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

DRAFT

2005 HYDROLOGY

STUDY STATUS REPORT

Prepared for:

Placer County Water Agency
144 Ferguson Road
Auburn, CA 95604

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1.0 INTRODUCTION

This report provides an update on the status of the early hydrology studies being conducted in association with 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 early 2006 following the approach outlined in the Hydrology Study Plan contained in PCWA's 2005-2006 Proposed Existing Environment Study Plan Package (Study Plan Package), dated June 17, 2005.

The development of a complete hydrology record for the MFP, accepted by stakeholders, that characterizes both existing (Project) and unimpaired flows is essential for evaluating potential effects of on-going operations of the Project and developing new license conditions. However, a complete hydrologic record is not available at this time to accurately characterize either the existing or unimpaired hydrology in all river/stream reaches influenced by the MFP. Therefore, the current hydrologic data needs to be supplemented by "filling in" missing data at existing flow gages, calculating unimpaired flows downstream of Project facilities, and determining accretion flows between existing gaging locations. Several approaches need to be implemented to augment the current hydrologic data due to differences in study objectives and data availability, both temporally and spacially.

The purpose of this status report is to summarize PCWA's progress on characterizing the existing and unimpaired hydrology in the vicinity of the MFP. Specifically, this status report: (1) summarizes the existing hydrology data that has been compiled to date; (2) presents recommendations to the resource agencies regarding the proposed period of record for hydrologic analysis; and (3) recommends technical approaches for augmenting the current hydrologic data. These recommendations are based on an extensive review of the existing hydrologic data and evaluation of different analytical approaches.

The goal of distributing this status report is to provide the resource agencies with information regarding the existing hydrologic data and proposed approaches for supplementing the existing hydrologic data. PCWA would like to discuss the merits of these approaches or any proposed alternatives. Once agreement is reached, PCWA will complete the analyses outlined in the Study Plan Package and provide the report and data files to the agencies for review and comment.

2.0 STUDY OBJECTIVES

The Hydrology Study Plan identified eight study objectives. Of these, three are discussed in detail in this report, as follows:

- Assemble the existing hydrologic data available in the Project vicinity into a comprehensive database;

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- Install or reinstall up to eight new flow gages, pending an access investigation; and
- Select the period of record for analysis of Project and unimpaired hydrology.

This report also provides a detailed description of the approaches that could be used to fill in data gaps, unimpair the Project hydrology, and address accretion flows. Preliminary results are provided in this report and on the enclosed CD for consideration by the resource agencies.

The remaining study objectives require a complete hydrologic record to complete. These objectives will be addressed shortly after agreement is reached regarding the technical approaches to be used to supplement the hydrologic data set. The remaining study objectives include:

- Select a preliminary water-year type classification for the watershed, in consultation with the resource agencies;
- Describe the Project and unimpaired hydrology through a series of hydrologic analyses;
- Perform an Indicators of Hydrologic Alteration (IHA) Analysis;
- Determine if additional data are needed to support the upcoming relicensing; and
- Provide a complete hydrologic data set and corresponding analyses to support the geomorphology, riparian and aquatic habitat, and water temperature studies.

PCWA's plan for completing each of these objectives is discussed under Next Steps (Section 4.0).

3.0 DEVELOPMENT OF A COMPLETE HYDROLOGIC RECORD

The Hydrology Study Plan described the type of hydrologic data currently available for the streams and rivers in the vicinity of the MFP. In addition, it identified basic methods that could be used to unimpair the existing hydrologic data set. This report builds on the information presented in the Study Plan and includes more detailed information regarding the following topics:

- Collection and Compilation of Existing Stream Flow and Storage Data
- Augmentation of Existing Hydrologic Data through Installation of New Gages
- Selection of the Period of Record for Analysis
- Approach for Filling in Data Gaps

- Approach for Developing Unimpaired Hydrology Downstream of Project Facilities
- Approach for Estimating Accretion Flows between Stream Gages

The information presented in this report is supported by the preliminary results contained on the accompanying CD.

3.1 COLLECTION AND COMPILATION OF EXISTING STREAM FLOW AND STORAGE DATA

Data from U.S. Geological Survey (USGS) gages in the Middle Fork American River Watershed was collected and compiled into a database. A complete list of the gages for which data are available is included as Table 1. Map 1 shows the locations of the numbered USGS gages in the watershed, their status if discontinued, and the locations where PCWA plans to install or re-install gages to supplement the existing flow data. In addition, gage station locations associated with the Georgetown Public Utility District's (GPUD's) Stumpy Meadows Reservoir and with the Sacramento Municipal Utility District's (SMUD's) Upper American River Project (UARP) are shown on Map 1 for reference. PCWA has obtained pertinent flow data from SMUD, including existing flow records, estimates of unimpaired flows at a number of locations and calculated accretion flows.

PCWA developed a central database that includes all of the flow data. This database is accessible to the resource agencies and public via the Internet. The URL for accessing these data has changed from the provisional www.ecorphydro.com site mentioned in the 2005 Study Plan. PCWA, USGS and SMUD flow data are now available at http://www.pcwamfpdata.net and are also provided on the enclosed CD. The Internet site includes gage numbers, locations, watershed size and period of records. In addition, maps and downloadable data reports are available. This database will be updated through 2010 as described in the Hydrology Study Plan as data becomes available from the USGS. As the data are used to develop hydrology, errors and spurious data will be corrected, and the corrected data added to the database. Data that have been corrected or changed will be noted/flagged in the database. Because multiple datasets are available in some locations, the PCWA data website will include the data in which PCWA is most confident (generally USGS data). If data quality is questionable, PCWA will consult with the entities that supplied the data and resource agencies when assembling the dataset to be used for the relicensing effort. Updates of the data will be provided to the resource agencies on CD.

