Placer County Water Agency
Middle Fork American River Project
(FERC No. 2079)

2005 - 2006

HYDROLOGY STUDY STATUS REPORT

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1.0 INTRODUCTION

The 2005-2006 Hydrology Study Status Report provides a description of the hydrology analyses completed to date for the relicensing of Placer County Water Agency's (PCWA's) Middle Fork American River Project (MFP or Project). The work summarized in this report was completed in 2005 and in 2006. The analyses presented in this report follows the technical approaches outlined in PCWA's 2005-2006 Existing Environment Study Plan Package (Hydrology Study Plan), dated June 17, 2005 (PCWA 2005).

An important step in the relicensing of the MFP is the development of a complete hydrology record, accepted by stakeholders, that characterizes both existing (Project) and unimpaired flows. However, a complete hydrologic record is not available from existing data sources in river and stream reaches influenced by the MFP. Therefore, the existing hydrologic record needs to be supplemented by 'filling in' missing data at existing flow gages, calculating unimpaired flows downstream of Project facilities, and estimating accretion flows between existing gaging locations. Several approaches were implemented to augment the existing hydrologic data due to differences in study objectives and data availability.

The purpose of this report is to summarize impaired and unimpaired hydrology in the vicinity of the MFP. Specifically, this status report summarizes the existing hydrology data compiled to-date; identifies the period of record (PoR) for hydrologic analysis; describes the technical approaches used to develop a complete hydrologic record; recommends a proposed water year (WY) type designation; and compares selected impaired and unimpaired flows in streams and rivers downstream of MFP. The approaches presented in this report are based on an extensive review of the existing hydrologic data, evaluation of different analytical approaches, and collaboration with the Hydrology Development Subgroup (PCWA and Resource Agencies). This report is presented to the Hydrology Development Subgroup to identify any additional analyses necessary to complete the MFP hydrologic record.

2.0 STUDY OBJECTIVES

The study objectives include:

- Assemble the existing hydrologic data available in the Project vicinity into a comprehensive database.
- Install or reinstall up to eight new flow gages, pending an access investigation. The data collected from these gages would be used to augment the existing hydrologic data set.
- Select the period of record for analysis of Project and unimpaired hydrology.
- Develop a complete draft hydrology dataset of both impaired and unimpaired flow for the period of record.
- Select a preliminary water year type classification for the Middle Fork American River (MFAR) Watershed, in collaboration with the resource agencies.

This report also provides a detailed description of the approaches used to develop the unimpaired Project hydrology, and the methods used to fill in hydrologic data gaps and to estimate accretion flows.

3.0 SUPPORTING DATA

The methodologies used to complete the hydrology record for the MFP and a summary of the resulting hydrology data are presented in this report. The existing hydrologic data set for the MFP is available on the attached CD.

The hydrology data set for MFP includes two representations of unimpaired flow and one representation of impaired flow.

- The two characterizations of unimpaired flows are based on considerations given to include the influences of Sacramento Municipal Utility District's (SMUD's) Upper American River Project (UARP) on the hydrologic record.
  - The first representation of unimpaired flows characterizes flows downstream of MFP facilities, with influences of both MFP and UARP operations (diversions) removed. The second representation of unimpaired flows (denoted "impaired by SMUD") characterizes flows downstream of MFP facilities, with influences of MFP operations removed but with the influences of the UARP included.
- The impaired flows present in this report represent historical flows downstream of MFP facilities as influenced by both the MFP and UARP operations.

The supporting documentation is available on the attached CD and is organized into the following appendices:

- Appendix A - The *Calculated Accretions* folder, which contains spreadsheets used to develop the accretions to the following areas: A (Middle Fork American River from French Meadows Dam to Interbay), B (Middle Fork American River from Middle Fork Interbay to Ralston Afterbay, C (Rubicon River from Hell Hole Dam to Ralston Afterbay), D (Middle Fork American River below Foresthill), and E (Long Canyon Creek). This folder also contains a file with GIS information, Disaggregation list document, and a PDF file labeled, *Reach by reach hydrologic analysis of the Middle Fork American River Project*.
- Appendix B - The *Calculated Inflows* folder contains the spreadsheets used to calculate Duncan Creek, French Meadows Reservoir, and Hell Hole Reservoir inflows. This folder also contains two spreadsheets labeled: Flushing_rate.xls and Unimpaired inflows for fill-in evaluation.xls.
- Appendix C - The *Recalculated Powerhouse Flows* folder contains a spreadsheet used to develop flow through the powerhouses based on generation records. The spreadsheet is labeled, *Recalculated PH flows 75-03.xls*.
- Appendix D - The *USGS Data and Reservoir Elevations* folder contains the USGS gage records in a HEC DSS file. Reservoir elevations are also provided in a spreadsheet labeled, *Reservoir Elevations.xls*.

- Appendix E - The *Fill-In* folder contains the files used to estimate the missing data within the available hydrologic records: Those files are labeled: Fillin_accretion_data, Fillin_foresthill_accretion_data, Fillin_HellHole_FrenchMeadows_flow_data, Fillin_InterbaytoFH_accretion_data, Fillin_LongCyn_data, Fillin_NFofMF_American_flow_data, and Fillin_Rubicon_Flow_data.
- Appendix F - The Maps folder contains two maps illustrating the accretion areas and the proposed model schematic. These maps were used as a reference to develop the hydrology data. The maps are labeled, *Accretion_Reference_Map.pdf* and *MFP_Schem.pdf*.
- Appendix G - The *Results* folder contains HEC DSS files including *Accretions and Calculated Inflows.dsc, Accretions and Calculated Inflows.dss*, *Impaired and unimpaired hydrology.dsc*, and *Impaired and unimpaired hydrology.dss*. The folder also contains a spreadsheet labeled, *Impaired and unimpaired hydrology.xls*, which summarizes all of the hydrology data. Two associated spreadsheets, *Impaired and unimpaired hydrology charts.xls* and *Impaired and unimpaired hydrology charts exceedance.xls* can be used to graphically view the data. Included in the appendix is a note regarding installation and operation of the macros in the spreadsheet files.

4.0 DEVELOPMENT OF A COMPLETE HYDROLOGIC RECORD

4.1 COLLECTION AND COMPILATION OF EXISTING STREAMFLOW AND STORAGE DATA

The existing network of stream gaging stations was initially used to describe the surface water hydrology in streams and rivers upstream and downstream of the MFP dams and diversions. Flow measurements have been recorded and published by the U.S. Geological Survey (USGS) from 47 locations within the MFAR Watershed. A complete list of the gages (discontinued or current) that have available data is provided in Table 1. The operational status of the USGS gages in the watershed and their locations are shown on Map 3-1. Most of the gages measure streamflow; however, some of the gages measure diversions from streams or flows through powerhouses.

PCWA and a number of other agencies also collect flow data in the American River Watershed, but these data are not necessarily submitted to and published by the USGS. These agencies include the Sacramento Municipal Utility District (SMUD) and Georgetown Public Utility District (GPUD). Streamflow data from SMUD is available at the 20 locations within the SMUD Watershed that are identified in Table 1. These data were used in developing and analyzing Project (impaired) and unimpaired flow conditions in the MFAR and its tributaries. PCWA has also obtained pertinent flow data from SMUD, including existing flow records, estimates of unimpaired flows at several SMUD locations, and calculated accretion flows.

PCWA has developed a central database that includes all of the existing flow data (PCWA, USGS, and SMUD). This database is accessible to the stakeholders via the website http://www.pcwamfpdata.net. Where the information is available, the website provides the gage number, location, watershed size, and PoR. As additional data becomes available from the USGS, PCWA will update the database during the relicensing as described in the Hydrology Study Plan (PCWA 2005). Changes to the database will be noted/flagged for easy identification. The website will include only the data in which PCWA is most confident of its accuracy (generally USGS data). The data is also available on the attached CD. Maps and downloadable data reports are available on the website as well.

4.2 Augmentation of the Existing Hydrologic Data by Installing New Streamflow Gages

To augment the existing hydrologic dataset, PCWA installed new gages and re-installed some non-operational historical gages. Data collected from these gages will be used to verify the estimated unimpaired hydrology. PCWA evaluated access conditions associated with each of the sites identified in the Hydrology Study Plan (PCWA 2005), in coordination with the resource agencies. It was determined that seven of the eight gage sites proposed in the Hydrology Study Plan allowed sufficient access to install a new gage. The fully executed Special-Use Permit for the installation of the streamflow gages and cableways was obtained from the Tahoe and Eldorado National Forests on October 31, 2006. Map 3-1 shows the locations of the newly installed gages. A typical cross section of a flow gage installation is provided in Figure 1.

PCWA completed the installation of the new gages in summer of 2006. The cableways required for two of the gages were installed in February 2007. All seven installed gages are operational and collecting water surface elevation data. PCWA will continue to collect the data and develop water surface elevation versus flow (stage-discharge) rating curves for each of the gages. The rating curve development process requires several field measurements at a wide range of flows. Typically, field measurements are made in the spring, during the descending limb of the hydrograph, where snow melt runoff provides an opportunity to measure a wide range of flows. PCWA began collecting flow data necessary to develop the rating curves in the spring of 2007. However, the large flows necessary to fully rate the gages did not occur. Additional flow measurements will be taken in the spring of 2008.

The following briefly describes the location of the seven new gages (P-F1 through P-F7) and access routes.

P-F1 North Fork of the Middle Fork American River upstream of the confluence with Middle Fork American River. This site is located on the North Fork of the Middle Fork American River approximately 175-feet downstream of the Circle Bridge on the left bank (looking downstream). The gage is installed in bedrock. The approximate NAD83 coordinates are latitude (Lat) 39.0233, longitude (Long) 120.7208. This site can be accessed by taking Mosquito Ridge Road to Circle Bridge and crossing over the North Fork of the Middle Fork American River.

P-F2 Middle Fork American River upstream of Ralston Afterbay. This site is located on the Middle Fork of American River upstream of Ralston Afterbay. The gage is installed in bedrock. The approximate coordinates are Lat 39.0075, Long 120.7317. This site is located a few hundred yards upstream of the Ralston Picnic Area and is accessed using a trail located on the north side (river right) of the Middle Fork American River.

<u>P-F3 Rubicon River upstream of Ralston Powerhouse</u>. This site is located on the right bank directly upstream of the Ralston Powerhouse (approximately 500-feet). The gage is installed in bedrock. The approximate coordinates are Lat 38.9925, Long 120.7205. This site is accessed from Ralston Ridge Road with a very short cross-country hike. A discontinued USGS streamflow gage was previously at this site (Rubicon River near Foresthill USGS No. 11433200).

<u>P-F4 Long Canyon Creek upstream of the confluence with the Rubicon River</u>. This site is located in Long Canyon Creek just upstream of the confluence with the Rubicon River. The gage is installed on the right bank (looking downstream) in bedrock. The approximate coordinates are Lat 38.9903, Long 120.6872. This site is accessed via Buckeye Flat Road from Ralston Ridge Road. Buckeye Flat Road is an OHV road that terminates at a washed-out section of the road near the Rubicon River about ½ mile downstream of the Long Canyon Creek mouth. A short hike along the Rubicon River to Long Canyon Creek is required to reach the site. This location may be inaccessible during wet conditions.

<u>P-F5 Long Canyon Creek downstream of the North Fork and South Fork Long Canyon Creeks</u>. This gage is placed on the right bank approximately 100-feet downstream of the bridge where USFS Road 2 crosses Long Canyon Creek. The gage is installed in bedrock and the approximate coordinates are Lat 39.0189, Long 120.5192. This site is accessed from USFS Road 2, also known as Eleven Pines Road.

<u>P-F6 Rubicon River downstream of the South Fork Rubicon River</u>. This site is located just upstream of Ellicott's Bridge on USFS Road 2. The gage is installed on the right bank (looking downstream) and the approximate coordinates are Lat 38.9600, Long 120.4811. The site is accessed via Wentworth Springs Road, also known as USFS Road 1, to Eleven Pines Road, also known as USFS Road 2. A discontinued USGS streamflow gage was at this site (Rubicon River near Georgetown USGS No. 11431000).

<u>P-F7 South Fork Rubicon River upstream of the confluence with the Rubicon River</u>. This site is located on the left bank of the South Fork Rubicon River, just upstream of the confluence with the Rubicon River. The gage is installed in bedrock. The approximate coordinates are Lat 38.9547, Long 120.4006. The site is accessed via a trail located on the left bank of the Rubicon River at Ellicott's Bridge. The trailhead can be difficult to find due to the many campsites and trails in the area. Two trails lead in the direction of the South Fork Rubicon; however, the lower trail near the edge of the terrace above the Rubicon River is washed out about ¼ mile upstream. The 1½-mile trail that leads to the gage site is higher up the slope. A discontinued USGS streamflow gage was previously at this site (South Fork Rubicon River at mouth near Georgetown, USGS No.11430500) and some of the old equipment is still visible at the site.

To augment the existing hydrologic dataset, PCWA also installed five supplemental flow gages (SF1 through SF5) within the FERC Project boundary. The data collected at these sites will be used to assist Project operations and verify the unimpaired hydrology estimates. Special-Use Permits for installing these gages were not necessary because the gage sites are within the FERC Project boundary. Map 3-1 shows the locations of the five supplemental flow gage sites. PCWA completed the installation of the supplemental gages during the winter of 2006/2007.

The following briefly describes the location of the supplemental gages and access routes.

SF1 Middle Fork American River upstream of French Meadows Reservoir. This site is located on the left bank of the MFAR approximately 100-feet upstream of the bridge at the upstream end of French Meadows Reservoir. This gage is installed in bedrock. The approximate coordinates are Lat 39.1345, Long 120.4066. This site can be accessed by taking Mosquito Ridge Road to French Meadows Reservoir. Once at the reservoir, cross the dam to the south side of the reservoir and continue east to the upstream end of the lake. The gage can be accessed via a short unpaved road immediately before the bridge over the MFAR.

SF2 Five Lakes Creek upstream of Hell Hole Reservoir. This site is located at the upstream end of Hell Hole Reservoir just upstream of the high water level. This gage is installed in bedrock. The approximate coordinates are Lat 39.0798, Long 120.3426 and is accessible by boat. To get to Hell Hole Reservoir from French Meadows Reservoir take Forest Service Road 22 also known as Soda Springs Riverton Road. At the intersection with Forest Service Rd 25 turn left on to Forest Service Road 2. Continue on Forest Service Road 2 up to Hell Hole Reservoir and follow the signs to the boat ramp.

SF3 Rubicon River upstream of Hell Hole Reservoir. This site is also located at the upstream end of Hell Hole Reservoir just upstream of the high water level. The gage is installed in bedrock. The approximate coordinates are Lat 39.0791, Long 120.3477 and is accessible by boat.

SF4 North Fork Long Canyon Creek at the Diversion Dam. This gage is a pressure transducer, installed on the existing concrete edge on the right side of the dam spillway. The purpose of this gage is to measure flow that passes over the spillway. The approximate coordinates are Lat 39.0491, Long 120.4833. This site can be accessed from Forest Service Road 2, also known as Blacksmith Flat Road. Access to the site is via a paved road on the north side of Forest Service Road 2.

SF5 South Fork Long Canyon Creek at the Diversion Dam. This gage is a pressure transducer, installed on the existing concrete edge on the right side of the dam spillway. This gage also measures flow that passes over the spillway. The approximate coordinates are Lat 39.0510, Long 120.4716. This site can be accessed from Forest Service Road 2, also known as Blacksmith Flat Road.

4.3 SELECTION OF PERIOD OF RECORD FOR ANALYSIS

The proposed period of record (PoR) for the hydrologic analyses associated with MFP relicensing begins in water year 1975 (October 1, 1974) and extends through water year 2003 (September 30, 2003), a period of 28 years. This PoR was selected for several reasons. First, this period best represents the recent operation of the MFP, since the issuance of the original FERC license. Second, the SMUD relicensing effort began its PoR in 1975, and some of the SMUD hydrology will be used as a part of the hydrology for the PCWA relicensing effort. The SMUD UARP is upstream of the PCWA system on the Rubicon River and South Fork Rubicon River and, therefore, SMUD operations affect flows through the MFP. Finally, USGS records of diversions and streamflows are more complete for the period after WY 1975 based on review of the historical streamflow records.

