow to the Central Valley from the rim watersheds. For these plots, the PRISM precipitation was used as input. Black lines represent the 1:1 slope. Multiple watersheds are shown in different colors for illustration and are not meant to differentiate on these plots. The fits associated with individual watersheds are reported in Table 5.

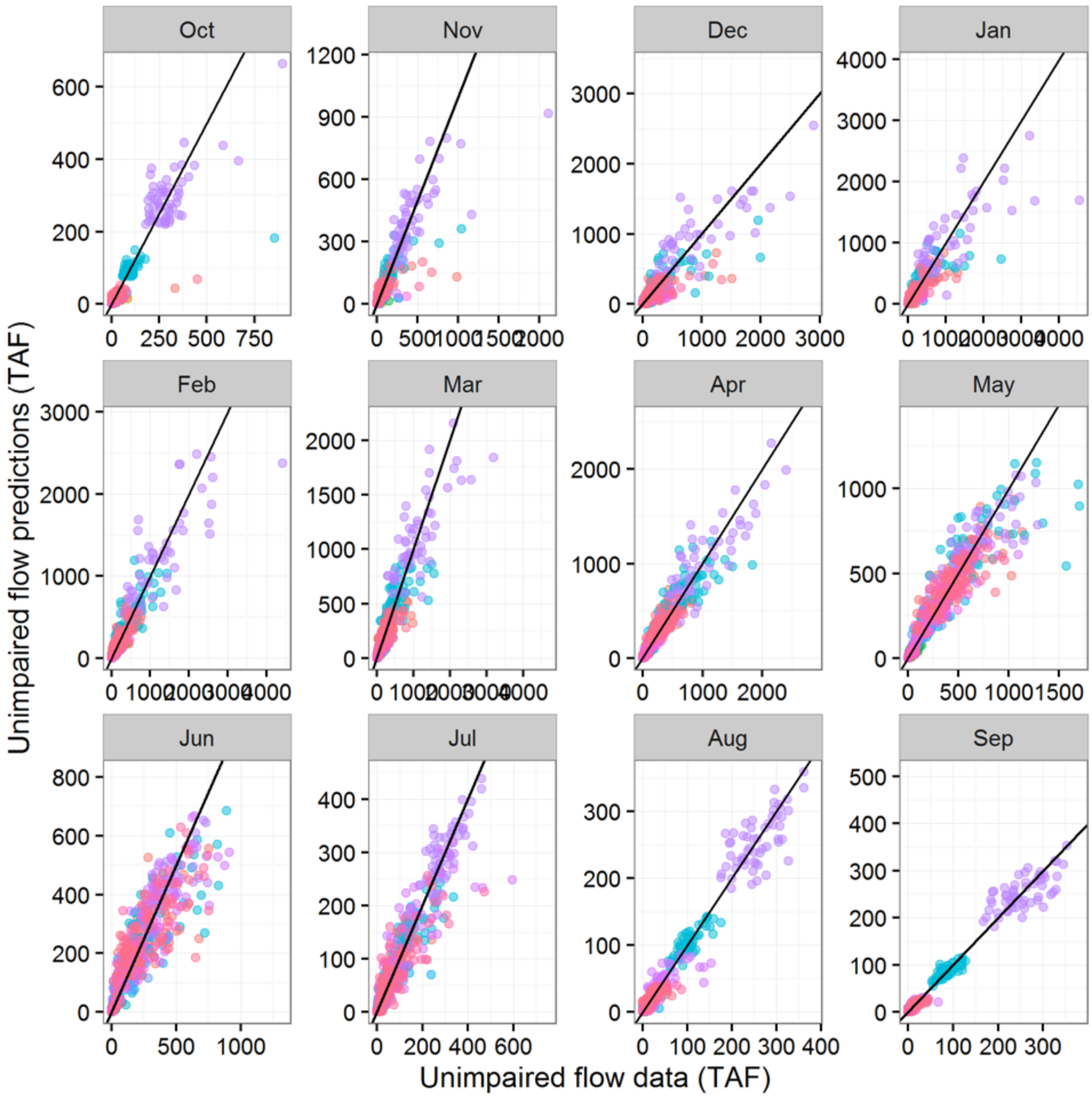


Figure 6 *Evaluation of unimpaired flow (DWR and MWH estimates) and modeled unimpaired flow to the Central Valley from the rim watersheds. For these plots, the estimated precipitation was used as input, i.e., these plots incorporate the error associated with the precipitation