3.2 AUGMENTATION OF THE EXISTING HYDROLOGIC DATA THROUGH INSTALLATION OF NEW GAGES

To augment the existing hydrologic data set, PCWA plans to install new gages and to re-install some currently non-operational gages, and use the data to verify the unimpaired hydrology before technical studies are completed. As stated in the Hydrology Study Plan, technical studies and analyses are anticipated to be completed by 2009. PCWA evaluated access conditions associated with each of the sites identified in the Hydrology Study Plan, in coordination with the resource agencies. Upon inspection, seven of the eight gages proposed in the Hydrology Study Plan were determined to have sufficient access to allow installation. Special-use permits for installation of the gages were obtained from the Tahoe and Eldorado National Forests in late 2005. Map 1 shows the locations of the seven proposed gages. A typical cross section of a flow gage installation is provided in Figure 1. PCWA plans to complete the installation of the new gages in late spring or early summer of 2006, depending on access and flows conditions.

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

<u>P-F1 NF of the MF American River upstream of confluence with MF American</u>. This site is located on the Middle Fork American River approximately 175-feet downstream of the Circle Bridge on the left bank (looking downstream). The gage will be installed on bedrock. The approximate coordinates are latitude (Lat) 39 01’ 24”, longitude (Long) 120 43’ 15”. 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.

<u>P-F2 Middle Fork American River above Ralston Afterbay</u>. This site is located on the Middle Fork of the American River upstream of Ralston Afterbay. The gage will be installed on bedrock. The approximate coordinates are Lat 39 0’ 27”, Long 120 43’ 54”. This site is located a few hundred yards upstream of the Ralston Day Use Area and can be accessed using a trail located on the north side of the Middle Fork American River near the bridge.

<u>P-F3 Rubicon River upstream of Ralston Powerhouse</u>. This site is located directly upstream of the Ralston Powerhouse approximately 500-feet on the right bank. The gage will be installed on bedrock. The approximate coordinates are Lat 38 59’ 33”, Long 120 43’ 14”. This site can be accessed from Ralston Ridge Road and involves a very short cross-country hike. The effort at this location will involve reinstalling USGS Gage No. 11433200.

<u>P-F4 Long Canyon Creek just above confluence with Rubicon</u>. This site is located just upstream of the mouth of Long Canyon Creek, near the confluence of the Rubicon River. The gage will be installed on the right bank (looking downstream) in bedrock. The approximate coordinates are Lat 38 59’ 25”, Long 120 41’ 14”. This site can be accessed via Buckeye Flat Road from Ralston Ridge Road. Buckeye Flat Road is an off-highway vehicle (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 is required to reach the site. This location may be inaccessible during wet conditions.

<u>P-F5 Long Canyon Creek below the confluence of North and South Forks</u>. This gage will be placed on the right bank approximately 100-feet downstream of the bridge where USFS Road 2 crosses Long Canyon Creek. The gage will be installed on bedrock. The

approximate coordinates are Lat 39 01’ 08”, Long 120 31’ 09”. This site can be accessed from USFS Road 2, also known as Eleven Pines Road.

P-F6 Rubicon River below confluence with South Fork Rubicon. This site is located just upstream of Ellicott’s Bridge on USFS Road 2. The gage will be installed on the right bank (looking downstream). The approximate coordinates are Lat 38 57’ 36”, Long 120 28’ 52”. The site can be accessed via Wentworth Springs Road, also known as USFS Road 1, to Eleven Pines Road, also known as USFS Road 2. The effort at this location will involve reinstalling USGS Gage No. 11431000.

P-F7 South Fork Rubicon just above confluence with Rubicon. This site is located on the left bank (looking downstream) of the South Fork Rubicon River, just above its confluence with the Rubicon River. The gage will be installed in bedrock. The approximate coordinates are Lat 38 57’ 17”, Long 120 24’ 02”. The site can be accessed via a trail located on the left bank of the Rubicon River at Ellicott’s Bridge. The trailhead is difficult to find due to the many campsites and trails in the area. There seem to be two trails that lead in the direction of the South Fork Rubicon. The lower trail near the edge of the terrace above the Rubicon River is washed out about ¼ mile upstream. The trail that leads to the gage site is higher up the slope. This particular trail is difficult to find because it is apparently not frequently used. The 1½-mile trail leads directly to the planned gage site, also the site of discontinued USGS Gage No. 11430500. Some of the old equipment is still visible at the site.

3.3 SELECTION OF THE PERIOD OF RECORD FOR ANALYSIS

PCWA recommends that the period of record for the hydrologic analyses for the MFP relicensing should begin in water year 1975 and extend through water year 2003. PCWA proposes this period for a number of 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 period of record 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 and South Fork Rubicon River, so SMUD operations affect the PCWA system. Finally, records of diversions and stream flows are more complete for the period after 1975 based on review of the historical records. Final selection of the period of record will be completed in consultation with the resource agencies.

3.4 APPROACH FOR FILLING IN DATA GAPS

A complete hydrologic record is needed for the MFP relicensing. However, the existing flow record is incomplete. PCWA proposes to use the Fill-in program developed by the USGS for statistical analysis to fill in missing data and for estimating accretion flows (Figure 2). The Fill-In program was written by the USGS in the 1980’s to estimate monthly flow volumes at stream flow gaging stations for periods of time when data are missing.

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The monthly unimpaired flow records (both complete and incomplete) from each of these gaging stations are input into the program. Fill-in reads the time series data directly from an HEC-DSS file and runs 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-squared 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 the monthly volumes into daily values, the use of the hydrographic pattern of a complete unregulated gage is proposed. Flow data from a well-correlated and complete record will be 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 are acceptable, the disaggregated values would be used only for the period that was missing data. If the original flow record is of poor quality (i.e. a noisy record), the disaggregated values would be used for the entire record.

3.5 APPROACH FOR DEVELOPING UNIMPAIRED HYDROLOGY AT HEADWATERS NEAR PROJECT FACILITIES

The general approach for development of unimpaired hydrology in the vicinity of the MFP involves two components. The first is the development of unimpaired hydrology near Project facilities located at the upper end of the Project area, 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 and South Long Canyon creeks. Unimpaired hydrology at these locations are derived from either existing gages located above Project facilities that directly measure unimpaired flows (Duncan Creek), development of a water balance calculation (French Meadows and Hell Hole reservoirs) or a combination of several methods that include using a water balance calculation where sufficient flow records exist, Filling-in of incomplete flow records to calculate total contribution from the basin and distribution of the derived basin contribution into sub-watersheds (Long Canyon Creek). The second component involves the development of unimpaired flows at downstream diversions by estimating accretion flows between flow measurement locations. These two components are discussed further in the following sections.