4.4 COMPLETION OF HYDROLOGIC DATA SET

Development of Impaired Hydrology

A complete hydrologic record from WY 1975-2003 is needed for the MFP relicensing. However, some of the published streamflows for streams and rivers downstream of MFP facilities have gaps of missing streamflow data for various years (Figure 2). The gaps in streamflow records are described below:

- Middle Fork Powerhouse, USGS gaging station 11428600. Missing WY 1987.
- Oxbow Powerhouse, USGS gaging station 11433212. Missing WY 1985, 1992, 1993, 1996, 1997, and 1998.
- French Meadows Powerhouse, USGS gaging station 11427200. Missing WY 1972, 1974, and 1987.
- SMUD Watershed streamflow data calculated through September 30, 2001. Missing WY 2002 and 2003.
- Middle Fork American River near Foresthill, USGS gaging station 11428600. The gage station is missing various days throughout record ranging from two days up to 45 days. In addition, there is no flow data for WY 1987.
- Middle Fork American River below Interbay Dam, USGS gaging station 11427770. The gage station is missing data for 40 periods, with the longest extending for 130 days. Nine of the missing periods are longer than one week and three are longer than one month. In addition, since 1985, this gage has been operated as a low flow station only.
- North Fork of the Middle Fork American River below Foresthill, USGS gaging station 11433260. Missing flow data from water years 1986 though 2003.
- South Fork Long Canyon Creek downstream of the diversion, USGS gaging station 11433065. Data from this station is missing for 23 periods, with the longest extending for 379 days. Sixteen of the missing periods are longer than six months and two missing periods extend for more than nine months. The purpose of this gage is to verify that minimum instream flow requirements are met when flows are being diverted. Diversions generally begin in late fall or winter and end in late spring

or early summer. The gage does not record spills over the diversion or flows when the diversion is not being operated.

- North Fork Long Canyon Creek downstream of the diversion, USGS gaging station 14433085. Data from this station is missing for 23 periods, with the longest extending for 380 days. Eighteen of these periods last for more than one month and fourteen extend for more than six months. As on the South Fork, the purpose of this gage is to verify that the minimum instream flow requirements are met when flows are being diverted. Diversions generally begin in late fall or winter and end in late spring or early summer. The gage does not record spills over the diversion or flows when the diversion is not being operated.

- Rubicon River below Hell Hole Dam, USGS gaging station 11428800. This gage only records flows for meeting minimum instream flow requirements. Spill is calculated by using the spillway rating curve and recorded reservoir elevations, added to the recorded minimum flow.

To fill in the data gaps, a USGS-developed computer program was used to estimate monthly flow volumes at streamflow gaging stations for the periods of time when data is missing. The program, called *Fill-In*, uses statistical analysis to calculate missing data and to estimate accretion flows (Alley and Burns 1983). The purpose behind using *Fill-In* was to complete the MFP data set as described below. Data taken from the *Fill-In* program is available on the attached CD under Appendix E – Fill-In.

The monthly-unimpaired flow records (both complete and incomplete) from each of the appropriate USGS gaging station are input into the *Fill-In* program. *Fill-In* reads the time series data directly from an HEC-DSS file on a water year basis (October through September). The program compares all the flow records and calculates the volumes within the data gaps on a monthly time step based on the best-correlated unregulated flow record using R^2 values. Each month may be filled in using the correlation for that month from a different gage, or using an annual correlation between the gaging station with the data gap and a gaging station with data available for that period of time.

To disaggregate, or separate the monthly flows (from the Fill-In program) into daily streamflow values, the hydrologic pattern from a complete unregulated gage was used. Flow data from a well-correlated and complete record was used to disaggregate the filled-in monthly flows based on the complete historical flow pattern for that gaging station, using the following equation:

$$Flow_{daily} = \frac{CompleteGage_{daily}}{CompleteGage_{monthly}} \times FillIn_{monthly}$$

If the original daily inflow data for the gage or accretion were acceptable, the daily values derived from *Fill-In* were used only for the period that was missing data. If the original flow record is of poor quality (i.e., a noisy record), the daily values derived from *Fill-In* values were used for the entire record.

Development of Unimpaired Hydrology

Three approaches were employed to develop unimpaired hydrology at MFP Project diversions and reservoirs. A fourth approach was used to develop unimpaired hydrology in stream reaches between existing stream gages.

- Unimpaired hydrology was developed at Project facilities located in the upper portions of the MFP, including Duncan Creek near Duncan Creek Diversion, Middle Fork American River at French Meadows Reservoir, Rubicon River at Hell Hole Reservoir, and Long Canyon Creek near the confluence of North Fork and South Fork Long Canyon creeks.
  - Unimpaired hydrology flows at Duncan Creek Diversion were derived from an existing gage located above the diversion that directly measure unimpaired flows.
  - Unimpaired flows into French Meadows and Hell Hole Reservoir were developed using a water balance calculation.
  - Unimpaired flows at North and South Fork Long Canyon Diversion involved using a combination of several methods that include a water balance equation where sufficient flow records exist and filling-in of incomplete flow records to calculate total contribution from the basin.
- Unimpaired flows downstream of diversions were developed by estimating accretion flows between existing streamflow gage locations.

Both of these components are discussed further in the following sections.

4.4.1 Development of Unimpaired Hydrology

Duncan Creek

A complete record of unimpaired flow for the Duncan Canyon Creek near French Meadows gage (USGS No. 11427700) is located immediately upstream of the Duncan Creek Diversion (Map 3-1). The streamflow data at this gaging station is available for the entire PoR required for analysis (WY 1975-2003). This data was used to develop the unimpaired hydrology for the headwaters of Duncan Creek.

Middle Fork American River at French Meadows Reservoir

Development of unimpaired flows of MFAR at French Meadows Reservoir required using a water balance calculation to account for inflow, outflow, and evaporation from the reservoir. A record of French Meadows Reservoir water storage (elevation) is available from the USGS (Gage No. 11427400) since operations began in December 1964. However, due to missing diversion data from French Meadows Reservoir to Hell Hole Reservoir in the late 1960's, 1972, and 1974, unimpaired flows can only be reasonably estimated for WY 1975-2003.

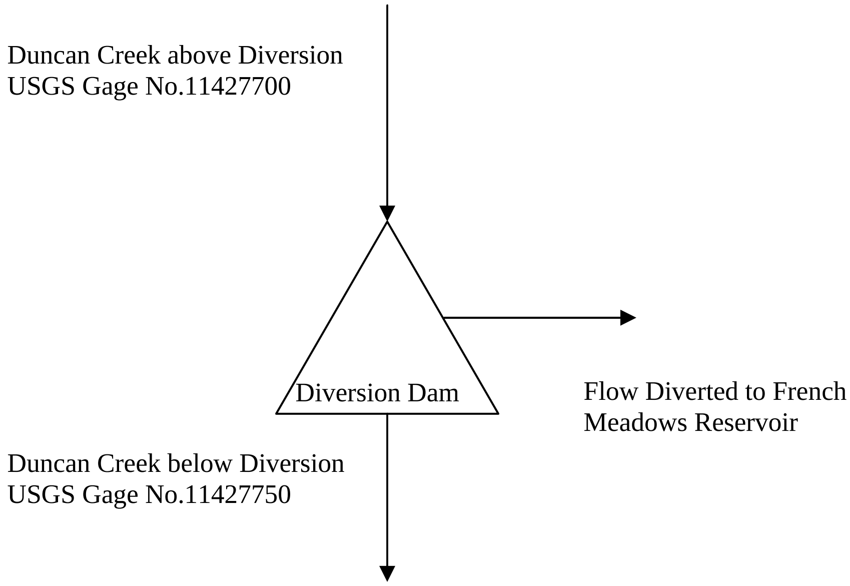
The equation used to develop the unimpaired inflow record (I_{FM}) involves the following:

- Subtract the previous day's reservoir storage (Si-1) from the current day's reservoir storage (Si);
- Subtract the diverted flow from Duncan Creek to French Meadows Reservoir (DivDC); and then
- Add in the diverted flow to Hell Hole Reservoir (DivHH), the downstream flow release (Rel), and the estimated evaporative losses for the day (Evap).

The development of the unimpaired inflow record is displayed by the equation below:

Equation 1 - $$I_{FM} = S_i - S_{i-1} - Div_{DC} + Div_{HH} + Rel + Evap$$

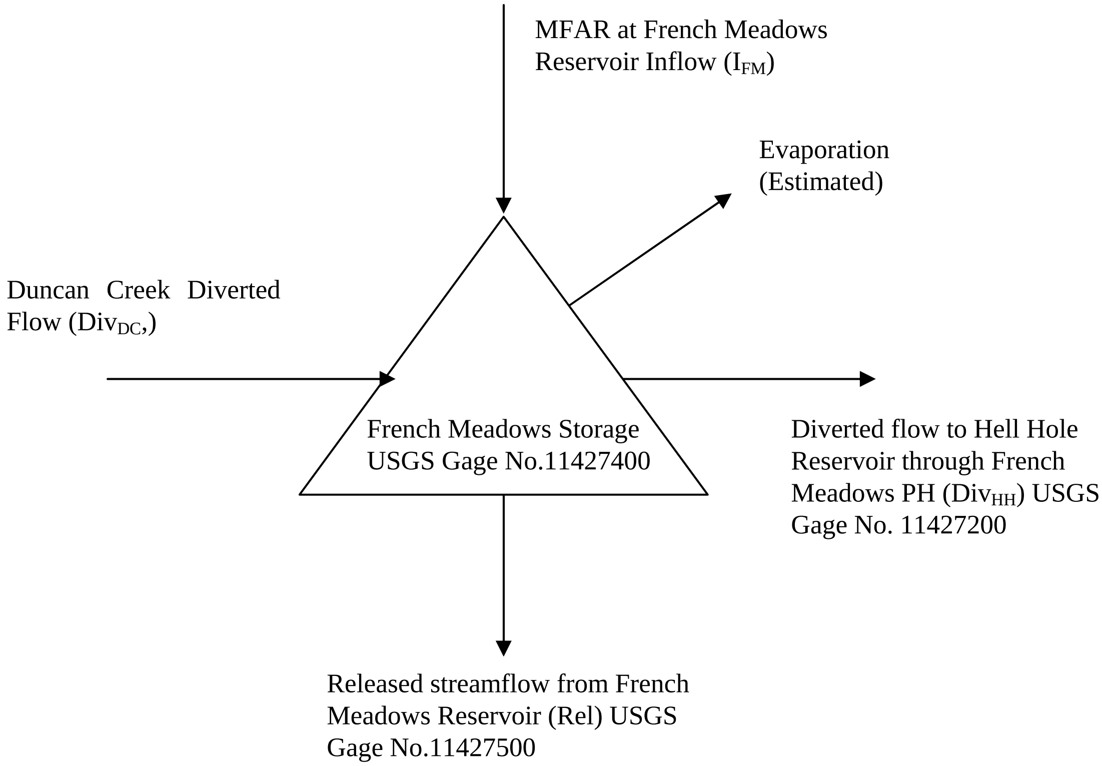
The diverted flow from Duncan Creek to French Meadows Reservoir (Div_{DC}) is not gaged but was calculated using a water balance equation. The water balance equation involved subtracting gaged streamflows downstream of the Duncan Creek Diversion (USGS Gage No. 11427750) from gaged streamflows upstream of the Duncan Creek Diversion (USGS Gage No. 11427700). The difference between the two gages was considered the diverted flow. Streamflow data above and below the diversion is available for the entire PoR for analysis.



Duncan Creek Diversion Water Balance

As a note, PCWA operators report the Duncan Creek gages are only marginally within USGS standards of precision. Additionally, the side channel inflow between the gages may potentially be significant during times of peak snowmelt. On occasion, the downstream gage records show higher flows than the upstream gage records, resulting in the calculation of a negative diversion (accretion flows from an area of less than 0.5 square miles likely contributes to the difference). In these cases, the diversion is assumed to be zero. Spreadsheets containing the calculations for Duncan Creek flows are available on the attached CD in Appendix B – Calculated Inflows.

Except for daily evaporation from the reservoir, daily data is available from the USGS for each of the remaining components. The water balance equation for the MFAR at French Meadows Reservoir is shown in the diagram below. The calculation for this equation is available on the attached CD in Appendix B – Calculated Inflows in the French Meadows folder under the “FM_calculations” tab in the file designated FMUnimpairedInflow_Didaggregation_v1.6.xls.



MFAR at French Meadows Reservoir Inflow Water Balance

However, use of the daily data in the calculation of unimpaired inflow resulted in a daily inflow record that contained numerous negative inflows. These negative values may be the result of several factors, including: underestimation of evaporation; lack of precision in the reservoir storage curve exacerbated by the low net inflow volumes and low reservoir storage; gage error; or, other factors. Wind effects on the reservoir level and other recording inaccuracies also may have affected the calculation of unimpaired flows. To remove the negative values from the calculated inflow record (Equation 1 shown above), a four-step process was used.

Step 1: The daily reservoir inflow record (I_{FM}) was grouped into monthly volumes. When these monthly volumes were negative, *Fill-in* data was used to generate a positive monthly inflow volume based on correlations with other basins with a complete record: Duncan Creek near French Meadows (above diversion), USGS Gage No 11427700; North Fork American River at North Fork Dam, USGS Gage No 11427000; Pilot Creek above Stumpy Meadows Reservoir, USGS Gage No 11431800; and North Fork of the Middle Fork American River, USGS Gage No 11433260. The *Fill-In* data used is available on the attached CD in Appendix E – Fill-in, the Fillin_HellHole_FrenchMeadows_flow_data folder.

Step 2: Daily inflows were re-computed, using disaggregation. To disaggregate or smooth a record, the daily flow values from the noisy record was compared to the daily flow values from a gage with a complete and acceptable flow record. The daily values for the noisy (or incomplete) records ($Flow_{daily}$) were calculated using the monthly inflow ($Volume_{monthly}$) (from the noisy record) and the daily/monthly relationship ($CompleteGage_{daily}$ and $(I_{FM})_{monthly}$) for the complete record:

$$\frac{Flow_{daily}}{Volume_{monthly}} = \frac{CompleteGage_{daily}}{CompleteGage_{monthly}}$$

This disaggregation was performed to smooth inflow records to French Meadows Reservoir by redistributing the recorded monthly volume of inflow to French Meadows Reservoir using the pattern recorded at the Duncan Creek gage (Duncan Canyon Creek near French Meadows, USGS No. 11427700). Regression analysis showed that French Meadows and Duncan Creek monthly volumes were well correlated, with an R^2 value of 0.97 (Figure 3).

The daily inflow values for the French Meadows Reservoir ($FM\ Flow_{daily}$) were estimated using the same percentage of the reservoir's monthly inflow ($FM\ Volume_{monthly}$) as the Duncan Creek daily streamflow value ($DC\ Flow_{daily}$), and compared to the Duncan Creek monthly streamflow volume ($DC\ Volume_{monthly}$). This proportional relationship is shown with the following equation:

$$\frac{DCFlow_{daily}}{DCVolume_{monthly}} = \frac{FM\ Flow_{daily}}{FM\ Volume_{monthly}}$$

This second step in the analysis as described above provides a more accurate pattern for daily inflow to the reservoir, but the flow record still had some discontinuities. These discontinuities occurred at the start of months during the ascending and descending limbs of the hydrograph, particularly in May, June, and July. At these times, when the differences in total monthly inflow from one month to the next were large (signaling the onset or end of spring runoff), the flow for the first day of the new month was often greater than the previous day's inflow by several hundred acre-feet.

Step 3: To resolve the discontinuities following the completion of Step 2, another inflow record was developed using disaggregation based on weekly, rather than monthly, inflow volumes. This procedure resolved the discontinuities, and resulted in a more reasonable simulation of both the ascending and descending limbs of the hydrograph and reservoir storage. The calculations used are available on the attached CD in Appendix B – Calculated Inflows in the French Meadows folder in the Disaggregation tab in the file, FMUnimpairedInflow_Disaggregation_v1.6.xls .

The third step in the analysis was to eliminate these negative monthly volumes by grouping together positive and negative volume weeks into a multi-week volume. As few weeks as possible that would yield a net positive volume were grouped together for this averaging calculation. If grouping positive and negative inflow weeks could not eliminate the negative inflow values without significantly affecting the shape of the overall hydrograph and storage curve (e.g., the month of August in 1977 and the months of September and October of 1991), then Fill-in was used to generate a positive monthly inflow volume based the correlations with other basins with a complete record (same basins used in Step 1 above). These negative values may be the result of several factors including: underestimation of evaporation, particularly in the stream channel; lack of precision in the reservoir storage curve exacerbated by the low net inflow volumes and low reservoir storage; gage error; or other factors.

Step 4: The final step in the development of the French Meadows Reservoir inflow record was to smooth out any remaining inflow jumps, particularly in the drier summer months. Weeks were grouped together to reduce the number and magnitude of inflow jumps.