estimate. Black lines represent the 1:1 slope. Multiple watersheds are shown in different colors for illustration and are not meant to differentiate on these plots. The fits associated with individual watersheds are reported in Table 5.*

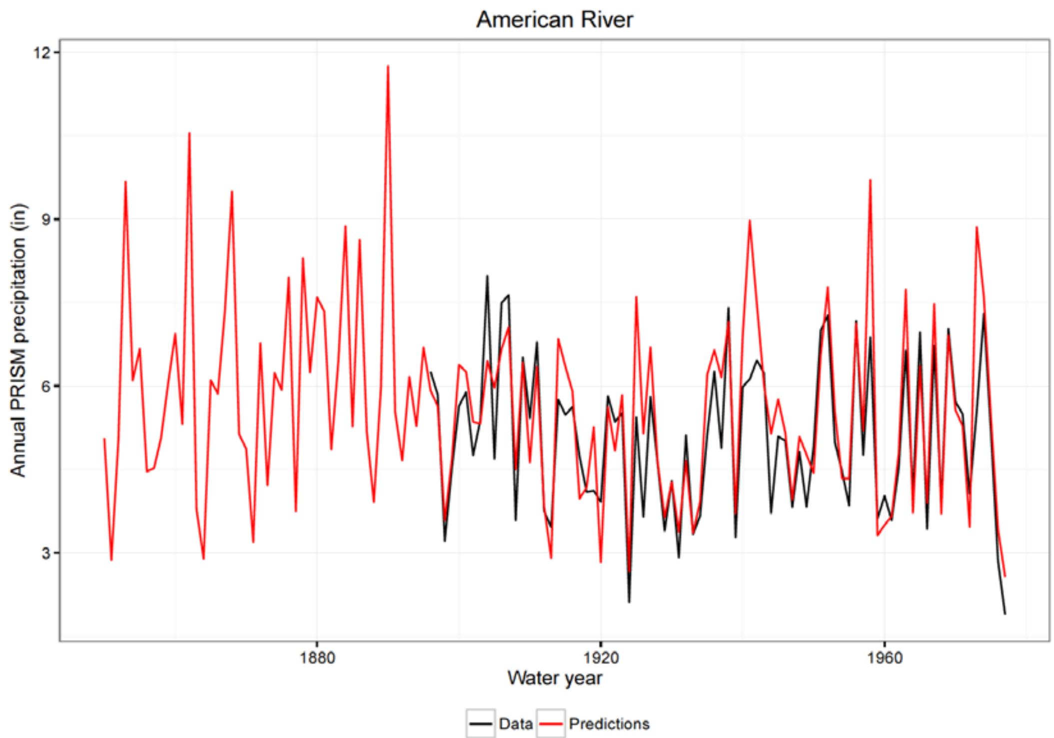
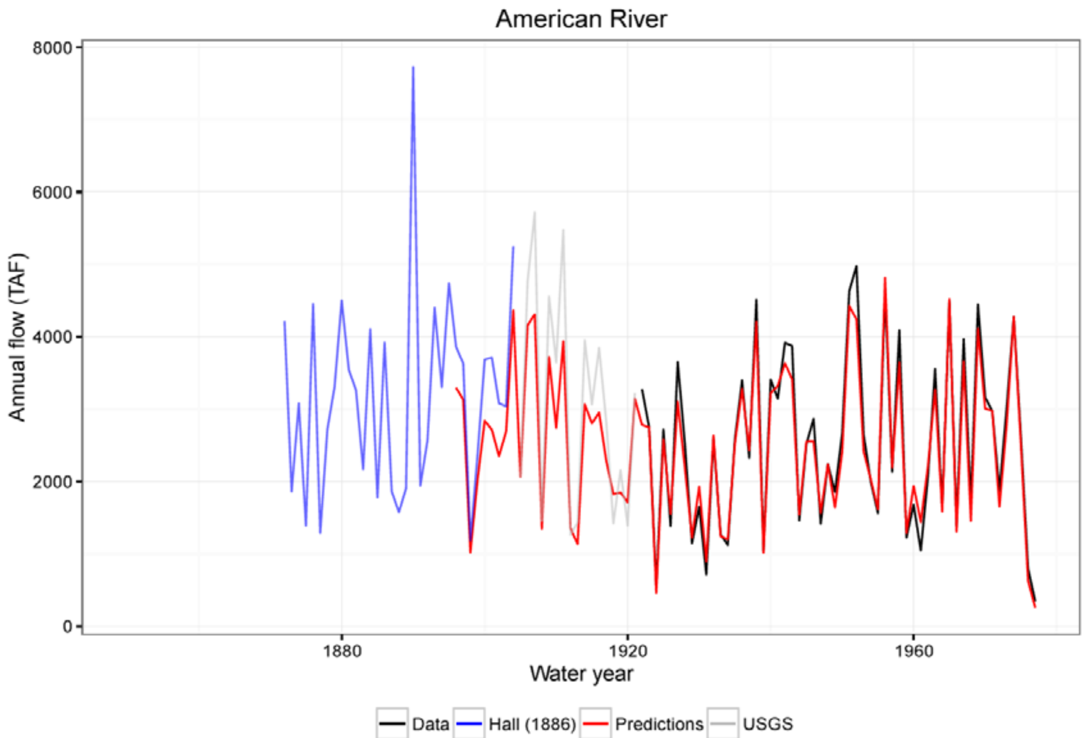