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3.5.1 Developing Unimpaired Hydrology

The following subsections describe how PCWA proposes to unimpair flows in the upper portion of the MFP area. PCWA tested the methods described below and the resulting output is provided on the CD that accompanies this report.

3.5.1.1 Duncan Creek Unimpairment

A complete record of unimpaired flow for the period of 9/1/1960 through 9/30/2004 exists immediately above the Duncan Creek Diversion as measured at USGS Gaging Station No. 11427700. This data was used to develop the unimpaired hydrology at this location.

3.5.1.2 French Meadows Inflow Unimpairment

Development of unimpaired flows at French Meadows requires using a water balance calculation to account for inflow, outflow and evaporation. The following discusses each of these components and data sources.

USGS record of French Meadows Reservoir storage from 1965 through 2003 is available. 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 simulated for the period from 1975 to 2003. The first step to develop the unimpaired inflow record (I_{FM}) involves subtracting the previous day's storage (S_{i-1}) from the current day's storage (S_i), subtracting the diversion from Duncan Creek to French Meadows Reservoir (Div_{DC}), and adding back in the diversion to Hell Hole Reservoir (Div_{HH}), the River release (Rel), and the evaporative losses for the day ($Evap$) in accordance with the following equation:

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

The diversion from Duncan Creek to French Meadows Reservoir is ungaged, but a record from 10/1/1964 through 9/30/2004 of flows downstream of the diversion is available (USGS Gage No. 11427750). The following diagram shows a schematic of the Duncan Creek Diversion Water Balance.

The diversions to French Meadows Reservoir were calculated as the difference between these two gages. PCWA operators report that the Duncan Creek gages are considered not to be very accurate (i.e. barely within USGS standards of precision). Additionally, the inflow between the gages can be significant relative to the gage measurements 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 that likely contributes to the difference). In these cases, the diversion is assumed to be zero.

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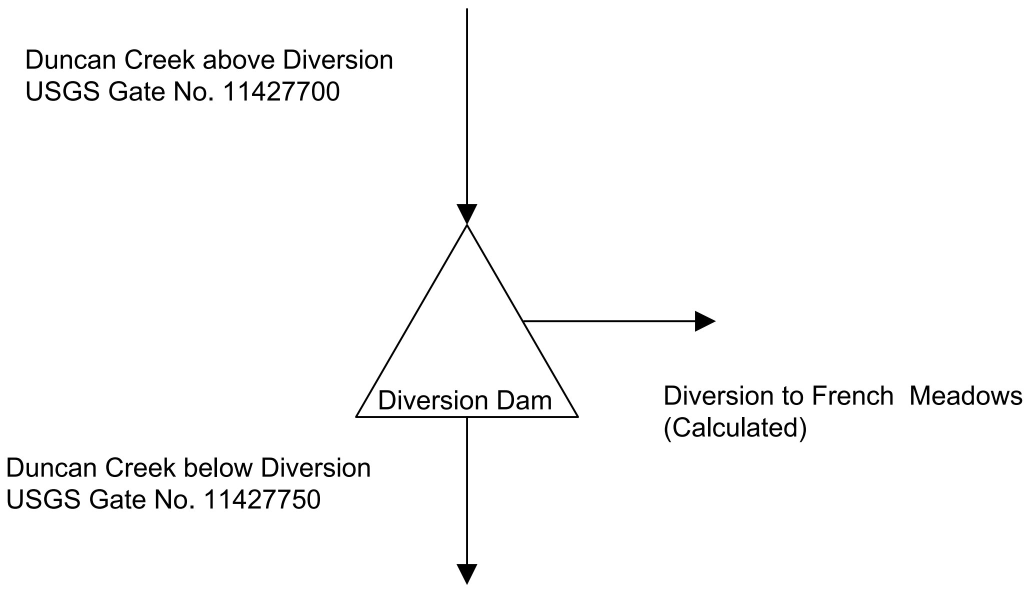

Duncan Creek Diversion Water Balance

Except for evaporation, daily data are available from the USGS for each of the remaining components, as shown in the following French Meadows Water Balance diagram. However, use of the daily data in step one of the calculation of unimpaired inflow resulted in a daily inflow record of poor quality, with numerous negative inflows. These negative values may be the result of several factors, including an underestimate of evaporation, particularly in the stream channels, during the hottest part of the driest year on record, 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 may also have affected the calculation of unimpaired flows.

To develop an inflow record of better quality, daily inflows were re-computed in a second step, using disaggregation. To disaggregate or smooth a record, the daily flow values from the noisy record is compared to the daily flow values from a gage with a complete and acceptable flow record. The daily value for the noisy record ($Flow_{daily}$) is calculated as the same percentage of the monthly inflow ($Volume_{monthly}$) as the complete record's daily value ($CompleteGage_{daily}$) is of the monthly flow ($CompleteGage_{monthly}$):

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

This disaggregation was performed to smooth inflow to French Meadows by redistributing the recorded monthly volume of inflow to French Meadows Reservoir using the pattern of the Duncan Creek runoff measured at USGS Gage No. 11427700. Regression analysis shows that French Meadows and Duncan Creek monthly volumes are well correlated, with an R-squared value of .9691 (Figure 3).