An example is illustrated in Figure 4, which shows a comparison of the unimpaired and impaired French Meadows Reservoir inflow during water year 1979.

Rubicon River at Hell Hole Reservoir

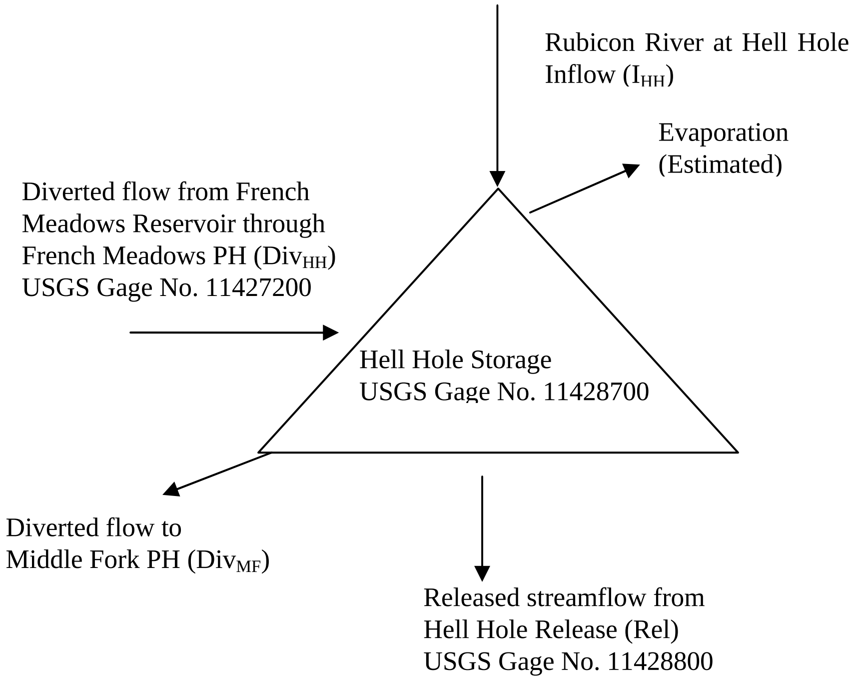
Development of unimpaired flows for the Rubicon River at Hell Hole Reservoir required using a water balance calculation to account for inflow, outflow, and evaporation, similar to that used to develop unimpaired inflow to French Meadows Reservoir.

USGS records of Hell Hole Reservoir storage (USGS No. 11428700) are available for the PoR for analysis and were used to develop the inflow record for the reservoir. *Fill-In* data was used to generate a positive monthly inflow volume based on correlations with other basins with a complete record.

Developing the unimpaired inflow record (I_{HH}) for the Rubicon River at Hell Hole Reservoir was similar to the equation used for the unimpaired inflow to French Meadows Reservoir. The inflow was calculated by subtracting the previous day's reservoir storage (S_{i-1}) from the current day's reservoir storage (S_i). From there subtract the diverted flow from French Meadows Reservoir to Hell Hole Reservoir (Div_{HH}), and then add the diverted flow to the Middle Fork Powerhouse (Div_{MF}) (calculated from generation at the Middle Fork Powerhouse and diversions at Long Canyon Creek), the downstream flow release (Rel), and the estimated evaporative losses for the day (Evap) and is represented as follows:

Equation 2 - $$I_{HH} = S_i - S_{i-1} - Div_{HH} + Div_{MF} + Rel + Evap$$

Daily records for each of the components are available from the USGS for the PoR, except for evaporative losses, which were estimated. As a note, the flow diversion out of the upper Rubicon basin through the Buck-Loon Tunnel (Gage No 11428300) was not added to the unimpaired record at this time because the inflow to Hell Hole Reservoir was historically impaired by operations of SMUD's UARP. The following diagram illustrates the Rubicon River at Hell Hole Reservoir inflow water balance.



Rubicon River at Hell Hole Reservoir Inflow Water Balance

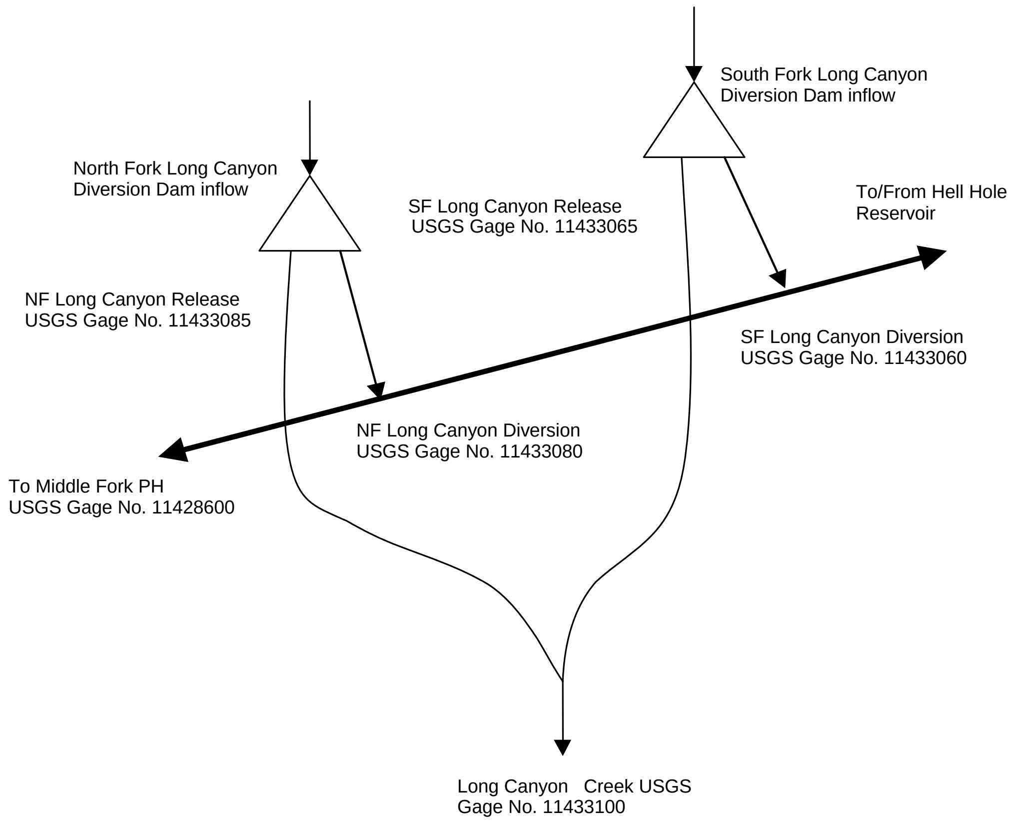
As with data for French Meadows Reservoir inflow, the calculation of unimpaired inflow at Hell Hole Reservoir resulted in a daily inflow record with numerous negative values. The same four-step process described above was used to smooth-out the inflow record for unimpaired flows on the Rubicon River at Hell Hole Reservoir. The calculation used is available on the attached CD in Appendix B – Calculated Inflows, the HH_Calculations tab in the file, HHUnimpairedInflow_Disaggregation_v1.6.xls.

The disaggregation performed in Step 2 of the process also utilized the Duncan Creek Gage (Duncan Canyon Creek above the diversion, USGS No. 11427700). Regression analysis showed that the Hell Hole Reservoir and Duncan Creek monthly volumes were well correlated, with an R^2 value of 0.95 (Figure 5).

An example comparison is illustrated in Figure 6, which shows the unimpaired and impaired simulated and recorded inflows and storage to the Rubicon River at Hell Hole Reservoir during Water Year 1979.

Long Canyon Creek

Development of unimpaired flows in Long Canyon Creek involved using a combination of several methods that include a water balance equation where sufficient flow records exist and filling-in of incomplete flow records to calculate total contribution from the basin. A diagram of the Long Canyon Creek diversions (North and South Fork Long Canyon Creek diversions) and USGS gages is shown below.



North Fork and South Fork Long Canyon Creek Diversions

The gaging station for Long Canyon Creek near French Meadows Reservoir (USGS No. 11433100) covers most of the PoR for analysis (WY 1975-1992). The gage was located immediately downstream of the confluence of the North Fork and South Fork Long Canyon creeks, and was operated year-round until 1992.

To create a complete Long Canyon Creek unimpaired flow record, the available USGS data were added to the diverted flows from North Fork and South Fork Long Canyon creeks. These calculations are available on the attached CD in Appendix A – Calculated Accretions, the Long Canyon Creek folder, the Calculations tab in the file, LongCanyon_development_v1.3.xls .

For the remaining PoR (WY 1993-2003), monthly flow volumes were developed using *Fill-In*. This *Fill-In* run data is available on the attached CD in Appendix E - Fill-In, the Fillin_LongCyn_data folder. The monthly volumes were then disaggregated into daily values following the same procedures as described in Steps 2-4 above. Flow patterns on Pilot Creek were used on the analysis because the regression analysis between Long Canyon Creek and Pilot Creek were well correlated, with an R^2 value of 0.90 (Figure 7). The disaggregation calculations are available on the attached CD in Appendix A – Calculated Accretions in the Long Canyon Creek folder in the Disaggregation tab in the file, LongCanyon_development_v1.3.xls.

4.4.2 Estimating Accretion Flows

This section describes the approach used for calculating accretions in streams and rivers downstream of MFP existing stream gage locations.

Downstream of diversions or reservoirs, the MFAR Watershed was divided into five major watercourses or accretion areas (designated A through E) and two additional watersheds, SMUD and the North Fork of the Middle Fork American River. The accretion areas were identified based on Project facility locations or by natural watershed boundaries (Map 3-2). Accretion flows in each Accretion Area were calculated by subtracting the streamflow recorded at an upstream gage from the streamflow recorded at a downstream gage. Accretion flows were calculated for the following areas:

- Middle Fork American River from French Meadows Dam to Middle Fork Interbay (recorded PoR available) (Accretion Area A)

- Middle Fork American River from Middle Fork Interbay to Ralston Afterbay (recorded PoR available from October 1, 1974 to February 6, 1986; remaining PoR calculated by Fill-In) (Accretion Area B)

- Rubicon River (including Long Canyon Creek from the North Fork and South Fork Long Canyon creek confluence to the confluence with the Rubicon River) from Hell Hole Dam to Ralston Afterbay (recorded PoR available from October 1, 1974 – September 30, 1984; remaining PoR calculated by Fill-In) (Accretion Area C)

- Middle Fork American River below Oxbow Powerhouse to the Middle Fork American River near Auburn streamflow gage (USGS No. 11433500) (recorded PoR available from October 1, 1974 – September 30, 1984; remaining PoR calculated by Fill-In) (Accretion Area D)

- North Fork and South Fork Long Canyon creeks from the headwaters to their confluence (recorded PoR available) (Accretion Area E)

- Accretions on the South Fork Rubicon between Gerle Creek and the confluence with the Rubicon River were developed by SMUD for the UARP relicensing (October 1, 1974 – September 30, 2001; remaining PoR calculated by Fill-In)

- North Fork of the Middle Fork American River from the headwater to the confluence with the Middle Fork American River near Foresthill

Distribution by Sub-watersheds

To describe the hydrology of the Middle Fork American River watershed, it was necessary to split the five accretion areas (A through E) into smaller sub-watersheds ranging from four to twelve sub-watersheds (Map 3-2). These sub-watersheds are at a sufficient level of detail to support the anticipated technical studies and the development of a water balance model.

Precipitation and Drainage Area Data

The hydrology within these sub-watersheds was developed by using the average precipitation and drainage area of each sub-watershed and distributing the measured or calculated streamflows based on the proportion of total runoff that each sub-watershed contributes to the larger accretion area. The precipitation and drainage area information used was based on a Geographic Information System (GIS) analysis performed using 10-meter resolution Digital Elevation Model (DEM) data and isohyetal data from the Oregon Climate Service website (http://www.ocs.oregonstate.edu/index.html) for the period from 1971-2001. This analysis is available on the attached CD in Appendix A – Calculated Accretions in the “GIS Info” folder.

Calculation of Accretion Flows

Accretion flows for each accretion area were calculated following two different methods: a synthetic basin method and an area/rainfall weighted method. Accretion flows in the upper watershed (Accretion Area A - Middle Fork American River from French Meadows Dam to Middle Fork Interbay and Accretion Area E - North Fork and South Fork Long Canyon creeks) are influenced by distinct periods of snowmelt and rainfall runoff. Accretion flows in the lower watershed are only influenced by rainfall runoff. The specific method used to estimate accretion flows in each Accretion Area is described below.

Middle Fork American River from French Meadows Dam to Middle Fork Interbay (Accretion Area A)

Accretion flows for the Middle Fork American River from French Meadows Dam to Middle Fork Interbay were calculated by subtracting the following two USGS gage data from the Middle Fork American River above Middle Fork Powerhouse near Foresthill gage (USGS No. 11427760):

- Middle Fork American River at French Meadows (USGS No. 11427500)
- Duncan Canyon Creek below the diversion dam near French Meadows (USGS No. 11427750)

A few daily accretion flow calculations during the low flow months resulted in negative values. In these cases, accretion flows were adjusted to match those from adjacent days. The details of this calculation are available on the attached CD in Appendix A – Calculated Accretions in the Calculations tab "FMtoInterbay_Accretion_v1.4.xls".

Distribution of Accretion Flows (Synthetic Basin Method)

The Middle Fork American River from French Meadows Dam to Middle Fork Interbay (Accretion Area A) was divided into four smaller sub-watersheds identified as A-1 through A-4 on Map 3-2. The accretion flows were distributed into the four sub-watersheds using an elevation runoff correlation with Pilot Creek and Duncan Creek. The Pilot Creek and Duncan Creek watersheds were selected because they are the only two watersheds that have a complete unimpaired hydrologic record, are similarly sized, and have runoff characteristics of both snowmelt and rainfall. Runoff (estimated in acre-feet) was determined through GIS analysis for Accretion Area A, and was estimated in 500-foot elevation bands for each sub-watershed.

The daily streamflow pattern used to disaggregate Accretion Area A monthly streamflow values was based on different multipliers determined for each sub-watershed. These multipliers were determined for each sub-watershed to create a synthetic basin that matches the runoff-elevation characteristics of the sub-watershed (A-1 through A-4). The resulting synthetic basin is the product of Pilot Creek and Duncan Creek runoff-elevation characteristics and their respective multipliers. The following calculations were used to determine the daily streamflow pattern to disaggregate monthly streamflow values:

Daily Streamflow Value = Daily Percentage * Monthly Streamflow Volume

where,

Daily Percentage = **X** * (Pilot Creek Streamflow/Pilot Creek Monthly Volume)

+ **X** * (Duncan Creek Streamflow/Duncan Creek Monthly Volume)

*X: Represents the computed multipliers and change depending upon sub-watershed.

When compared on a double mass diagram, the Middle Fork American River Accretion Area A sub-watersheds and the synthetic basins were correlated with R^2 greater than 0.53. The results are shown in Table 2.

Although this method provided suitable runoff patterns for each of the sub-watersheds, the total streamflow volume and monthly streamflow volumes were not always equivalent between the sub-watershed and the synthetic basin. To resolve this discrepancy, daily streamflows were multiplied by a scaling factor to ensure that monthly volumes between the sub-watershed and the synthetic basin were equal. Each month was given a specific scaling factor. It is important to note that although total monthly sub-watershed volumes were equal to the volumes for the entire watershed, daily volumes could differ by up to 25%.