Figure 7 *Evaluation of PRISM precipitation (identified as "data" for this purpose) and modeled precipitation in the American River watershed (Figure 2). Similar plots for other watersheds are shown in Appendix B.*



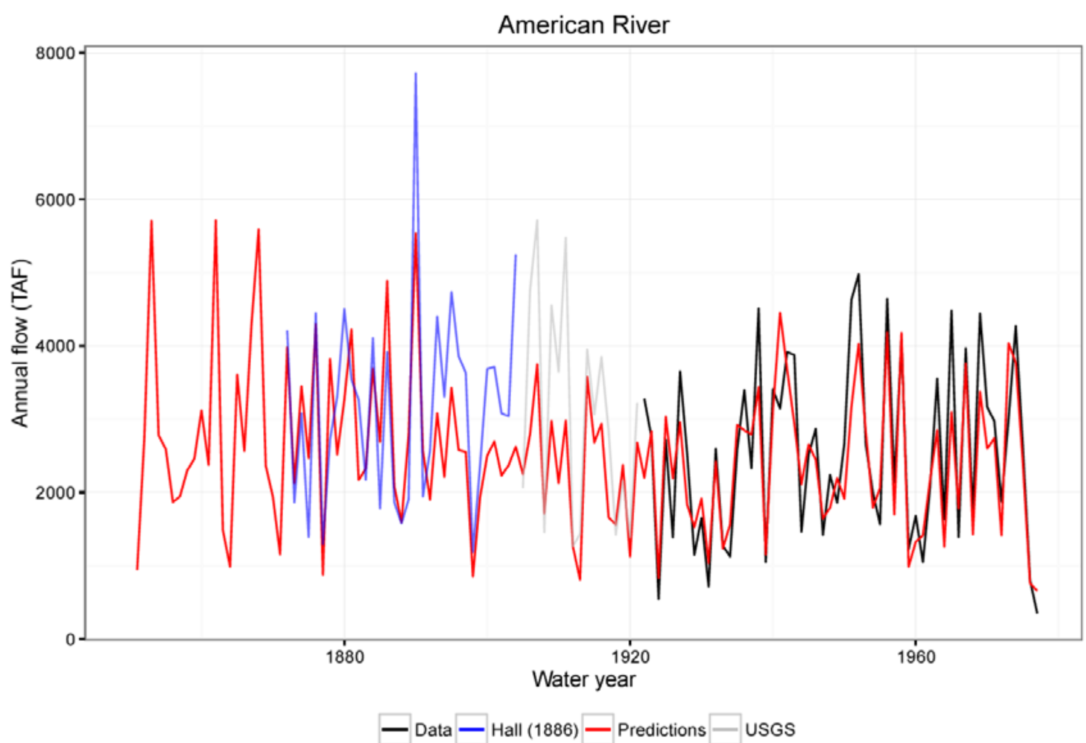


Figure 8 *Comparison of flow data from different sources with modeled estimates at the outflow of the American River watershed to the Sacramento Valley (Figure 2). The upper plot shows