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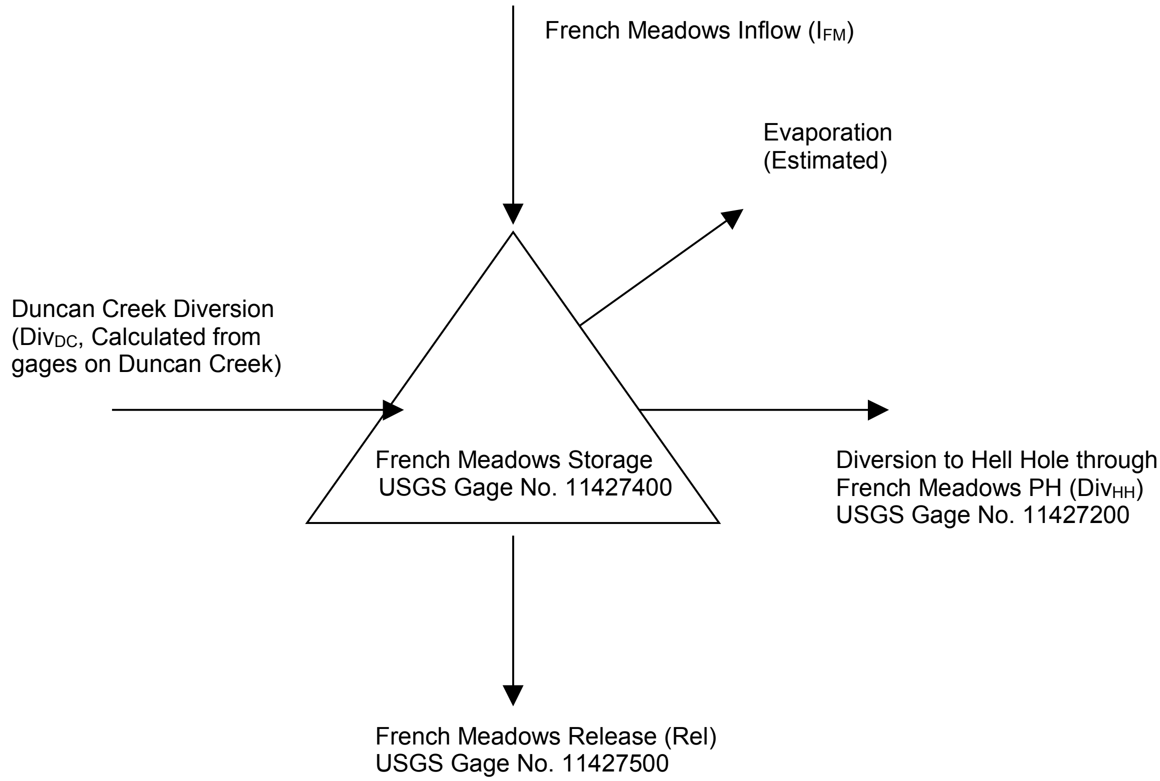


French Meadows Water Balance

The daily value for the French Meadows record ($FM\ Flow_{daily}$) was calculated as the same percentage of the reservoir's monthly inflow ($FM\ Volume_{monthly}$) as the Duncan Creek daily value ($DC\ Flow_{daily}$) is of the Duncan Creek monthly flow ($DC\ Volume_{monthly}$):

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

This second-step in the analysis provided a better pattern for daily inflow, but had some discontinuities. These discontinuities occurred particularly at the start of months during the ascending and descending limb of the hydrograph in May, June and July. At this time, when the difference in total monthly inflow from one month to the next was 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.

To resolve these discontinuities, a record was developed using disaggregation based on weekly inflow volumes, rather than on a monthly inflow basis, for the spring and summer period, from May to September. This generally resolved the discontinuities, and resulted in a more reasonable simulation of both the ascending and descending limbs of the hydrograph and reservoir storage. The procedure led, however, to negative weekly volumes during certain periods of the drier summer weeks.

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. August 1977, September and October 1991), Fill-in was used to generate a positive monthly inflow volume based on correlations with other basins with a complete record.

The fourth step in development of the French Meadows 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.

Figure 4 shows an example comparison of the simulated French Meadows Reservoir record (red line) and the original calculated inflow (blue line). The black line represents the recorded storage; the turquoise line represents the simulated storage. The example hydrograph (Figure 4) shows inflow to French Meadows Reservoir in water year 1979; inflow to Folsom Lake during 1979 was 95% of the average for the period of 1921-2001.