Middle Fork American River from Middle Fork Interbay to Ralston Afterbay (Accretion Area B)

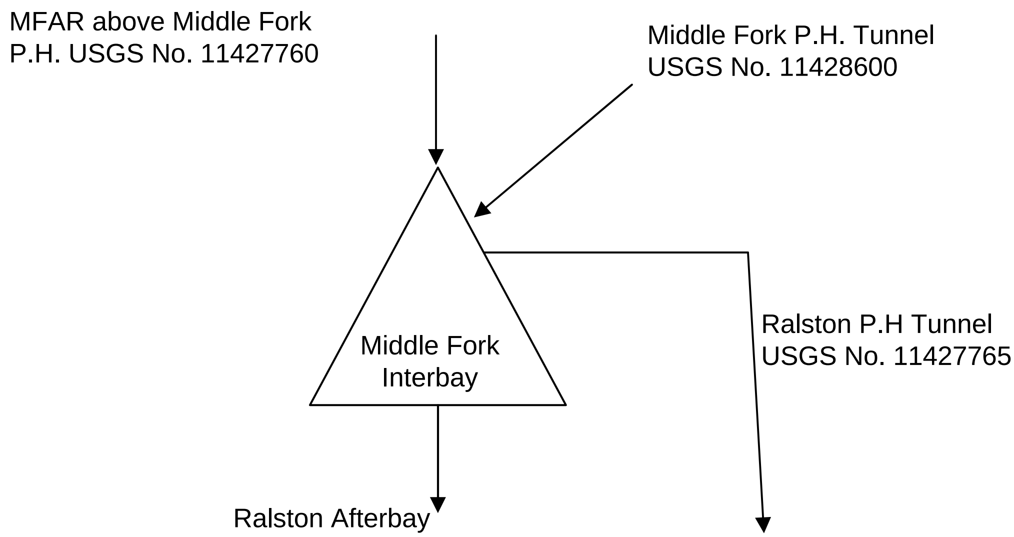
Accretion flows on the MFAR between Middle Fork Interbay and Ralston Afterbay were calculated by subtracting the following streamflow data from those at the Middle Fork American River near Foresthill (USGS Gage No. 11433300):

- Middle Fork American River below Interbay Dam near Foresthill (Calculated streamflow described below)
- North Fork of the Middle Fork American River near Foresthill (USGS No. 11433260; calculated streamflow after water year 1986)
- Rubicon River near Foresthill (USGS No. 11433200; calculated streamflow after water year 1984)
- Middle Fork Powerhouse near Foresthill (Calculated streamflow described below) and, adding
- Daily changes in storage (converted to cfs) at Ralston Afterbay (PCWA operations records)

Streamflow on the Middle Fork American River between Middle Fork Interbay and Ralston Afterbay had to be calculated instead of using the measured stream gage at Middle Fork American River below Interbay Dam near Foresthill stream gage (USGS No.11427770) because the streamflow recorded at this gage was not accurate or reliable. After 1985, the gage only measured flows less 35 cfs, thus large flows were not captured in the data. In addition, inspection of the gage data between December 1981 and June 1982 suggest that the gage was stuck and recorded only a single flow value for extended periods.

To resolve this gaging inaccuracy, PCWA calculated an alternate streamflow below Middle Fork Interbay using other nearby gages. To estimate the total flow on the Middle Fork American River between Middle Fork Interbay and Ralston Afterbay after 1985, the Ralston Tunnel flow (USGS gage No. 11427765) was subtracted from the sum of the Middle Fork Tunnel flow (USGS gage No. 11428600) and the Middle Fork American River above Middle Fork Powerhouse gage (USGS No. 11428600) flow. These calculations, including recalculation of the flow below Interbay, are available on the attached CD in Appendix C – Recalculated Powerhouse Flows.

The following diagram depicts the water balance equation used to calculate daily streamflow for MFAR between Middle Fork Interbay and Ralston Afterbay.



Middle Fork American River between Middle Fork Interbay and Ralston Afterbay Water Balance

The USGS published Middle Fork Tunnel and Ralston Tunnel flow data are based on a calculation using recorded power generation assuming constant head and constant efficiency. This calculation was determined to overestimate flow during times of low storage or low flows and to underestimate flow during times of high storage or high flow. To improve the estimates of flow through the Middle Fork, Ralston, and Oxbow powerhouses, equations were developed that accounted for changes in reservoir elevation (head) and efficiency curves based on the recorded generation. The following is a detailed explanation of the method used for recalculating the flows through the Middle Fork, Ralston, and Oxbow powerhouses.

Flow (Q, in cfs) through each powerhouse was calculated using the following equation:

$$Q = \frac{11.8 \cdot P}{E \cdot H}$$

where 11.8 is a unit conversion factor, P is power generation in kW, H is net head in feet, and E is efficiency (unit-less).

The generation records (P) were obtained from PCWA operations records. Head loss (L) was calculated as $L = k \cdot Q^2$, where k is a parameter representing overall tunnel resistance (K Value), and Q is the flow through the penstock.

K values used for each powerhouse are shown below and were provided by PCWA:

Powerhouse	K Value	Powerhouse Elevation (ft)
Middle Fork Powerhouse	0.000189	2,536
Ralston Powerhouse	0.000118	1,186
Oxbow Powerhouse	Negligible[1]	1,089

[1]Although the head losses due to friction are negligible, the difference in head between a full reservoir and an empty one are not negligible.

Net head (H) was calculated by subtracting the elevation of the powerhouse from the water surface elevation of the upstream reservoir and then subtracting the head loss. Reservoir elevation data is available and can be provided on CD as requested.

Powerhouse efficiency (E) was based on Pacific Gas & Electricity (PG&E) efficiency tests conducted in 1981. The results of the efficiency tests are shown in Figures 8 and 9. For various streamflows, the corresponding efficiency was used in an iterative process with the equation above.

The resulting estimates of streamflow through the powerhouses were improved for the full range of streamflows, which resulted in a better estimate of streamflow on the MFAR between Middle Fork Interbay and Ralston Afterbay.

The calculated streamflows were compared to complete unimpaired gage records (Duncan Canyon Creek above the diversion dam, USGS No, 1142770; Pilot Creek above Stumpy Meadows Reservoir, USGS No. 11431800; and North Fork American River at North Fork Dam, USGS No. 11427000) using regression analysis. The Pilot Creek stream gage had the best correlation due to similar basin characteristics and was used to re-compute the monthly flows to daily flows. Refer to Steps 2 through 4 (detailed in the above text) in the development of unimpaired inflows to MFAR at French Meadows Reservoir for streamflow disaggregation.

The same smoothing technique described above for the French Meadows and Hell Hole Reservoir data was used where negative accretions were estimated. The entire summer record was used to smooth large jumps between months during the low flow period between June 1 and September 30 and to replace negative accretion values. Weekly records were used to smooth negative accretion values between October 1 and May 30.

Distribution of Accretion Flows (Area/Rainfall Weighted Method)

To determine unimpaired flows at locations between flow gage data, available sub-watershed accretion flows were determined using a runoff relationship. Accretion flows were split proportionally to the total annual precipitation contributed to the accretion area by the sub-watershed using a calculated weight for each of the sub-watersheds. The sub-watershed weight (w_i) was calculated by multiplying the mean annual precipitation for the sub-watershed (p_i in inches, divided by 12 to convert to feet) by its drainage area in acres (A_i) and dividing by the mean annual volume of precipitation for the entire accretion area (P_T, in acre-feet):

$$w_i = \frac{A_i \times \frac{p_i}{12}}{(P_T)}$$

P_T was calculated as the sum of the total annual precipitation in all the sub-watersheds. After the sub-watershed weight was calculated, the unimpaired flow at intermediate locations within the larger accretion areas was calculated as:

$$Q_i = Q_T \times w_i$$

where Q_i is the daily flow for the sub-watershed, Q_T is the daily flow for the larger accretion area, and w_i is the weight calculated for that sub-watershed.

The Middle Fork American River from Middle Fork Interbay to Ralston Afterbay (Area B) was divided into four sub-watersheds identified as B-1 through B-4 on Map 3-2. Streamflows were distributed amongst the sub-watersheds according to the percentage of average annual runoff that each sub-watershed contributes to Accretion Area B. Total area of runoff and the corresponding contribution percentages per sub-watershed for Accretion Area B are shown in Table 3. These calculations are available on the attached CD in Appendix A – Calculated Accretions in the sub-basins tab InterbaytoForesthill_Accretion_v1.4.xls.

Rubicon River from Hell Hole Dam to Ralston Afterbay (Accretion Area C)

Accretion flows on the Rubicon River between Hell Hole Dam and Ralston Afterbay were calculated by subtracting the following USGS gage data from those at the Rubicon River near Foresthill (USGS No. 11433200):

- Pilot Creek below Mutton Canyon near Georgetown (USGS No.11433040)
- Rubicon River below Hell Hole Dam (USGS No. 11428800)
- Long Canyon Creek near French Meadows (USGS No. 11433100)
- South Fork Rubicon River below Gerle Creek near Georgetown (USGS No.11430000)
- Accretions on the South Fork Rubicon River upstream of the Rubicon River (SMUD, “Gerle 5”)

Because the Rubicon River near Foresthill gage was discontinued in 1984, daily values from October 1, 1984 to September 30, 2003 were estimated using Fill-In and the disaggregation method Steps 1 through 4 (see Section 4.4.1). These calculations are available on the attached CD in Appendix A – Calculated Accretions in the disaggregation tab in “RubiconHHtoRalston_Accretion_v1.1.xls”.

Distribution of Accretion Flows (Area/Rainfall Weighted Method)

The Rubicon River from Hell Hole Dam to Ralston Afterbay (Accretion Area C) was divided into 12 sub-watersheds identified as C-1 through C-12 on Map 3-2. Streamflows were distributed amongst the sub-watersheds according to the percentage of average annual runoff that each sub-watershed contributes to Accretion Area C. Total area of runoff and the corresponding contribution percentages per sub-watershed for Accretion Area C are shown in Table 4. The calculation used is available on the attached CD in Appendix A – Calculated Accretions in the Sub-basins tab in "RubiconHHtoRalston_Accretion_v1.1.xls".

Middle Fork American River below Oxbow Powerhouse at Foresthill (Accretion Area D)

Accretion flows on the Middle Fork American River below Oxbow Powerhouse (downstream of North Fork of the Middle Fork American River confluence) to the Middle Fork American River near Auburn streamflow gage (USGS No. 11433500) were calculated by subtracting the unimpaired flow at the Middle Fork American River near Foresthill gage (USGS No.11433300) from the unimpaired flow at the Auburn streamflow gage site.

Foresthill Unimpaired Streamflow

Unimpaired streamflow up to the Middle Fork American River at Foresthill streamflow gage was calculated by adding streamflow accretions to unimpaired inflows calculated at French Meadows and Hell Hole reservoirs (calculated flows), North Fork of the Middle Fork American River near Foresthill (USGS gage No. 11433260), South Fork Rubicon River below Gerle Creek near Georgetown (USGS gage No. 11430000), Duncan Canyon Creek above the diversion (USGS gage No. 11427700), Long Canyon Creek near French Meadows Reservoir (USGS gage No. 1143300 and calculated flows), and Pilot Creek above Stumpy Meadows Reservoir (USGS No. 11431800) gage locations.

Auburn Unimpaired Streamflow

The Middle Fork American River at Auburn streamflow gage (USGS No. 11433500) has collected streamflow data from October 1, 1911 to January 31, 1986. The gage on the North Fork American River at North Fork Dam (USGS Gage No. 11427000) has a PoR from October 1, 1941 to current. Data from the 24-years of common pre-Project gaged streamflow was used to develop a correlation between the two gages during the period when both gages recorded unimpaired flow. This correlation was used to extend the unimpaired streamflow record for the Middle Fork American River at Auburn from January 1, 1986 to September 30, 2003.

Distribution of Accretion Flows (Area/Rainfall Weighted Method)

The Middle Fork American River below Oxbow Powerhouse (Accretion Area D) was divided into six sub-watersheds identified as D-1 through D-6 on Map 3-2. Accretions on the Middle Fork American River below Oxbow Powerhouse were calculated by subtracting the calculated unimpaired flow at Middle Fork American River at Foresthill, from the calculated unimpaired flow at the Middle Fork American River at Auburn. This record was then smoothed using the Rock Creek Gage, calculated in SMUD's hydrology set, following Steps 2 through 4 (see Section 4.4.1). This method produced negative accretions during summer months. Further investigation of the historic USGS flow data at the MFAR at Foresthill gage and the MFAR at Auburn gage confirmed that losses in this reach were likely. This calculation is available on the attached CD in Appendix A – Calculated Accretions in the Foresthill Unimpaired tab in "MFBelowForesthill_Accretion_v1.4.xls".

Streamflows were distributed amongst the sub-watersheds according to the percentage of average annual runoff that each sub-watershed contributes to Accretion Area D. Total area of runoff and the corresponding contribution percentages per sub-watershed for Accretion Area D are shown in Table 5. This calculation is available on the attached CD in Appendix A – Calculated Accretions in the Sub-basins tab in "MFBelowForesthill_Accretion_v1.4.xls".

North Fork and South Fork Long Canyon Creeks (Accretion Area E)

Development of unimpaired flows along the North Fork and South Fork Long Canyon creeks used a combination of techniques including a water balance equation (described in Section 4.4.2) where sufficient flow records exist and the *Fill-In* method for periods of incomplete streamflow data were implemented. Streamflow data for Long Canyon near French Meadows Reservoir (USGS No. 11433100), located below the confluence of North Fork and South Fork Long Canyon creeks, covers most of the PoR for analysis (WY 1975-1992). Streamflow data for the diversion tunnels is available at the North Fork Long Canyon Creek Diversion Tunnel near Volcanoville (USGS No. 11433080) and South Fork Long Canyon Creek near Volcanoville (USGS No. 11433060). Unimpaired flows for 1974 through 1992 were calculated by adding the diverted streamflows to the Long Canyon Creek gage (USGS No. 11433100). Monthly streamflow volumes for WY 1993-2003 were calculated using *Fill-In*. The daily values were determined by disaggregating the monthly streamflow volumes.

Accretion Flows (Synthetic Basin and Area/Rainfall Weighted Methods)

Accretion flows on the North Fork and South Fork Long Canyon creeks required the use of two accretion flow methods in order to capture the pattern of rainfall runoff and snowmelt runoff in the upper portions of the Long Canyon Creek watershed. To account for both periods of runoff, a GIS analysis was performed using 10-meter Digital Elevation Models and isohyetal data from the Oregon Climate Service to calculate runoff (AF) within 500-foot elevation bands for the Duncan Creek, Pilot Creek, and Long Canyon Creek basins. A synthetic basin was created using a weighted combination of the Duncan Creek and Pilot Creek basins, similar to Accretion Area A methods. The results of the synthetic basin were compared on a double mass diagram and were correlated with an R^2 of 0.91**.** The results are shown in Table 6.

Streamflows were calculated following the same method described above for Accretion Area A. These calculations are available on the attached CD in Appendix A – Calculated Accretions in the Long Canyon folder in the Calculations tab in LongCanyon_development_v1.3.xls.

Distribution of Accretion Flow

The synthetic basin developed above was used when dividing the North Fork and South Fork Long Canyon creeks into three sub-watersheds (identified as E-1 through E-3 on Map 3-2), which capture the different periods of rainfall and snowmelt. Once the sub-watersheds were divided, the area/rainfall weighted method was used to calculate accretion flows (Map 3-2). Total area of runoff and the corresponding contribution percentages per sub-watershed for Accretion Area E are shown in Table 7. These calculations are available on the attached CD in Appendix A – Calculated Accretions in the Long Canyon folder in the Sub-basins tab of “LongCanyon_development_v1.3.xls” .

South Fork Rubicon River

The record for accretion flows on the South Fork Rubicon River was developed by SMUD for the UARP relicensing, and extends from WY 1975-2001 (the period of analysis for the SMUD relicensing). The South Fork Rubicon River accretion record was extended from October 1, 2001 to September 30, 2003 using the methods previously described above using the Fill-In method for missing unimpaired flow records. This *Fill-In* run data is available on the attached CD in Appendix E – Fill-In the Fillin_accretion_data folder.

A preliminary analysis of the data showed that SMUD’s accretions on the South Fork Rubicon River (SMUD’s “Gerle 5” accretion) were proportionally similar to the daily flow at Pilot Creek above Stumpy Meadows (USGS Gage No. 11431800) in that these systems responded similarly in years with overlapping data. The 1993 Water Year is depicted in Figure 10 as an example of the correlation in streamflow between the two systems.

North Fork of the Middle Fork American River

Recorded streamflow data for the North Fork of the Middle Fork American River near Foresthill (USGS No. 11433260) extends from August 1, 1965 to September 30, 1985. Daily values from October 1, 1985 to September 30, 2003 were estimated using the *Fill-In* data and the disaggregation methods described above. Monthly streamflow volumes and daily streamflow values were developed from data obtained at the Pilot Creek above Stumpy Meadows gage (USGS No. 11431800). The correlation in daily streamflows between the North Fork of the Middle Fork American River and Pilot Creek for water year 1983 is shown in Figure 11.