unimpaired flow data, and observed data from the USGS and Hall (1886), with estimates of runoff using exact PRISM data (available from 1895-1980. The lower plot shows the same data, but the line for prediction is based on the estimated precipitation values. The fit in the lower plot is poorer because it also reflects the error in the precipitation estimate.*

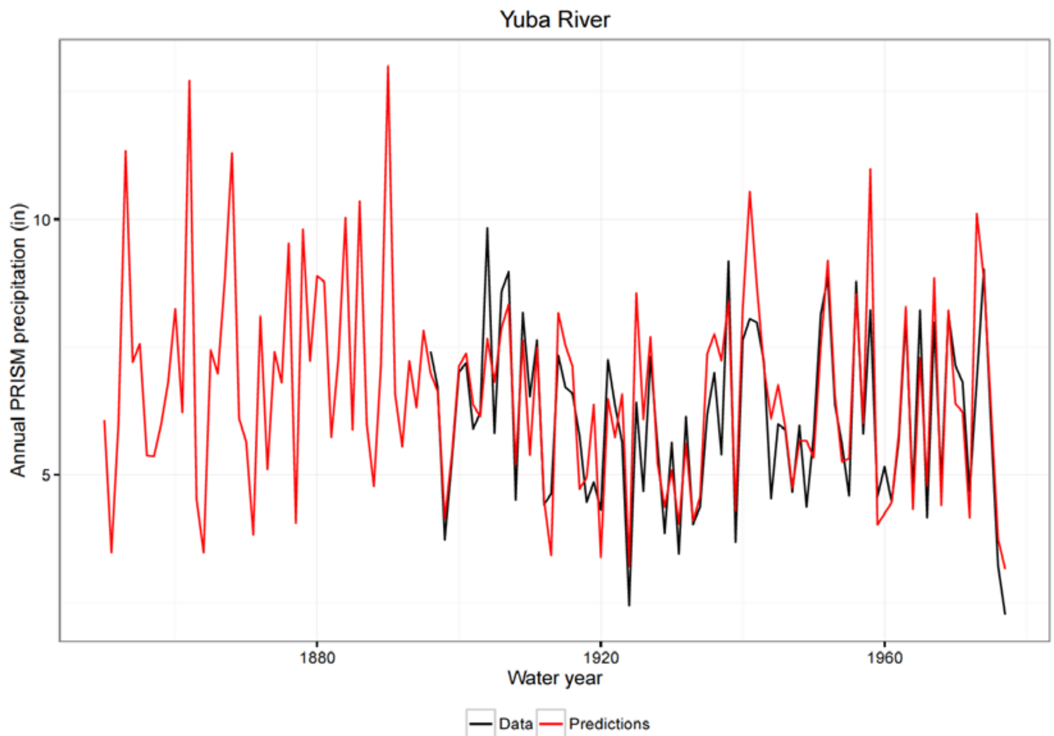
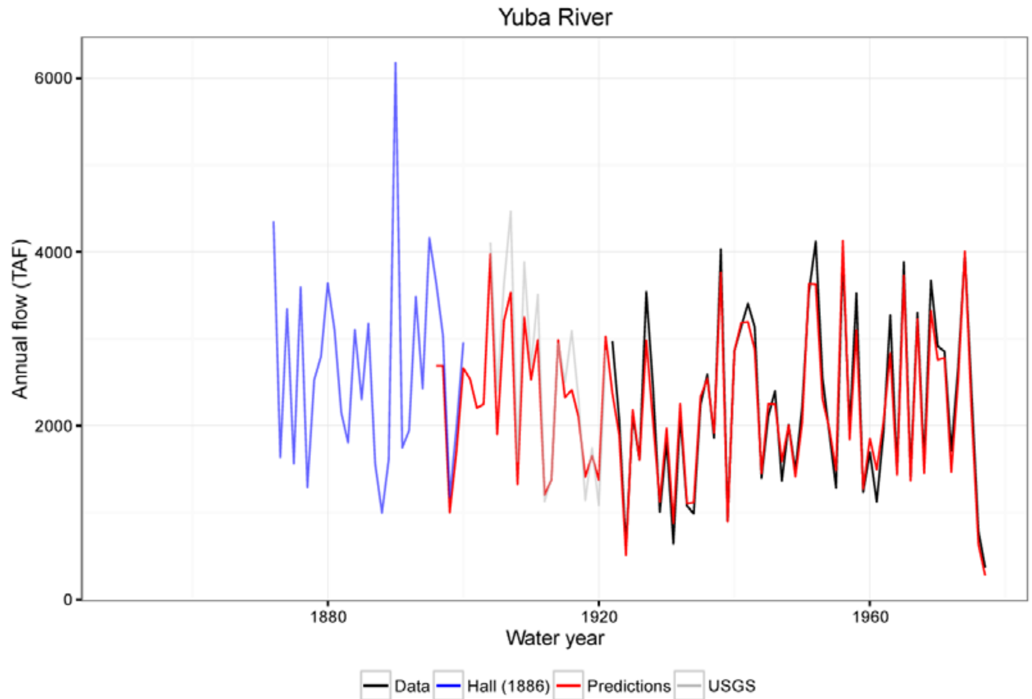