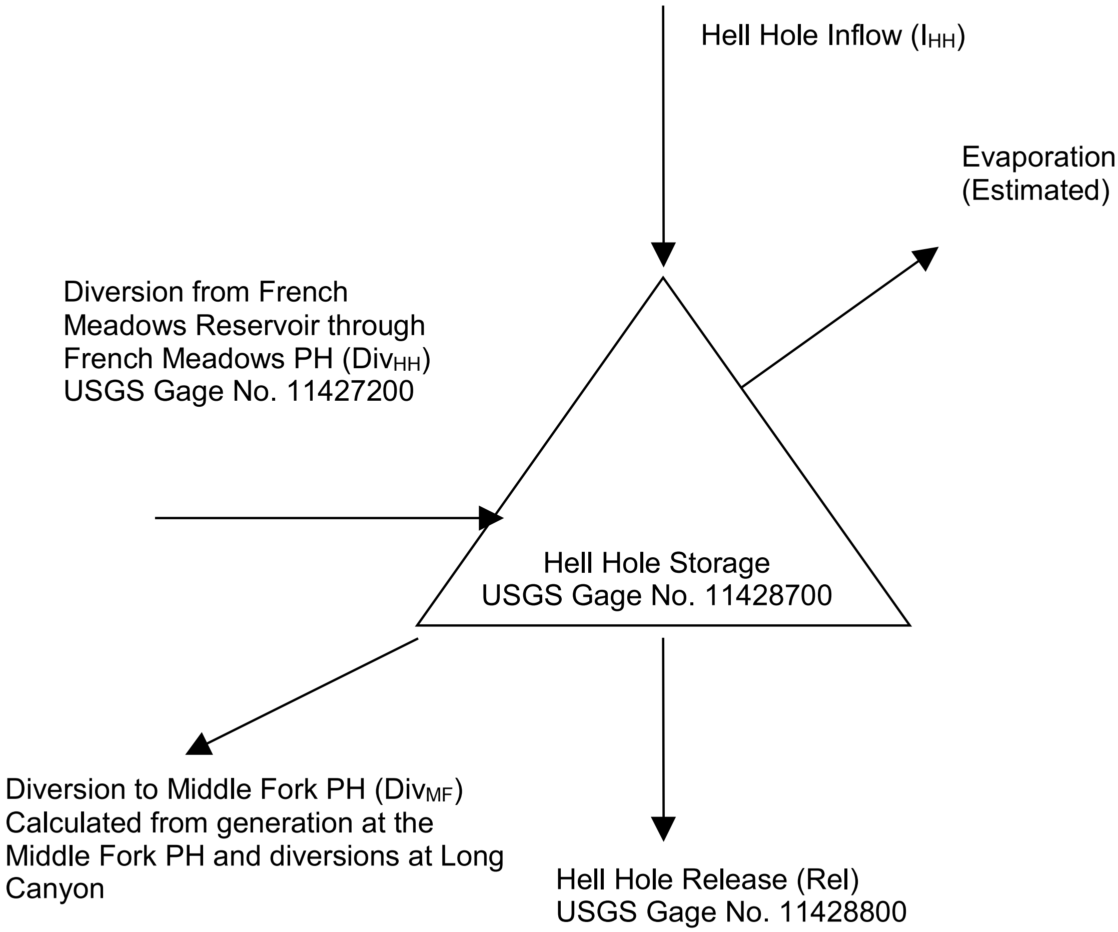
3.5.1.3 Hell Hole Inflow Unimpairment

Development of unimpaired flows at Hell Hole Reservoir requires using a water balance calculation to account for inflow, outflow and evaporation. The following discusses each of these components and data sources.

USGS records of Hell Hole Reservoir storage from 1965 through 2003 are available to develop the inflow record for the reservoir. The first step in developing an unimpaired inflow record (I_{HH}) was to calculate inflow by subtracting the previous day's storage (S_{i-1}) from the current day's storage (S_i), subtracting the diversion from French Meadows Reservoir to Hell Hole Reservoir (Div_{HH}), and adding the diversion to the Hell Hole Middle Fork Power Plant (Div_{MF}), the River release (Rel), and the evaporative losses for the day ($Evap$):

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

The following diagram shows a schematic of the Hell Hole Water Balance. Daily records for each of the components of the equation except evaporation are available from the USGS. As with data for French Meadows Reservoir, available storage records at Hell Hole Reservoir were not sufficiently accurate to result in an inflow record of good quality.



Hell Hole Water Balance

The second step in developing the Hell Hole Reservoir inflow record was to perform disaggregation on a monthly basis using the Duncan Creek record, the same method as was used for French Meadows Reservoir. Regression analysis showed Hell Hole inflow and Duncan Creek inflow to be well correlated, with an R-squared value of 0.95 (Figure 5).

The daily value for the Hell Hole Reservoir record ($HH\ Flow_{daily}$) was calculated as the same percentage of the reservoir's monthly inflow ($HH\ Volume_{monthly}$) as the Duncan Creek daily value ($DC\ Flow_{daily}$) is of the Duncan Creek monthly flow ($DC\ Volume_{monthly}$):

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

Because the inflow to Hell Hole Reservoir was historically impaired by the operation of the SMUD system on the upper Rubicon River, the diversion out of the upper Rubicon basin through the Buck-Loon tunnel was not added to the unimpaired record at this time.

In a third step, the inflow record was calculated using weekly volumes from May to September, and then disaggregated using the Duncan Creek pattern. This procedure led to some negative weekly volumes during the drier summer weeks, so positive- and negative-volume weeks were grouped together, and a positive multiple-week volume was used. As few weeks as possible that would yield a net positive volume were grouped together for these calculations.

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. August 1977, September and October 1991), Fill-in was used to generate a positive monthly inflow volume based on correlation with other basins with a complete record. These negative values may be the result of several factors, including an underestimate of evaporation, particularly in the stream channels, during the hottest part of the driest year on record, lack of precision in the reservoir storage curve exacerbated by the low net inflow volumes and low reservoir storage, gage error or other factors.

As with French Meadows, disaggregation on a monthly basis left some inflow jumps in the record, when the inflow volume was significantly different from one month to the next. The fourth step in development of the Hell Hole 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.

Figure 6 shows an example comparison of the simulated Hell Hole record (orange line) and the original calculated inflow (blue line). The black line represents the recorded storage; the turquoise line represents the simulated storage. The example hydrograph (Figure 6) shows inflow to Hell Hole Reservoir during water year 1979; the inflow to Folsom Lake during 1979 was 95% of the average for the period of 1921-2001.

3.5.1.4 Long Canyon Creek Unimpairment

Development of unimpaired flows in Long Canyon Creek involves using a combination of several methods that include using a water balance calculation where sufficient flow records exist, Filling-in of incomplete flow records to calculate total contribution from the basin and distribution of the derived basin contribution into sub-watersheds. The unimpairment methods are discussed here. Distribution of the derived unimpaired flow records into the sub-watershed areas is discussed in Section 3.5.2.4, Calculating Accretion Flows on Specific Reaches.

The gaging records for Long Canyon near French Meadows (USGS Gaging Station No. 11433100) extends from 9/1/1960 to 9/30/1992. This gage was located at the confluence of the North and South forks of the creek and recorded flows year-round, but was discontinued in 1992. The record provides unimpaired flows when upstream diversions were not occurring. Records of these diversions are currently available from 10/1/1965 (when diversions started) through 9/30/2004. The following diagram shows a schematic of the North Fork and South Fork Long Canyon.