5.0 PROPOSED WATER YEAR TYPE CLASSIFICATION

The proposed water year type classification is based on the predicted unimpaired inflow (runoff) to Folsom Reservoir from the spring forecast information provided by the California Department of Water Resources Bulletin 120. Bulletin 120 is published each month from February through May (DWR 2007). The final forecast (May) determines the water year type until February of the following year. Five different water year types are proposed for the MFP:

1) Wet (W) - greater than or equal to 3.5 million acre feet (MAF)
2) Above Normal (AN) - greater than or equal to 2.6 MAF but less than 3.5 MAF
3) Below Normal (BN) - greater than or equal to 1.7 MAF but less than 2.6 MAF
4) Dry (D) - greater than or equal to 0.9 MAF to but less than 1.7 MAF
5) Critically Dry (CD) - less than 0.9 MAF

The proposed water year type classifications are based on review of the existing and unimpaired hydrologic record and are consistent with water year type classification used for the UARP. The proposed water year types for each month in the period for the hydrologic analyses for the MFP relicensing (WY 1975-2003) are shown in Table 8.

6.0 BRIEF OVERVIEW OF IMPAIRED AND UNIMPAIRED STREAMFLOWS

A complete overview of the impaired and unimpaired hydrology associated with the MFP using the method outlined in this report is available on the attached CD in Appendix G – Results. Summary statistics of the hydrology can be illustrated using the interactive spreadsheets on the CD.

The following presents a brief overview of impaired and unimpaired hydrology in rivers and streams downstream of MFP diversions.

The MFP diverts water from Duncan Creek, the Middle Fork American River, the Rubicon River, and North Fork and South Fork Long Canyon creeks altering natural flows in these rivers and streams. These flow alterations result in two general types of stream and river reaches: (1) bypass river reaches and (2) a peaking reach. The bypass reaches include the portions of these streams and rivers that are located between the MFP dams or diversions and Ralston Afterbay. These are river reaches where water is diverted for storage into French Meadows Reservoir or Hell Hole Reservoir, or diverted directly into a powerhouse (Middle Fork or Ralston powerhouse).

In the bypass reaches, there are two main patterns of flow alteration: 1) flows are altered all year long, or 2) flows are altered only during the winter/spring high flow season. In the large river bypass reaches such as the Middle Fork American River and Rubicon River flows are altered all year long. During the winter/spring season flows are reduced as water is captured by French Meadows and Hell Hole reservoirs. During the summer and fall baseflow season flow may be augmented due to required minimum flow releases from storage. In the smaller stream bypass reaches (Duncan, North Fork

Long Canyon, South Fork Long Canyon, and Long Canyon creeks) flows are altered only during the winter/spring season. The diversions on these creeks are not operated during the summer and fall base flow season. The flow in these creeks is natural during summer and fall - no storage is available to augment flow.

The peaking reach is the Middle Fork American River from downstream of Ralston Afterbay to the confluence with the North Fork American River and the North Fork American River from the confluence of Middle Fork American River downstream to the high water mark of Folsom Reservoir. In the peaking reach, flows are altered seasonally due to the timing of storage and release at French Meadows and Hell Hole reservoirs. In addition, flows in the peaking reach often fluctuate both daily and within a day as a result of releases from Oxbow Powerhouse, which is operated in conjunction with the upstream powerhouses (Ralston and Middle Fork) to meet daily power demand and provide whitewater rafting flows.

Flow accretion from the surrounding sub-watersheds occurs along the length of the bypass and peaking stream reaches. The accretions, in some cases, are large enough to transform the altered flow regimes at the top of the reaches, (e.g., just downstream of French Meadows and Hell Hole reservoirs and Duncan Creek) into a flow regime, that has a relatively natural seasonal flow pattern (high winter/spring flows and low summer/fall flows).

<u>Large River Bypass Reach Summary: Middle Fork American River (French Meadows Reservoir to Ralston Afterbay) and Rubicon River (Hell Hole Reservoir to Ralston Reservoir)</u>

- Under impaired conditions, a large portion of the streamflow is diverted for storage and power generation during all water year types. In the winter/spring season, streamflows are much lower and more stable (less variation in flow volume) than unimpaired flows.
- Summer and fall base flows (average daily flow) are sometimes higher under impaired conditions in dry and below normal water years than the unimpaired conditions.
- Annual streamflows in the bypass reaches immediately below the French Meadows and Hell Hole dams are reduced between 69 and 97 percent; actual reductions in volume are greatest in wet years and less in dry and critically dry years.
- Spills at French Meadows and Hell Hole dams tend to only occur during the wettest water years. The high streamflows that are the result of spills typically have a shorter duration than the unimpaired high flows.
- Accretions from tributaries during the winter/spring period are large compared to the re-regulated releases, resulting in a relatively natural-shaped hydrograph in the lower portion of the Rubicon River above Ralston Afterbay and in the Middle Fork American River above and below Middle Fork Interbay.

- In general, flows in the Middle Fork American River below Middle Fork Interbay mimic flows above Middle Fork Interbay. A small reduction in the magnitude of the flow typically occurs as a result of diversion from Middle Fork Interbay into Ralston Powerhouse.

Small Stream Bypass Reach Summary: Duncan Creek and Long Canyon Creek

- During most water year types, a large portion of the winter/spring river flow is diverted for storage and power generation. In the winter/spring season, streamflows are generally lower and more stable (less variation in flow volume) than unimpaired flows. The exception is during wet water years when the diversion is small relative to the streamflow. Under these conditions the resulting flow is similar to the unimpaired hydrographs.
- Summer and fall base flows are the natural flows, as water is not diverted during this time period.
- Spills from high flow events occur primarily during wet water year types, as winter/spring high flow events frequently exceed the capacity of the diversion structures.
- In the lower reach of Duncan Creek and Long Canyon Creek, flows resemble a natural-shaped hydrograph as the result of inflow from tributaries.

Peaking Reach Summary: Middle Fork American River below Oxbow Powerhouse

- The Middle Fork American River below the Oxbow Powerhouse and Ralston Afterbay Dam experiences highly variable daily flows at all times of the year, in all water year types.
- Impaired flow fluctuations are highly variable during the day as a result of MFP operations at the powerhouses.
- Average daily flows are generally lower in the winter/fall period than under unimpaired conditions due to upstream diversion to storage. During wet water years, the winter/spring hydrograph is similar in shape and magnitude to the unimpaired hydrograph. This is in part due to accretion flows (see accretion bullet below).
- During the summer/fall period, impaired flows are generally considerably higher than what would have occurred under unimpaired conditions.
- Substantial accretion occurs during the winter/spring season in the upstream portion of the peaking reach due to inflow of the North Fork of the Middle Fork American River just downstream of Ralston Afterbay. Additional accretion occurs during the winter/spring period along the length of the peaking reach, including a large contribution from the North Fork American River. The accretion flows create a relatively natural-shaped hydrograph in the peaking reach during the winter/spring period, except during the drier water year types. Accretion flow is minimal during the summer/fall period and has little effect on the summer/fall flow pattern. During the

summer/fall period, impaired flows are higher and more variable compared to the unimpaired flows as a result of Oxbow Powerhouse releases.

7.0 NEXT STEPS

This draft status report is provided to the resource agencies to facilitate the review of technical approaches proposed by PCWA for completion of the Hydrology Study Plan. The information provided in this report presents the approaches and supporting data for developing a complete impaired and unimpaired hydrologic record for the MFP. PCWA recognizes that consensus by the resource agencies on these approaches is a critical step in developing a credible, comprehensive hydrologic record that can be used to evaluate potential Project effects and future license conditions.

Once consensus is reached on the technical approach for completion of the hydrologic record and water year type classification, PCWA will conduct the hydrologic analyses outlined in the Hydrology Study Plan including:

- Provide a complete hydrologic dataset and corresponding analyses
- Perform an Indicators of Hydrologic Alteration analysis (IHA)
- Determine if additional data are needed to support the upcoming relicensing

Results of these additional hydrologic analyses will be provided to the resource agencies and stakeholders in a draft report for review and comment (60 day comment period). A final report will be distributed to the agencies and stakeholders which addresses comments received on the draft report.

8.0 REFERENCES

Alley, W. and Burns, Alan. 1983. Mixed-Station Extension of Monthly Streamflow Records. Journal of Hydraulic Engineering-ASCE. 109(10): 1272-1284. October 1983.

California Department of Water Resources (DWR). 2007. Water Conditions in California DWR Bulletin 120 for May 2007. http://cdec .water.ca.gov/snow/bulletin120.

Placer County Water Agency (PCWA). 2005. 2005-2006 Existing Environment Study Plan Package. June 17, 2005.

TABLES

Table 1. Streamflow Gages and Locations.

Gage Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
USGS Streamflow Gaging Locations							
11426190	LAKE VALLEY CN NR EMIGRANT GAP CA	39°17'56"	120°38'31"	ND	ND	10-1-1964	9-30-2003
11426500	NF AMERICAN R NR COLFAX CA	39°2'25"	120°54'6"	308	897 ft	10-1-1911	9-30-1941
11426400	N. SHIRTAIL C NR DUTCH FLAT CA	39°7'49"	120°47'44"	9.1	ND	10-1-1956	9-30-1985
11427000	NF AMERICAN R A NORTH FORK DAM CA	38°56'10"	121°1'22"	715	342 ft	10-1-1941	9-30-2003
11427200	FRENCH MEADOWS PP NR MEEKS BAY C CA	39°4'	120°24'	ND	ND	10-1-1970	9-30-2003
11427500	MF AMERICAN R A FRENCH MEADOWS CA	39°6'35"	120°28'49"	47.9	4920 ft	10-1-1951	9-30-2003
11427700	DUNCAN CYN C NR FRENCH MEADOWS CA	39°8'9"	120°28'39"	9.9	5270 ft	9-1-1960	9-30-2003
11427750	DUNCAN CYN C BL DIV DAM NR FRENCH MEADOWS CA	39°7'59"	120°28'58"	10.5	5210 ft	10-1-1964	9-30-2003
11427760	MF AMERICAN R AB MF PH NR FORESTHILL CA	39°1'31"	120°35'40"	87.8	2540 ft	9-1-1965	9-30-2003
11427765	RALSTON PH NR FORESTHILL CA	39°0'1"	120°43'23"	ND	ND	10-1-1973	9-30-2003
11427770	MF AMERICAN R BL INTERBAY DAM NR FORESTHILL CA	39°1'35"	120°36'9"	89.1	2470 ft	10-1-1965	12-19-2002
11427940	RUBICON-ROCKBOUND TUNNEL NR MEEKS BAY CA	38°59'16"	120°13'29"	ND	6533 ft	10-1-1963	9-30-2003
11427960	RUBICON R BL RUBICON LK CA	38°59'20"	120°13'20"	26.8	ND	2-27-1991	9-30-2003
11428000	RUBICON R A RUBICON SPRINGS NR MEEKS BAY CA	39°1'10"	120°14'46"	31.4	6053 ft	2-1-1910	9-30-1986
11428001	COMBINED RUBICON R-ROCKBOUND TUNNEL CA	39°1'10"	120°14'46"	31.4	ND	1-1-1964	9-30-1983

Table 1. USGS Gage Names and Locations (continued).

Gage Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
11428300	BUCK-LOON TUNNEL NR MEEKS BAY CA	39°0'17"	120°15'21"	ND	6425 ft	10-1-1963	9-30-2003
11428400	L RUBICON R BL BUCK ISLAND DAM CA	39°0'20"	120°15'20"	6	ND	10-24-1984	9-30-2003
11428600	MF PH NR FORESTHILL CA	39°1'30"	120°35'43"	ND	ND	10-1-1974	9-30-2003
11428800	RUBICON R BL HELL HOLE DAM CA	39°3'24"	120°24'25"	114	4232 ft	11-6-1965	9-30-2003
11429000	SF RUBICON R A SM NR QUINTETTE CA	38°56'54"	120°23'57"	16.1	ND	2-1-1910	6-30-1914
11429300	ROBBS PEAK PH NR KYBURZ CA	38°53'50"	120°22'38"	ND	4880 ft	10-1-1962	9-30-2003
11429340	LOON LK PH NR MEEKS BAY CA	38°58'57"	120°19'27"	ND	ND	10-1-1974	9-30-2003
11429500	GERLE C BL LOON LK NR MEEKS BAY CA	39°0'20"	120°18'52"	8	6250 ft	9-1-1962	9-30-2003
11429800	ROBBS PEAK TU NR RIVERTON CA	38°54'12"	120°22'18"	ND	ND	10-1-1962	9-30-1967
11430000	SF RUBICON R BL GERLE C NR GEORGETOWN CA	38°57'17"	120°24'2"	47.6	4970 ft	8-1-1961	9-30-2003
11430500	SF RUBICON R A MOUTH NR GEORGETOWN CA	38°58'5"	120°27'55"	56.9	ND	7-27-1956	9-30-1962
11431000	RUBICON R NR GEORGETOWN CA	38°57'30"	120°29'5"	195	3350 ft	4-1-1910	11-30-1964
11431500	GEORGETOWN DIVIDE DITCH ABOVE PILOT CREEK	38°56'18"	120°28'42"	ND	ND	10-1-1950	12-31-1961
11431800	PILOT C AB STUMPY MEADOWS RES CA	38°53'41"	120°35'2"	11.7	4280 ft	10-1-1960	9-30-2003
11432000	GEORGETOWN DIVIDE DITCH NR GEORGETOWN CA	38°54'12"	120°36'12"	ND	ND	3-29-1947	9-30-1960
11432500	PILOT C NR GEORGETOWN CA	38°54'14"	120°36'11"	15.1	4120 ft	4-1-1946	9-30-1960

Table 1. USGS Gage Names and Locations (continued).

Gage Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
11433040	PILOT C BL MUTTON CANYON NR GEORGETOWN CA	38°55'25"	120°38'27"	21.1	3760 ft	7-1-1961	9-30-2003
11433060	SF LONG CANYON C DIV TUNNEL NR VOLCANOVILLE CA	38°55'25"	102°38'27"	ND	4630 ft	10-1-1965	9-30-2003
11433065	SF LONG CYN C F REL BL DIV TU NR VOLCANOVILLE CA	39°3'4"	120°28'14"	ND	4630 ft	11-27-1988	6-11-2003
11433080	NF LONG CANYON C DIV TU NR VOLCANOVILLE CA	39°2'57"	120°28'56"	ND	4700 ft	10-1-1965	9-30-2003
11433085	NF LONG CYN C F REL BL DIV TU NR VOLCANOVILLE CA	39°2'57"	120°28'56"	ND	4700 ft	11-26-1988	6-5-2003
11433100	LONG CANYON C NR FRENCH MEADOWS CA	39°1'16"	120°30'53"	18	ND	9-1-1960	9-30-1992
11433200	RUBICON R NR FORESTHILL CA	38°59'33"	120°43'14"	315	1362 ft	10-1-1958	9-30-1984
11433212	OXBOW PH NR FORESTHILL CA	39°0'14"	120°44'44"	ND	ND	10-1-1973	9-30-2003
11433260	NF OF MF AMERICAN R NR FORESTHILL CA	39°1'27"	120°43'3"	88.9	ND	8-1-1965	9-30-1985
11433300	MF AMERICAN R NR FORESTHILL CA	39°0'22"	120°45'35"	524	1070 ft	10-1-1958	9-30-2003
11433400	CANYON C NR GEORGETOWN CA	38°56'3"	120°52'21"	12.5	ND	7-1-1966	10-10-1979
11433420	MAINE BAR CANYON C NR GREENWOOD CA	38°55'34"	120°56'51"	0.8	ND	10-1-1972	9-30-1986
11433500	MF AMERICAN R NR AUBURN CA	38°55'5"	121°0'51"	614	552 ft	10-1-1911	1-31-1986
11433799	COMB FLOW N FK AMERICAN R + M FK AMERICAN CA	38°52'20"	121°3'18"	ND	ND	10-1-1973	9-30-1981
11433800	NF AMERICAN R BL AUBURN DAMSITE NR AUBURN CA	38°52'20"	121°3'18"	973	ND	5-11-1972	2-6-1986
11434000	NF AMERICAN R A RATTLESNAKE BAR CA	38°48'50"	121°5'35"	996	344 ft	10-1-1930	3-31-1955

Table 1. USGS Gage Names and Locations (continued).