Figure 9 Evaluation of PRISM precipitation (identified as "data" for this purpose) and modeled precipitation in the Yuba River watershed (Figure 2). Similar plots for other watersheds are shown in Appendix B.



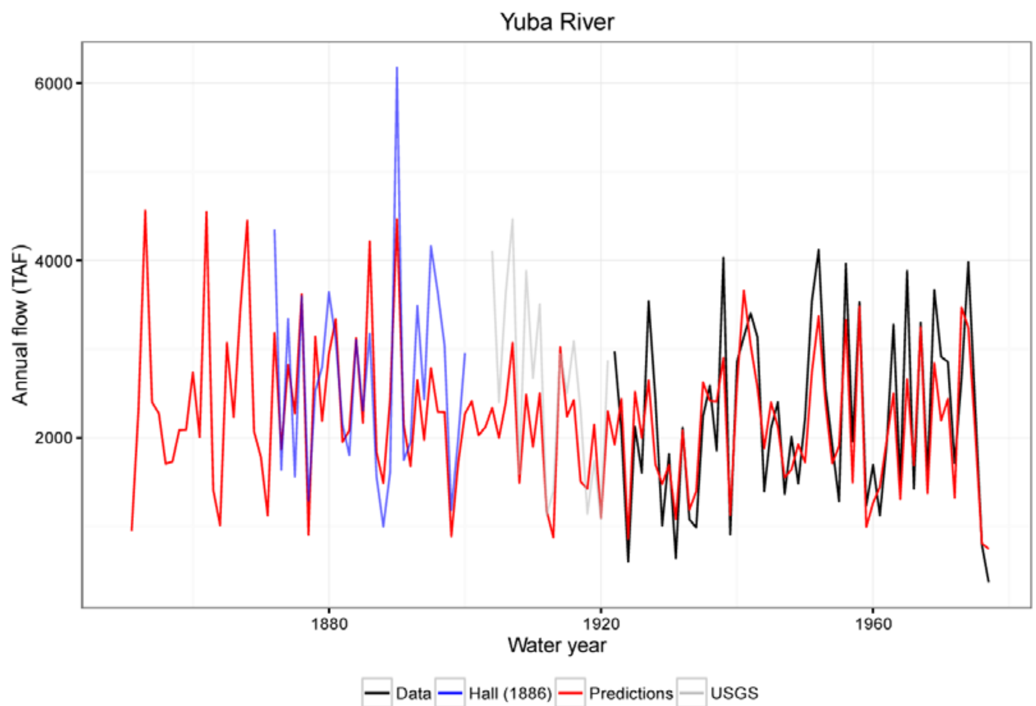


Figure 10 *Comparison of flow data from different sources with modeled estimates for at the outflow of the Yuba River watershed to the Sacramento Valley (Figure 2). The upper plot shows unimpaired flow data, and observed data from the USGS and Hall (1886), with estimates of runoff using exact PRISM data (available from 1895-1980. The lower plot shows the same data, but the line for prediction is based on the estimated precipitation values. The fit in the lower plot is poorer because it also reflects the error in the precipitation estimate.*

Appendix A – List of USGS Water Supply Papers Reviewed

USGS Water Supply Paper	Year	Title	Comments/Data Contained
--	1886	Physical Data and Statistics of California: Tables and Memoranda	This is the report produced by William Hall of the State Engineering Department of California. Provides monthly average discharge data for two of the selected streamflow stations (Merced River at Merced Falls and San Joaquin River below Friant/at Hamptonville) from 1878-1884. These data were also provided in Water Supply Paper 81.
38	1900	Operations at River Stations, 1899 - Part IV	Provides eight measurements of streamflow for the Tuolumne River near Lagrange that overlap with NWIS data.
39	1900	Operations at River Stations, 1899 - Part V	Does not contain any data that pertains to the study area.
51	1901	Operations at River Stations, 1900 - Part V	Provides six measurements of streamflow for the Tuolumne River near Lagrange that overlap with NWIS data. Thirteen measurements of streamflow from this paper for the Yuba River near Smartsville were added to the streamflow dataset.
66	1902	Operations at River Stations, 1901, Part II (West of Mississippi River)	Provides five measurements of daily streamflow at the Tuolumne River near Lagrange that overlap with monthly mean flow data obtained from USGS, 1950 report.
75	1903	Progress of Stream Measurements for the Calendar Year 1901	Provides monthly mean streamflow measurements from 1901 for Tuolumne River at Lagrange that overlap with monthly mean flow data obtained from USGS, 1950 report.
1	1903	California Hydrography	Provides random measurements of daily streamflow on the American River that could not be matched to selected site (American River at Fair Oaks, CA). Provides three measurements of daily streamflow on the Feather River at Oroville that do not overlap with NWIS data and were added to the streamflow dataset. Also, provides monthly mean streamflow measurements from 1902 for the Feather River at Oroville that overlap with NWIS data. Provides measurements of daily streamflow and monthly mean streamflow data on the Merced River near Merced Falls. This site was replaced with the selected site (Merced River at Exchequer, CA). Merced Falls data from this paper that does not overlap was added to the database. Provides daily streamflow measurements and monthly mean streamflow measurements for the Sacramento River near Red Bluff that overlap with NWIS data. Provides the Hall, 1886 data for the San Joaquin River (San Joaquin River below Friant, CA). Provides random measurements of daily streamflow and monthly mean streamflow data on the Stanislaus River that could not be matched to the selected site (Stanislaus River near Knights Ferry, CA). Provides daily streamflow measurements and monthly mean streamflow measurements for the Tuolumne River above La Grange Dam near La Grange, CA that overlap with data obtained from USGS, 1950 report. Provides random measurements of daily streamflow on the Yuba River some of these were from selected site (Yuba River at Smartsville, CA). These data match the data that was already added to the dataset from WSP 51 for the Yuba