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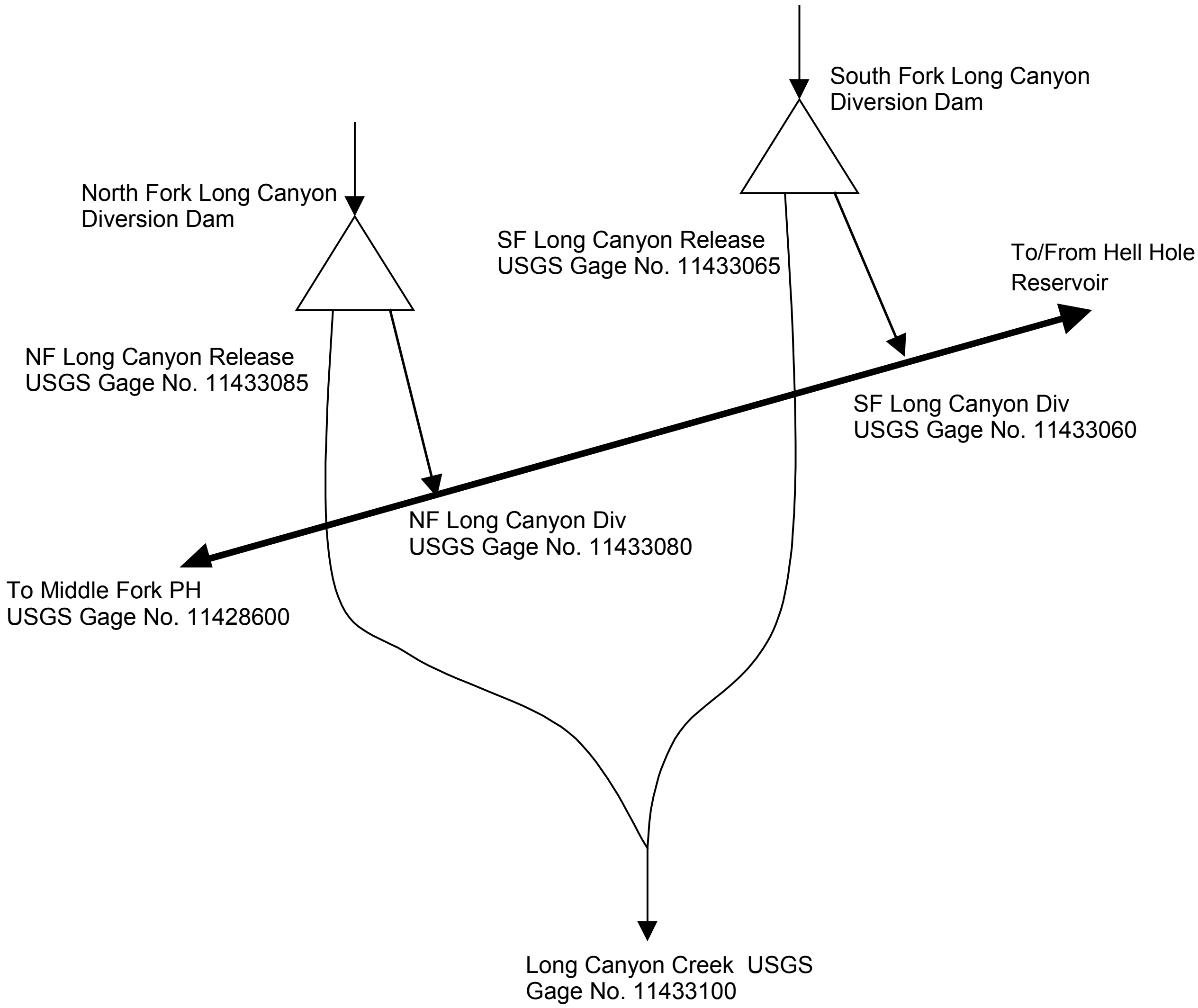

North Fork and South Fork Long Canyon

To create a complete Long Canyon record, available data was used to calculate unimpaired flows from 1974 through 1992, and estimated unimpaired flow values were used from 1993 through 2003. Unimpaired daily values from 1974 to 1992 were calculated by adding the diversions from the North Fork of Long Canyon Creek and the South Fork of Long Canyon Creek to the Long Canyon flow record at the confluence (USGS Gaging Station No. 11433100) (Figure 7). Monthly flow volumes from 10/1/1992 through 9/30/2003 were developed using Fill-in. The daily values were determined by disaggregating the monthly volume according to the Pilot Creek flow pattern. Figure 8 shows a regression analysis of Long Canyon Creek and Pilot Creek, which found the two records to be well correlated, with an R-squared value of 0.90.

3.5.2 Estimating Accretion Flows

This section proposes an approach for calculating accretion in the major watercourses of the Middle Fork American River watershed located between measured flow locations. The accretions can be calculated by subtracting the flow recorded at upstream gages from the recorded flow at a downstream location. The proposed accretion areas are:

- Middle Fork American River from French Meadows Dam to Interbay (complete record);
- Middle Fork American River from Interbay to Ralston Afterbay at Foresthill gage (10/1/1974 – 2/6/1986);
- Rubicon River (including Long Canyon from the North Fork and South Fork confluence to the mouth) from Hell Hole Dam to Ralston Afterbay (10/1/1974 – 9/30/1984);
- North Fork and Middle Fork American River below Foresthill (10/1/1974 – 9/30/1984);
- Long Canyon Creek from the headwaters to the NF and SF confluence (10/1/74 – 9/30/2003);
- Accretions on the South Fork Rubicon between Gerle Creek and the confluence with the Rubicon River (10/1/1974 – 9/30/2001, developed by SMUD for the UARP relicensing).

When a complete record is not available, the missing data will be synthesized using the Fill –in techniques described above.

3.5.2.1 Distribution by Sub-Watersheds

To adequately describe the hydrology of the Middle Fork American River watershed, it will be necessary to break the proposed accretion areas down into sub-watersheds.

However, gage data are not available on the small sub-watershed level, so the available data must be distributed among sub-basins. The sub-basins were proposed in the Hydrology Study Plan, and are shown on the Unimpaired Flow Locations and Basins Map (Map 2). These basins are proposed at a sufficient granularity to support the anticipated technical studies and the development of a water balance model. A number of the basins proposed are in the range of five square miles; sub-watersheds smaller than this would not be well supported by the accuracy of existing data.

3.5.2.2 Precipitation and Drainage Area Data

In order to develop the hydrology using these sub-basins, PCWA proposes to compare the average precipitation and drainage area of the sub-watersheds, and distribute flows among sub-basins according to the proportion of total runoff that a sub-watershed contributes to the larger accretion area. The precipitation and drainage area information used is 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 for the period of 1971-2001. Sub-basin numbers correspond to the basin numbers shown in Map 2. Section 3.5.2.3 describes how the precipitation and drainage area data will be used to establish relationships between the sub-watersheds and the larger accretion watershed areas.