Gage Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
Sacramento Municipal Utility District Gages							
SMUD01	UNIMPAIRED Rubicon River below Rubicon Reservoir	ND	ND	ND	ND	10-1-1974	9-30-2001
SMUD02	UNIMPAIRED Little Rubicon River at Buck Island Reservoir	ND	ND	ND	ND	10-1-1974	9-30-2001
SMUD03	UNIMPAIRED Gerle Creek at Loon Lake	ND	ND	ND	ND	10-1-1974	9-30-2001
SMUD04	UNIMPAIRED Gerle Creek at Gerle Creek Reservoir	ND	ND	ND	ND	10-1-1974	9-30-2001
SMUD05	UNIMPAIRED SF Rubicon River at Robbs Peak Diversion Dam	ND	ND	ND	ND	10-1-1974	9-30-2001
SMUD06	ACCRETION Gerle Creek above Basin Creek	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD07	ACCRETION Gerle Creek above SF Rubicon excl Gerle Creek Abv Gerle Res	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD08	ACCRETION Gerle Creek at Gerle Reservoir	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD09	ACCRETION Gerle Creek below Barts & Deller Creek	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD10	ACCRETION Gerle Creek below Jerret Creek excl inflow to Loon	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD11	ACCRETION Gerle Creek below Rocky Basin Creek	N/A	N/A	ND	ND	10-1-1974	8-30-2001
SMUD12	ACCRETION Little Rubicon River outflow from Rockbound Lake (excluding diversions)	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD13	ACCRETION Rubicon River at Rubicon Springs	N/A	N/A	ND	ND	10-1-1974	9-29-2001
SMUD14	ACCRETION Rubicon River below Little Rubicon	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD15	ACCRETION Rubicon River blw Miller Creek excluding above Rubicon Springs	N/A	N/A	ND	ND	10-1-1974	9-30-2001

Table 1. USGS Gage Names and Locations (continued).

Gage Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
SMUD16	ACCRETION SF Rubicon u/s of Rubicon River	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD17	UNREGULATED Rubicon River Inflow to Rubicon Reservoir	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD18	UNREGULATED Highland Creek Inflow to Rockbound Reservoir (Inflow at Rockbound Reservoir)	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD19	UNREGULATED Ellis Creek Inflow to Loon Lake	N/A	N/A	ND	ND	10-1-1974	9-30-2001
SMUD20	UNREGULATED SF Rubicon Inflow to Robbs Reservoir	N/A	N/A	ND	ND	10-1-1974	9-30-2001

ND- No data available
N/A- Not applicable

Table 2. Middle Fork American River from French Meadows Dam to Middle Fork Interbay (Accretion Area A) Elevation Runoff Profile.

Sub-watershed A-1

Pilot Creek Multiplier: 0.61
Duncan Creek Multiplier: 0.00 R^2=0.60

Elevation (ft)	A-1 Runoff (AF)	Duncan Creek (AF)	Pilot Creek (AF)	Synthetic Basin (AF)
4,000-4,500	3,987	0	1,701	1,038
4,500-5,000	4,459	0	14,287	8,715
5,000-5,500	4,693	373	12,126	7,397
5,500-6,000	271	4,997	7,326	4,469

Sub-watershed A-2

Pilot Creek Multiplier: 0.57
Duncan Creek Multiplier: 0.28 R^2=0.74

Elevation (ft)	A-2 Runoff (AF)	Duncan Creek (AF)	Pilot Creek (AF)	Synthetic Basin (AF)
4,000-4,500	4,620	0	1,701	970
4,500-5,000	6,095	0	14,287	8,143
5,000-5,500	5,695	373	12,126	7,016
5,500-6,000	5,430	4,997	7,326	5,575
6,000-6,500	1,156	13,574	417	4,038

Sub-watershed A-3

Pilot Creek Multiplier: 0.73
Duncan Creek Multiplier: 0.70 R^2=0.53

Elevation (ft)	A-3 Runoff (AF)	Duncan Creek (AF)	Pilot Creek (AF)	Synthetic Basin (AF)
4,000-4,500	2,902	0	1,701	1,242
4,500-5,000	8,990	0	14,287	10,429
5,000-5,500	16,323	373	12,126	9,113
5,500-6,000	14,793	4,997	7,326	8,846
6,000-6,500	3,323	13,574	417	9,806
6,500-7,000	960	12,182	0	8,527
7,000-7,500	331	1,512	0	1,058

Table 2. Middle Fork American River from French Meadows Dam to Middle Fork Interbay (Accretion Area A) Elevation Runoff Profile (continued).

Sub-watershed A-4

Pilot Creek Multiplier: 0.325

Duncan Creek Multiplier: 0.035 R^2=0.82

Elevation (ft)	A-4 Runoff (AF)	Duncan Creek (AF)	Pilot Creek (AF)	Synthetic Basin (AF)
4,000-4,500	330	0	1,701	553
4,500-5,000	2,677	0	14,287	4,643
5,000-5,500	5,402	373	12,126	3,954
5,500-6,000	3,052	4,997	7,326	2,556
6,000-6,500	375	13,574	417	611

Table 3. Middle Fork American River from Middle Fork Interbay to Ralston Afterbay (Accretion Area B) Runoff Contribution by Sub-watershed.

	Accretion Area B	B-1	B-2	B-3	B-4
Runoff (AF)	90,269	1,783	15,199	15,641	57,645
Percentage	100	1.98	16.84	17.33	63.85

Table 4. Rubicon River from Hell Hole Dam to Ralston Afterbay (Accretion Area C) Runoff Contribution by Sub-watershed.

	Accretion Area C	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-10	C-11	C-12
Runoff (AF)	338,228	12,667	5,377	45,401	29,828	26,108	32,476	49,660	35,836	25,724	32,097	43,054
Percentage	100	3.74	1.59	13.42	8.82	7.72	9.6	14.68	10.59	7.6	9.49	12.72

Table 5. Middle Fork American River below Oxbow Powerhouse at Foresthill (Accretion Area D) Runoff Contribution by Sub-watershed.

	Accretion Area D	D-1	D-2	D-3	D-4	D-5	D-6	D-7
Runoff (AF)	232,974	60,558	12,779	41,261	50,065	31,862	22,621	13,828
Percentage	100	25.99	5.48	17.71	21.49	13.68	9.71	5.94

Table 6. North Fork and South Fork Long Canyon Creeks (Accretion Area E) Elevation Runoff Profile.

Pilot Creek Multiplier: 1.13

Duncan Creek Multiplier: 0.43 R^2=0.91

Elevation (ft)	Long Canyon Creek Runoff (AF)	Duncan Creek Runoff (AF)	Pilot Creek Runoff (AF)	Synthetic Basin Runoff (AF)
4,000-4,500	4,122	0	1,701	1,922
4,500-5,000	14,798	0	14,287	16,144
5,000-5,500	13,570	373	12,126	13,863
5,500-6,000	12,415	4,997	7,326	10,427
6,000-6,500	8,537	13,574	417	6,308
6,500-7,000	2,186	12,182	0	5,238
7,000-7,500	70	1,512	0	650

Table 7. North Fork and South Fork Long Canyon Creeks (Accretion Area E) Runoff Contribution by Sub-watershed.

	Accretion Area E	E-1	E-2	E-3
Runoff (AF)	55,685	23,340	11,153	21,192
Percentage	100	41.91	20.03	38.06

Table 8. Water Year Type Classification[1] for Water Years 1975–2003.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	---	---	---	---	---	---	---	---	---	W	W	W
1975	W	D	BN	BN	AN	AN	AN	AN	AN	AN	AN	AN
1976	AN	D	D	CD	CD	CD	CD	CD	CD	CD	CD	CD
1977	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD
1978	CD	AN	AN	AN	W	W	W	W	W	W	W	W
1979	W	D	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN
1980	BN	AN	W	W	W	W	W	W	W	W	W	W
1981	W	D	D	D	D	D	D	D	D	D	D	D
1982	D	W	W	W	W	W	W	W	W	W	W	W
1983	W	W	W	W	W	W	W	W	W	W	W	W
1984	W	W	W	W	W	W	W	W	W	W	W	W
1985	W	BN	BN	BN	D	D	D	D	D	D	D	D
1986	D	BN	W	W	W	W	W	W	W	W	W	W
1987	W	D	D	D	CD	CD	CD	CD	CD	CD	CD	CD
1988	CD	BN	D	CD	CD	CD	CD	CD	CD	CD	CD	CD
1989	CD	D	D	BN	BN	BN	BN	BN	BN	BN	BN	BN
1990	BN	D	D	D	D	D	D	D	D	D	D	D
1991	D	CD	CD	D	D	D	D	D	D	D	D	D
1992	D	D	D	D	D	D	D	D	D	D	D	D
1993	D	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN
1994	AN	D	D	D	CD	CD	CD	CD	CD	CD	CD	CD
1995	CD	W	AN	W	W	W	W	W	W	W	W	W
1996	W	BN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN
1997	AN	W	W	W	W	W	W	W	W	W	W	W
1998	W	AN	W	W	W	W	W	W	W	W	W	W
1999	W	AN	W	AN	AN	AN	AN	AN	AN	AN	AN	AN
2000	AN	BN	AN	AN	AN	AN	AN	AN	AN	AN	AN	AN
2001	AN	D	D	D	D	D	D	D	D	D	D	D
2002	D	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN
2003	BN	BN	BN	D	BN	BN	BN	BN	BN	---	---	---

[1] Water Year Type definitions: Wet (W) = greater than or equal to 3.5 million acre feet (MAF) / Above Normal (AN) = greater than or equal to 2.6 MAF but less than 3.5 MAF / Below Normal (BN) = greater than 1.7 MAF or equal to but less than 2.6 MAF / Dry (D) = greater than 0.9 MAF or equal to but less than 1.7 MAF / Critically Dry (CD) = less than 0.9 MAF

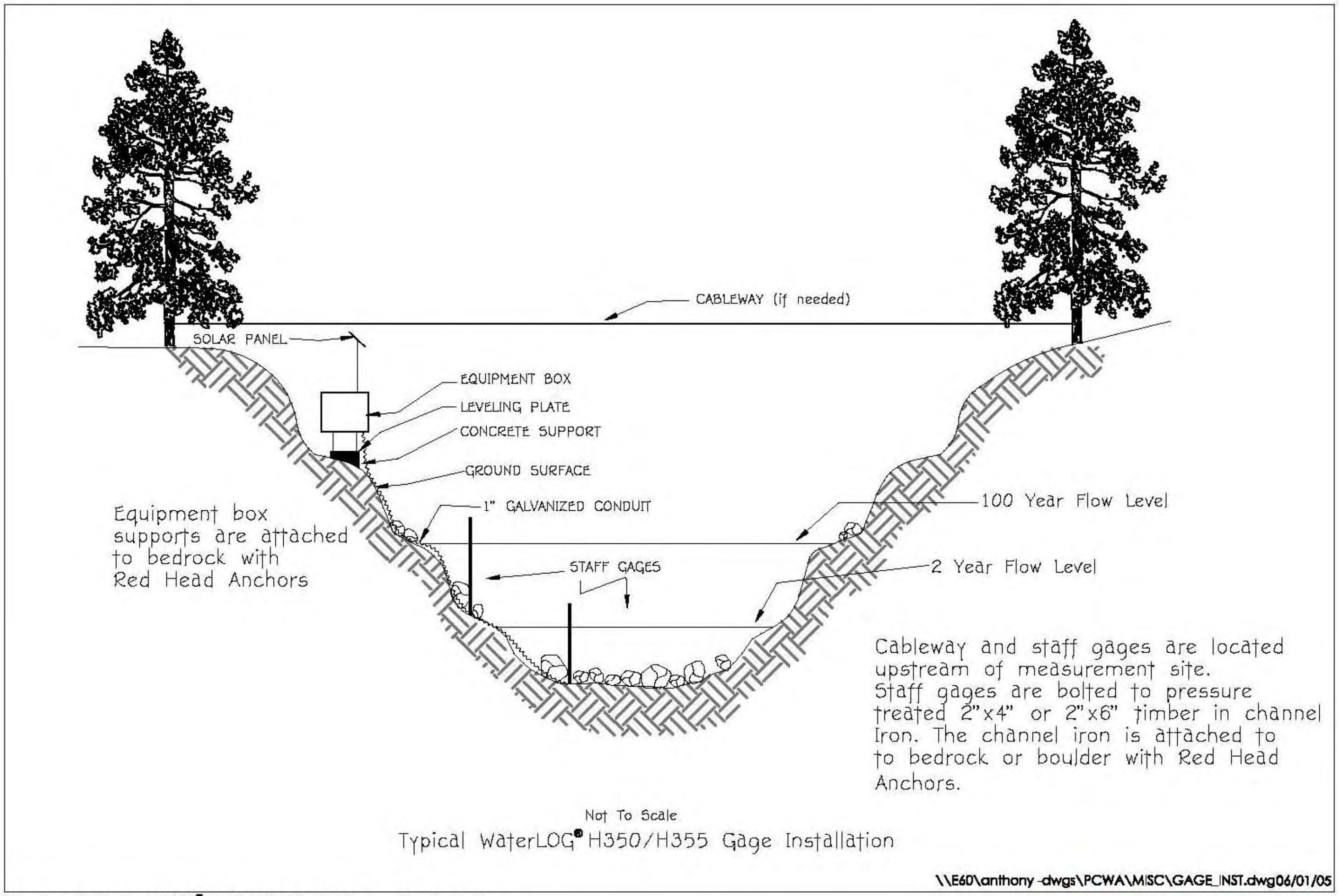
Table 9. Average Daily Flows from Selected Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

		Duncan Creek				Middle Fork American River									
		At Arc 800.804		At Arc 804.806		At Arc 530.802		At Arc 806.810		At Arc 810.812		At Arc 855.857*		At Arc 866.868*	
Water Year	Season	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired
1982	Oct-Mar	56	97	146	187	49	399	290	653	230	870	3,194	3,721	3,450	3,977
Wettest	Apr-Jun	61	156	169	264	202	603	598	1,087	504	1,247	3,834	4,340	5,367	6,021
	Jul-Sept	3	7	15	19	8	68	97	99	32	124	952	381	1,234	386
1986	Oct-Mar	57	90	136	169	84	346	313	581	373	783	2,567	3,271	2,600	3,305
Typical Wet	Apr-Jun	11	66	50	106	35	325	120	456	139	571	1,362	1,684	1,363	1,685
	Jul-Sept	15	42	6	6	9	31	22	41	33	50	781	192	781	192
1999	Oct-Mar	12	31	56	75	13	136	132	252	47	349	1,548	1,541	1,892	1,885
Above Normal	Apr-Jun	19	123	65	169	164	482	271	682	37	862	1,586	2,575	1,405	2,395
	Jul-Sept	3	3	7	8	10	35	24	47	23	57	774	220	727	173
2003	Oct-Mar	13	40	58	85	12	141	114	258	34	355	842	1,100	932	1,190
Below Normal	Apr-Jun	16	93	85	162	12	374	169	587	42	771	1,579	2,467	1,650	2,508
	Jul-Sept	2	2	8	8	10	17	28	32	24	43	713	159	699	145
2001	Oct-Mar	6	10	17	21	11	43	42	73	23	99	597	416	679	498
Dry	Apr-Jun	11	48	36	74	11	188	69	278	23	358	620	1,008	591	979
	Jul-Sept	1	1	1	1	11	6	13	8	16	9	556	70	552	66
1977	Oct-Mar	2	2	6	6	4	11	16	20	11	28	176	111	180	115
Critically Dry	Apr-Jun	4	12	10	18	4	80	19	102	18	121	118	360	118	360
	Jul-Sept	0	0	2	2	3	10	7	14	6	17	217	42	225	50

		Rubicon River				North Fork Long Canyon Creek		South Fork Long Canyon Creek		Long Canyon Creek	
		At Arc 540.832*		At Arc 840.842*		At Arc 817.819		At Arc 820.822		At Arc 825.828	
Water Year	Season	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired	Impaired	Unimpaired
1982	Oct-Mar	98	685	694	1,281	28	32	48	56	132	145
Wettest	Apr-Jun	266	897	1,372	2,029	34	34	58	60	153	155
	Jul-Sept	14	82	239	137	1	1	2	2	5	5
1986	Oct-Mar	101	525	801	1,225	22	27	11	17	108	121
Typical Wet	Apr-Jun	43	593	179	730	6	8	10	17	28	37
	Jul-Sept	22	36	62	76	1	1	1	1	58	44
1999	Oct-Mar	18	183	335	500	4	14	6	24	33	61
Above Normal	Apr-Jun	19	869	253	1,103	4	21	7	42	33	84
	Jul-Sept	23	39	69	85	1	1	1	1	3	3
2003	Oct-Mar	18	214	156	353	3	12	5	16	18	39
Below Normal	Apr-Jun	46	642	379	975	3	21	6	38	41	91
	Jul-Sept	21	11	62	52	1	1	1	1	3	3
2001	Oct-Mar	16	73	84	141	2	4	4	6	11	15
Dry	Apr-Jun	17	308	102	393	3	9	5	17	12	30
	Jul-Sept	22	6	41	25	0	0	0	0	1	1
1977	Oct-Mar	7	17	25	35	1	1	1	1	3	3
Critically Dry	Apr-Jun	8	164	22	178	1	1	2	4	5	6
	Jul-Sept	7	8	10	12	0	0	0	0	0	0

Abbreviations: MFAR = Middle Fork American River NFAR = North Fork American River NFLC = North Fork Long Canyon Creek SFLC = South Fork Long Canyon Creek
RR = Rubicon River LC = Long Canyon PH = Powerhouse
* Calculated flows impaired by SMUD.