USGS Water Supply Paper	Year	Title	Comments/Data Contained
			River.
85	1903	Progress of Stream Measurements for the Calendar Year 1902	Provides monthly mean streamflow data from 1902 for the Tuolumne River at Lagrange that overlap with monthly mean flow data obtained from USGS, 1950 report. Provides daily streamflow and monthly mean streamflow data for the Feather at Oroville that overlap with NWIS data.
100	1904	Progress of Stream Measurements for the Calendar Year 1903	Provides daily streamflow and monthly mean streamflow data from 1903 for the Sacramento River, Feather River, Merced River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
134	1905	Progress of Stream Measurements for the Calendar Year 1904	Provides daily streamflow and monthly mean streamflow data from 1904 for the Sacramento River, Feather River, Merced River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
147	1905	Destructive Floods in the United States in 1904	Provides daily streamflow data from the Sacramento River, Feather River, and Yuba River that overlap with daily streamflow data from NWIS.
213	1907	The Surface Water Supply of California, 1906	Provides daily streamflow and monthly mean streamflow data from 1906 for the American River, Feather River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
251	1910	Surface Water Supply of the United States 1907-8, Part XI. California	Provides daily streamflow and monthly mean streamflow data from 1907-08 for the American River, Feather River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
271	1911	Surface Water Supply of the United States 1909, Part XI. California	Provides daily streamflow and monthly mean streamflow data from 1909 for the American River, Feather River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
291	1912	Surface Water Supply of the United States 1910, Part XI. California	Provides daily streamflow and monthly mean streamflow data from 1910 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
298	1912	Water Resources of California - Part I: Stream Measurements in Sacramento River Basin	Provides daily streamflow and monthly mean streamflow data for the American River, Feather River, Merced River, Sacramento River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
299	1912	Water Resources of California - Part II: Stream Measurements in San Joaquin River Basin	Provides daily streamflow and monthly mean streamflow data for the Stanislaus River Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950

USGS Water Supply Paper	Year	Title	Comments/Data Contained
			report.
311	1912	Surface Water Supply of the United States 1911, Part XI. California	Provides daily streamflow and monthly mean streamflow data from 1911 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
331	1914	Surface Water Supply of the United States 1912, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1912 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
340-K	1915	Stream-Gaging Stations and Publications Relating to Water Resources 1885-1913, Part IX. Pacific Coast Basins in California	Does not contain any streamflow data. Report provides a summary of the studies that have been conducted on streamflow in the Pacific Coast Basins in California.
361	1916	Surface Water Supply of the United States 1913, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1913 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
391	1917	Surface Water Supply of the United States 1914, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1914 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
441	1918	Surface Water Supply of the United States 1916, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1916 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
447	1921	Surface Water Supply of the Pacific Slope of Southern California	Does not contain any data that pertains to the study area.
461	1920	Surface Water Supply of the United States 1917, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1917 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
481	1921	Surface Water Supply of the United States 1918, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1918 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
511	1923	Surface Water Supply of the United States 1919 and 1920, Part XI. Pacific Coast Basins in California	Provides daily streamflow and monthly mean streamflow data from 1919-20 for the American River, Feather River, Merced River, Sacramento River, Stanislaus River, Tuolumne River, and Yuba River that overlap with

USGS Water Supply Paper	Year	Title	Comments/Data Contained
			daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
636-D	1929	Surface Water Supply of the San Joaquin River Basin, California, 1895-1927	Provides monthly mean streamflow data for the Merced River, Stanislaus River, and Tuolumne River that overlap with daily streamflow data from NWIS and monthly mean flow data obtained from USGS, 1950 report.
--	1957	1957 Joint Hydrology Study: Sacramento and Sacramento-San Joaquin Delta	All of the data contained in this report is outside the time period of interest for historical data (all data is post-1920).
--	2010	Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay: A summary of historical reviews, reports, analyses, and measurements	Data presented for selected streamflow stations was also in Bulletin No. 5. Data was already extracted from Bulletin No. 5.