3.5.2.3 Calculation of Sub-watershed Weights

To determine flows at unimpaired flow locations where there is no gage, PCWA proposes to break the larger calculated accretion values down into flows proportional to the total annual precipitation contributed to the larger basin by the sub-watershed, using a calculated weight for each of the sub-watersheds. The sub-basin weight (w_i) was calculated by multiplying the mean annual precipitation for the sub-basin (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 basin (P_T, in acre-feet):

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

P_T is calculated as the sum of the total annual precipitation in all the sub-basins. Tables 2 to 6 provide the results of this analysis by accretion area. After the sub-basin weight has been calculated, the unimpaired flow at intermediate flow locations within the larger accretion areas can be 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 watershed, and w_i is the weight calculated for that sub-watershed. Tables 2 to 6 provide the calculated weights for the corresponding sub-basins ("% of Basin's Total Precip." column).

EXAMPLE:

The calculated total accretions on the Middle Fork American River between French Meadows Reservoir and Interbay represent the sum of accretions from sub-basins 13, 15, 16 and 17 (see Map 2). The total mean annual precipitation for the larger basin, P_T in acre-feet, is calculated as:

$$P_{T(FM-IB)} = (A_{13} \times \frac{p_{13}}{12}) + (A_{15} \times \frac{p_{15}}{12}) + (A_{16} \times \frac{p_{16}}{12}) + (A_{17} \times \frac{p_{17}}{12}) = 105{,}384\, acre\text{-}feet$$

Sub-basin 13 has an area of approximately 3,687 acres and a mean annual precipitation of 67 inches. The total watershed receives 105,384 acre-feet of precipitation each year (P_T). The weight for sub-basin 13 is calculated as:

$$w_{13} = \frac{3{,}687\, acres \times 67\, in \times \frac{1\, ft}{12\, in}}{105{,}384\, acre\text{-}feet} = 0.195\text{, or 19.5\%}$$

This weight indicates that sub-basin 13 contributes 19.5% of the total flows in the larger accretion area. To determine daily flows for sub-basin 13 (Q_{13}), the daily flow value for the larger accretion area (Q_T) would be multiplied by 19.5%.

3.5.2.4 Calculating Accretion Flows on Specific Reaches

PCWA applied the techniques described above to estimate accretion flows along specific reaches in the MFP area. The methods used in this effort are described below for consideration by the resource agencies.

Middle Fork American River from French Meadows Dam to Interbay

Reservoir and Interbay were calculated by subtracting the following USGS gage data from those at Middle Fork American River above Middle Fork Powerhouse near Foresthill (UGSS Gage No. 11427760) (Figure 9):

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

<u>Distributions of Accretions</u>

Accretion Area A in the Middle Fork American river watershed from French Meadows to Interbay was divided into four sub watershed areas as illustrated in Figure 10. Table 2 illustrates the contribution of each sub-watershed area, all of which are derived from a GIS based area-precipitation relationship.

Middle Fork American River from Interbay to Ralston Afterbay at Foresthill Gage

Accretions on the Middle Fork American River (MFAR) between Interbay and Ralston Afterbay were calculated by subtracting the following USGS gage data from those at the Middle Fork American River near Foresthill (USGS Gage No. 11433300) as shown on Figure 11:

- Middle Fork American River below Interbay Dam near Foresthill (USGS Gage No. 11427770);
- North Fork of Middle Fork American River near Foresthill (USGS Gage No. 11433260);
- Rubicon River near Foresthill (USGS Gage No. 11433200); and
- MF Powerhouse near Foresthill (USGS Gage No. 11428600).

The Rubicon River near Foresthill gage was discontinued in 1984, so Fill-in of monthly volumes and disaggregation to daily values was used to simulate the remaining data.

It has recently become known that the gage below Interbay (USGS Gage No. 11427770) is not very accurate. According to a PCWA operator, water flows through gravels under the weir at all flows. This error would have the largest effect on the accuracy of flow measurements during low flows.

To resolve this gaging inaccuracy, PCWA calculated an alternate flow below the Interbay using other gages, and compared it to the record at USGS Gage No. 11427770. The flow below Interbay dam was calculated using the following water balance: Middle Fork American River above Interbay (USGS Gage No. 11427760) plus the Middle Fork Powerhouse gage (USGS Gage No. 11428600), minus the diversion from Interbay to Ralston Powerhouse (USGS Gage No. 11427765). The accretion was then calculated using both the computed flow at Interbay and the measured flow at Interbay. Even with the measurement problems at low flow, the flow measured by USGS Gage No. 11427770 seemed to be the most reasonable. Calculated accretions on the Middle Fork from Interbay to Foresthill extend from 10/1/1974 to 9/30/1984; daily values from 10/1/1984 through 9/30/2004 will need to be estimated. Once calculated, the accretion will be compared with complete unimpaired gage records (e.g. Duncan Creek, Pilot Creek, North Fork American at North Fork Dam) using regression analysis. The gage with the best correlation will then used to disaggregate the filled-in accretions from monthly flows to daily flows.

It is likely some smoothing would be necessary to develop a reasonable inflow record. The smoothing techniques are described above under the sections which discuss the development of unimpaired inflows to French Meadows and Hell Hole reservoirs. If

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disaggregation based on a monthly pattern proves to be too coarse, particularly for the receding limb of the hydrograph, it is proposed that disaggregation based on a weekly pattern be used to create a smoother, more reasonable accretion record.

Distribution of Accretions

Accretion area B in the Middle Fork American River watershed from Interbay to Ralston Afterbay was divided into four sub-watershed areas as illustrated in Figure 12. Table 3 illustrates the contribution of each sub-watershed area, all of which are derived from a GIS based area-precipitation relationship.

Rubicon River from Hell Hole Dam to Ralston Afterbay

Accretions 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 Gage No. 11433200), just above Ralston Afterbay (Figure 13):

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

Because the Rubicon River near Foresthill gage was discontinued in 1984, accretions after 1984 were synthesized using the USGS Fill-in program and disaggregation.