FIGURES



Typical WaterLOG® H350/H355 Gage Installation.

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS

Figure 1. A Typical Cross Section of a Streamflow Gage Installation.

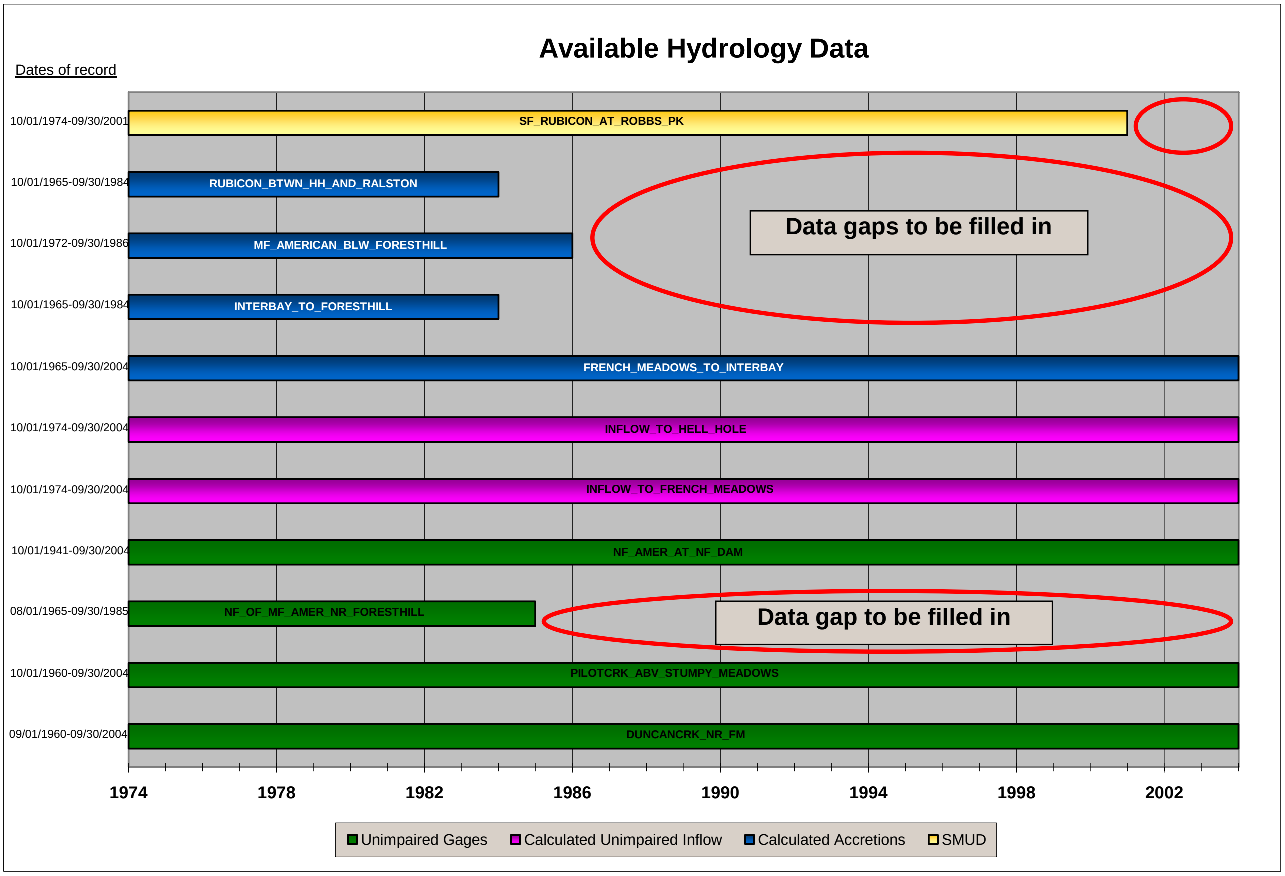


Figure 2. Hydrologic Dataset for Project Streams.

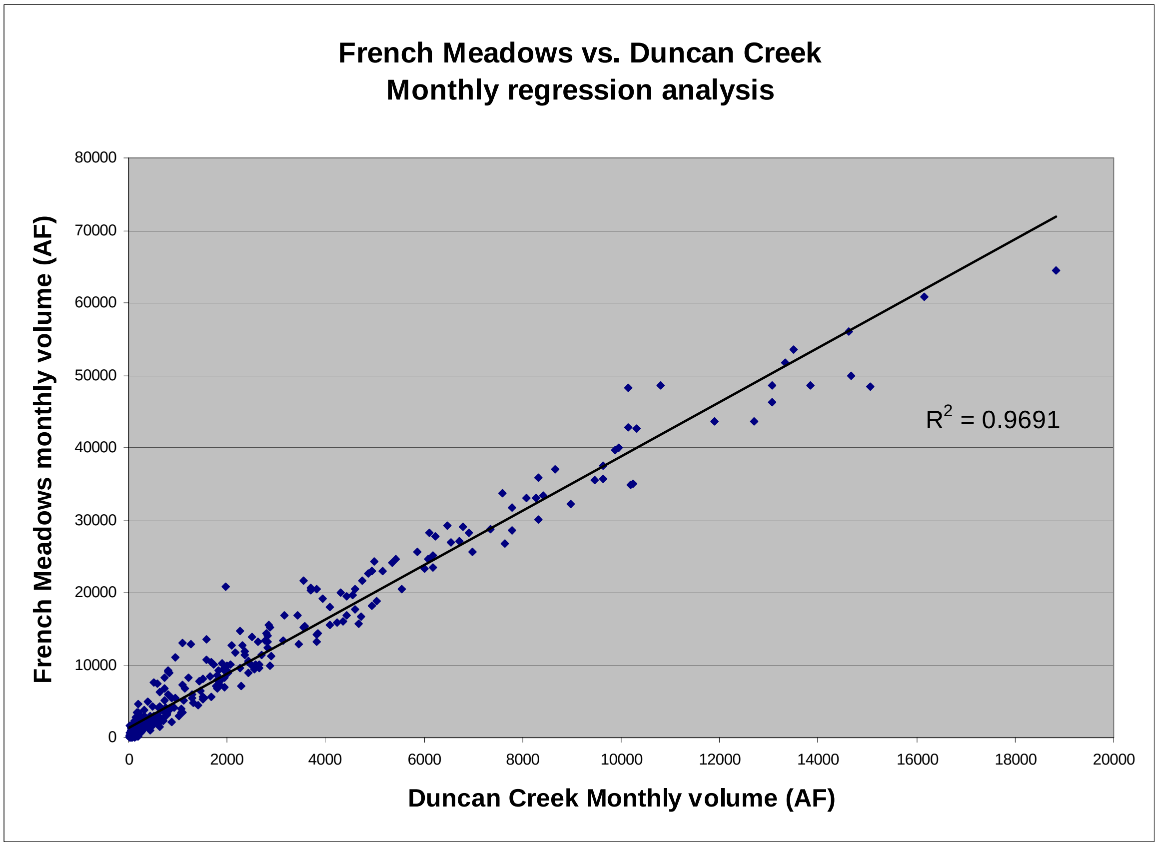


Figure 3. French Meadows and Duncan Creek Monthly Regression Results.

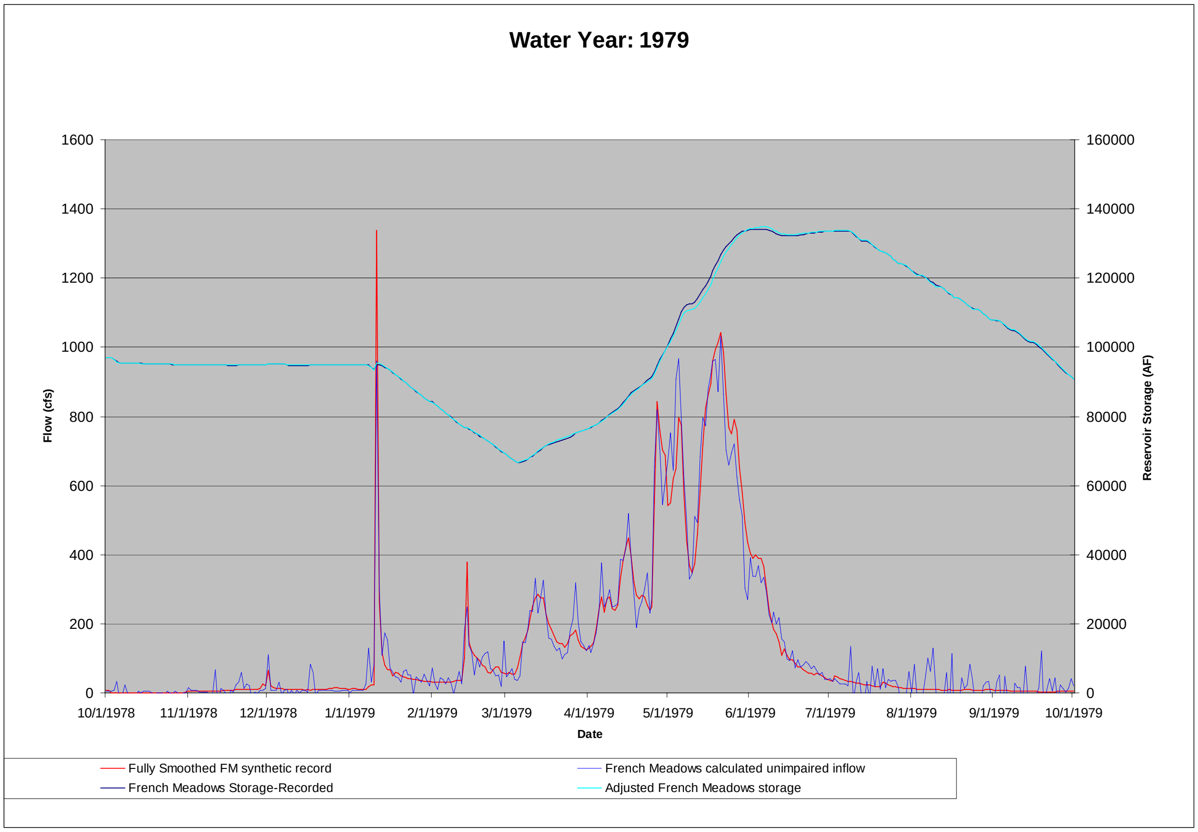


Figure 4. Unimpaired and Impaired French Meadows Reservoir Inflow during Water Year 1979.

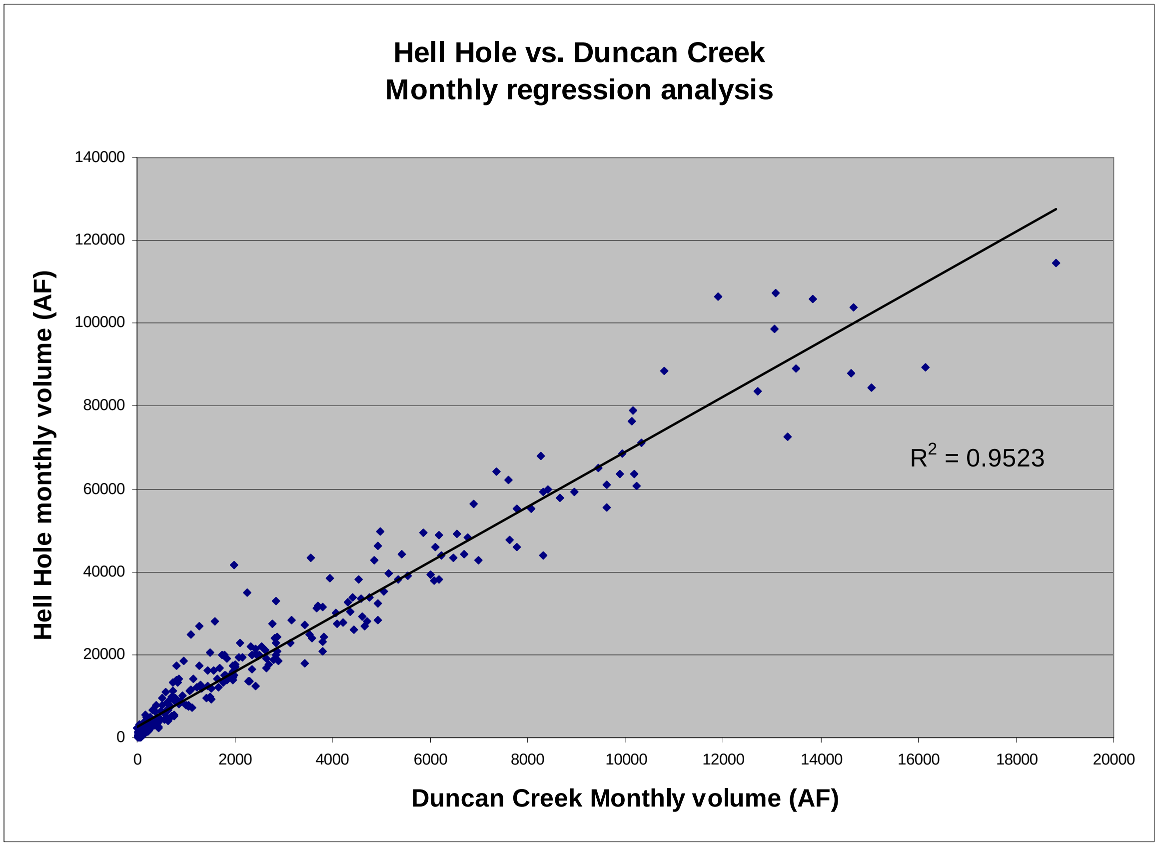


Figure 5. Hell Hole and Duncan Creek Monthly Regression Results.

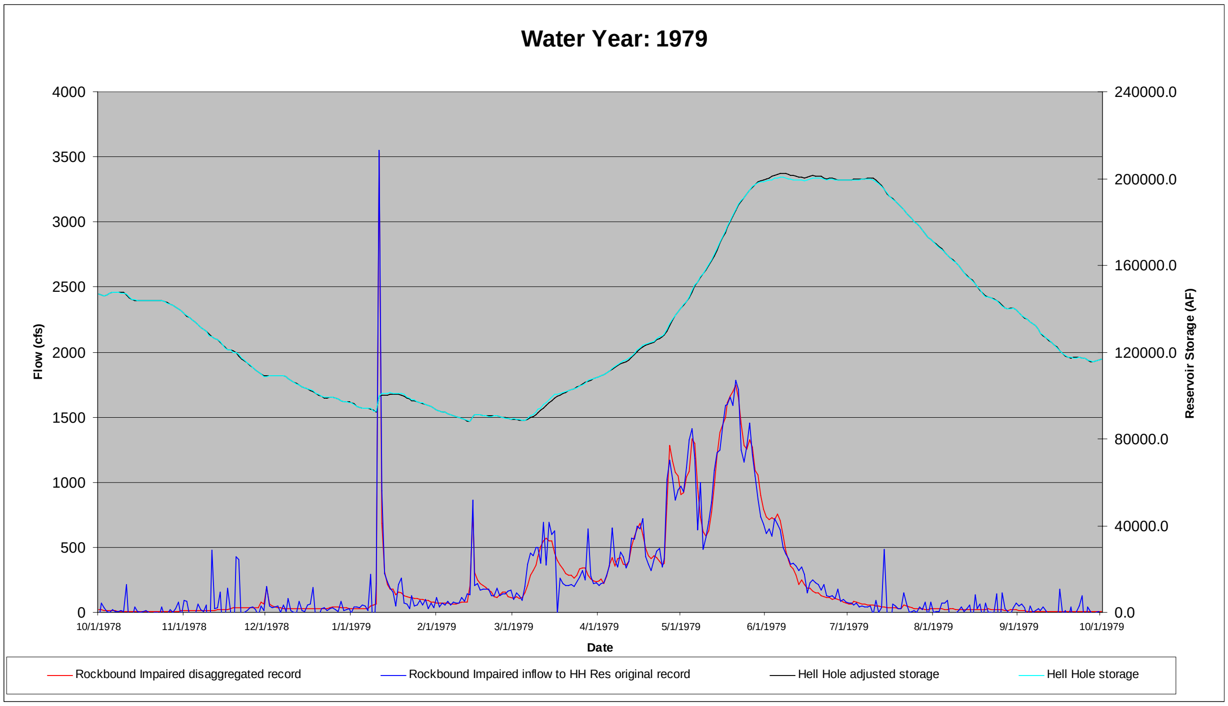


Figure 6. Unimpaired and Impaired Hell Hole Reservoir Inflow during Water Year 1979.

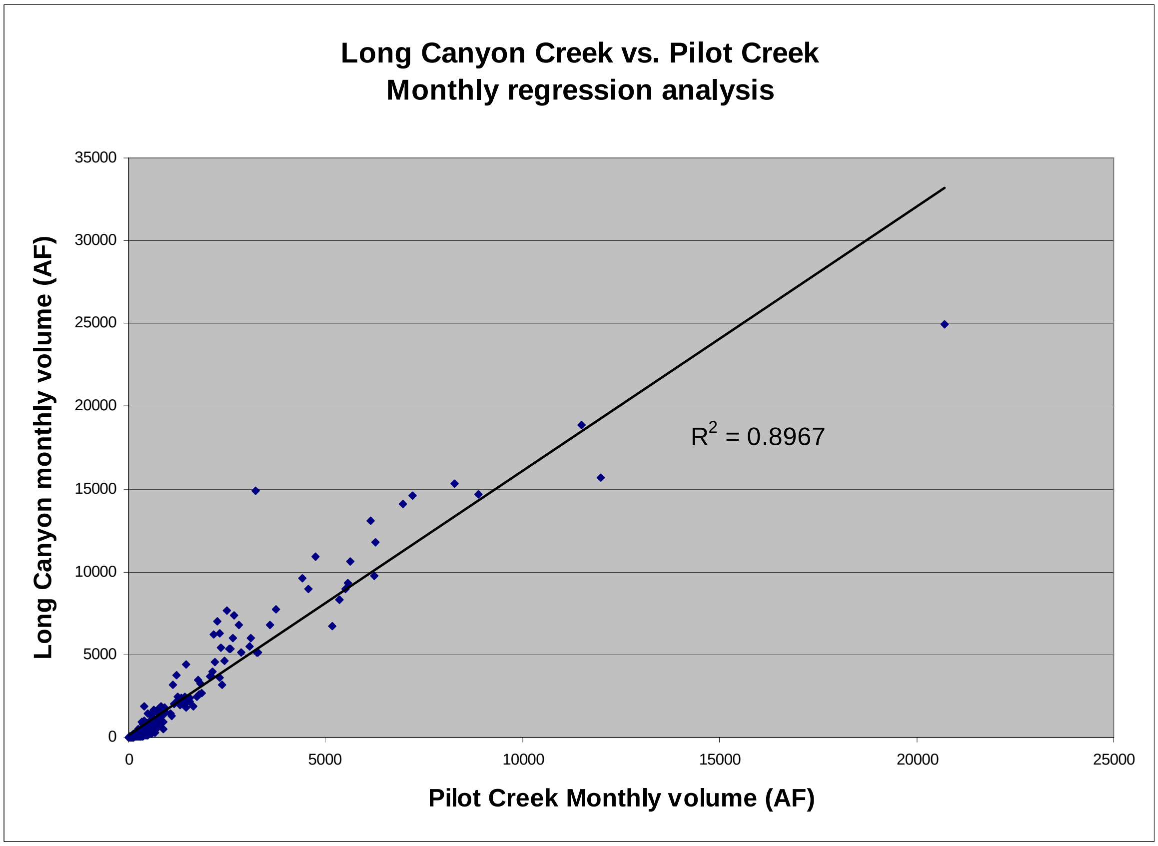


Figure 7. Long Canyon Creek and Pilot Creek Monthly Regression Results.

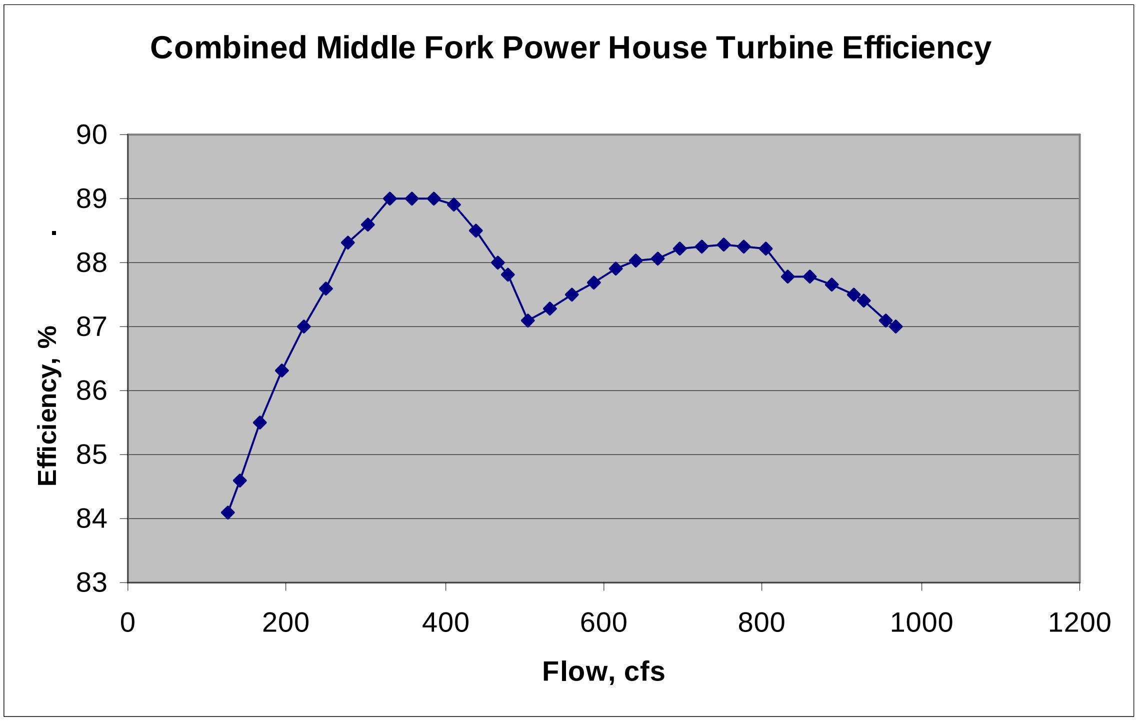


Figure 8. Middle Fork Powerhouse Efficiency Curve.

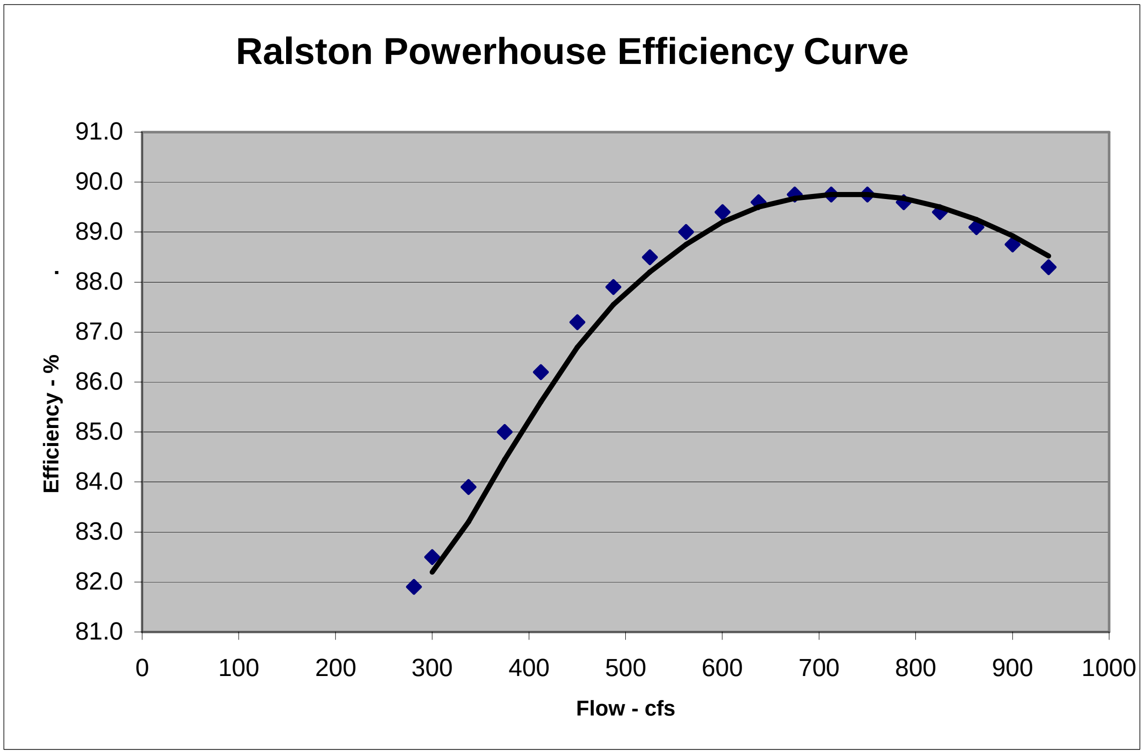


Figure 9. Ralston Powerhouse Efficiency Curve.

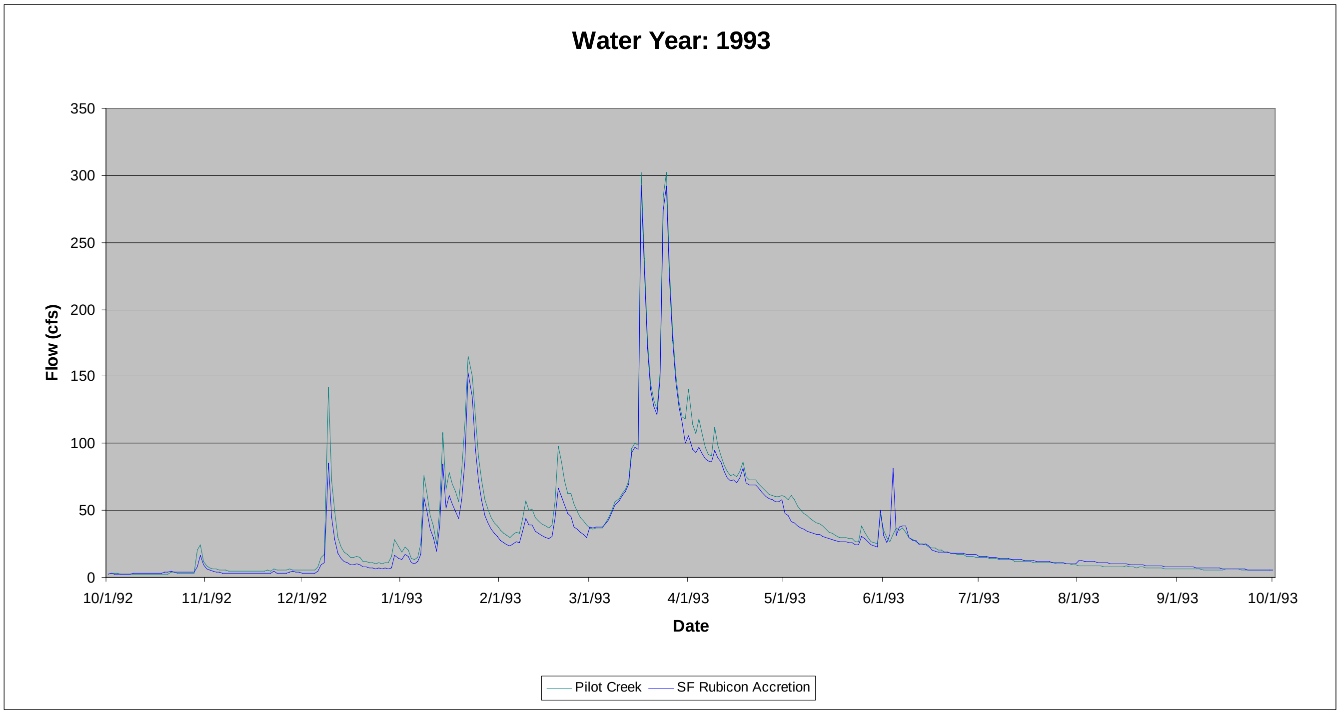


Figure 10. Correlation of Daily Streamflows at Pilot Creek (USGS Gage No. 11431800) with SMUD's South Fork Rubicon River Accretion Streamflows for Water Year 1993.

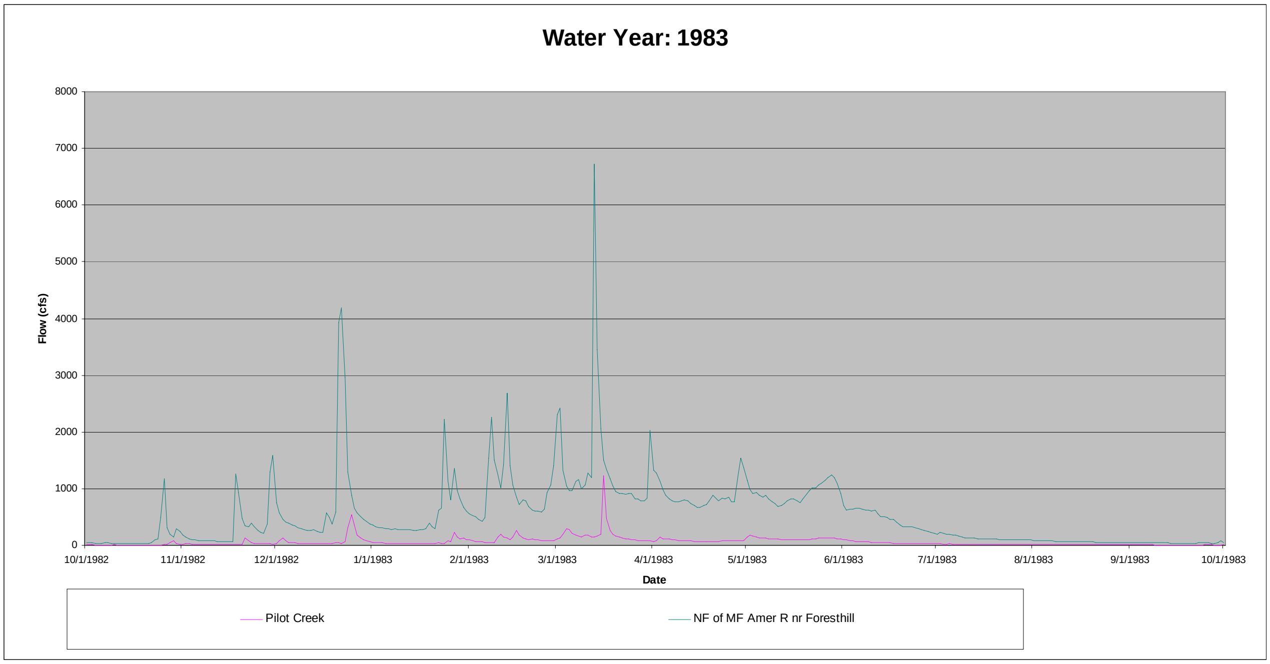


Figure 11. Correlation of Daily Streamflows at Pilot Creek (USGS Gage No. 11431800) with North Fork of the Middle Fork American River (USGS Gage No. 11433260) Streamflows for Water Year 1983.

MAPS

APPENDICES

PCWA MFP Hydrology CD

The data used to develop the hydrology study report is organized into the following Appendices folders:

Appendix A. The Calculated Accretions folder contains spreadsheets used to develop the accretions to areas: (A) (French Meadows to Interbay), (B) (Interbay to Foresthill), (C) (Rubicon River from Hell Hole to Foresthill), (D) (Middle Fork American below Foresthill), and (E) (Long Canyon Creek).

Appendix B. The Calculated Inflows folder contains the spreadsheets used to calculate the Duncan Creek, French Meadows, and Hell Hole inflows.

Appendix C. The Recalculated Powerhouse Flows folder contains spreadsheets used to develop flow through the powerhouses based on generation records.

Appendix D. The USGS Data and Reservoir Elevations folder contains the USGS gage records in a HEC DSS file and reservoir elevations in a spreadsheet.

Appendix E. The Fill-In folder contains the files used to estimate the missing data within the available records.

Appendix F. The Maps folder contains two maps illustrating the accretion areas and the proposed model schematic (labeled, Map 3-3). These maps were used for reference when developing the hydrology.

Appendix G. The Results folder contains both HEC DSS files and a spreadsheet summarizing all the hydrology data. Impaired and unimpaired hydrology spreadsheets are also included.

This supporting data is available on CD and provided upon request.