Calculated accretions on the Rubicon from Hell Hole to Ralston Afterbay extend from 10/1/1974 to 9/30/1984. Daily values from 10/1/1984 through 9/30/2004 need to be estimated. Accretion values were compared on a monthly basis to the complete unimpaired gage records in the basin, and the filled-in record was disaggregated using the best-correlated gage pattern. If disaggregation based on a monthly pattern does not result in an accretion record of the desired quality, it is proposed that the accretion flows be disaggregated on a weekly pattern basis to produce an accretion record of good quality.

Distribution of Accretions

The accretions in the Rubicon watershed from Hell Hole to Ralston Afterbay were divided into 12 sub watershed areas as illustrated in Figure 14. Table 4 illustrates the proposed contribution of each sub-watershed area.

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North Fork and Middle Fork American River Below Foresthill

Accretions on the North and Middle Forks American River between the North Fork Dam, Middle Fork American at Foresthill gage site and North Fork American at Auburn gage site (at the Auburn Dam site) can be calculated by subtracting the following USGS gage data from those at the NFAR below Auburn Dam site near Auburn (USGS Gage No. 11433800) (Figure 15):

- North Fork at North Fork Dam (11427000); and
- Middle Fork near Foresthill (11433300).

The NFAR below Auburn Dam gage washed out during failure of the Auburn Dam cofferdam in 1986. After the accretion has been calculated, from 1974-1986, data from 2/7/1986 through 9/30/2004 would be simulated using Fill-In, then disaggregated into daily flows. To develop a reasonable record of accretion, PCWA proposes to use the monthly accretion volume calculated as described above, and then disaggregate the monthly inflows according to the North Fork at North Fork Dam pattern. This accretion location has been the most problematic because of the frequent occurrence of negative accretions during the 1975-1986 period when all three records overlap. While it is possible that this reach of the river is a losing reach, the approach for correlation of the calculated accretions should be revisited.

Another approach may be to use calculated accretions on the Middle Fork American River below Foresthill which extend from 10/1/1974 to 9/30/1984. Daily values from 10/1/1984 through 9/30/2004 will need to be estimated. Because the average elevation of this accretion area is lower than most of the complete unimpaired gages, the use of the North Fork American at North Fork Dam is proposed. Though the North Fork American Basin has some higher-elevation portions than the accretion area between Auburn and Foresthill, the North Fork American has the most similar altitude distribution of any complete record in the basin. Additionally, when snowmelt from the higher elevations occurs in the North Fork Basin (late spring), the calculated monthly accretion should be near zero, since snow at lower elevations should have already melted, and heavy rains are unlikely in this season. It is expected that the pattern of flow at the North Fork American gage would not significantly affect the calculated daily accretion in the spring runoff period.

<u>Distribution of Accretions</u>

The accretions calculated between the Middle Fork American River at Foresthill gage and the North Fork American River at Auburn gage will be distributed based on the GIS based area and precipitation analysis. Figure 16 and Table 5 describes the distribution by basin number.

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Long Canyon above the NF and SF Confluence

Calculation of the Long Canyon accretions involves a multi-step process. The first task was to unimpair the Long Canyon Creek near French Meadows gage (USGS Gage No. 11433100). The unimpairment process is discussed in Section 3.5.1.4 Long Canyon Creek Unimpairment. The unimpairment process resulted in daily records from 10/1/74 – 9/30/2003. The daily values represent the inflow for the whole Long Canyon basin above the gage, from basins 19, 20 and 21 as shown on Figure 17. To develop separate daily flow values for the North and South Fork portions of the basin, the record was divided between the three basins by an area-precipitation relationship. Table 6 describes the distribution by basin number.

If the unimpaired daily flow values developed are not sufficient to satisfy the recorded Long Canyon diversions plus the minimum flow requirements, the record will be adjusted. In this case, the unimpaired flow will be the sum of the diversions, plus the required minimum flows below each diversion.

3.5.3 Hydrology Information Available From Nearby Gage Stations

Hydrologic records are available from a gage located on the North Fork American River near Foresthill and for the South Fork Rubicon River. Data from these stations will be utilized by PCWA as briefly described in the following two subsections.

3.5.3.1 North Fork of the Middle Fork American River Near Foresthill

The record for the North Fork of the Middle Fork American River extends from 8/1/1965 to 9/30/1985. Daily values from 10/1/1985 through 9/30/2004 will need to be estimated. Monthly data for this location would be developed using the Fill-in and disagregation techniques described above. Monthly volumes and daily values would be developed using a well-correlated gage with a complete record.

Analysis shows that North Fork of Middle Fork near Foresthill is proportionally similar to the daily flow at Pilot Creek above Stumpy Meadows (USGS Gage No. 11431800). An example year of both records is shown in Figure 18.

3.5.3.2 South Fork Rubicon Accretion Data from SMUD

The record for accretions on the South Fork Rubicon River was developed by SMUD for the UARP relicensing, and extends from 10/1/1974 to 9/30/2001 (the period of the SMUD relicensing). The record will need to be extended from 10/1/2001 for use in the PCWA MFP relicensing, using the methods described above to fill in missing unimpaired flow records.

Analysis shows SMUD's accretions on the South Fork Rubicon (SMUD's "Gerle 5" accretion) are proportionally similar to the daily flow at Pilot Creek above Stumpy

Meadows (USGS Gage No. 11432500), and that these systems respond similarly in years of overlapping data. An example year of both records is shown in Figure 19.

4.0 NEXT STEPS

This status report was provided to the resource agencies to facilitate discussions regarding the selection of appropriate technical approaches for carrying out the Hydrology Study Plan. The information provided in this report presents PCWA's proposed approach for developing a complete hydrologic record for the MFP (both project an unimpaired hydrology). PCWA recognizes that agreement 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 during the relicensing process. PCWA looks forward to collaborating with the resource agencies to refine and obtain consensus on the technical approaches.

The following are key decisions needed to proceed:

- Selection of the period of record for analysis of Project and unimpaired hydrology;
- Approach for Filling in Data Gaps in the flow records;
- Approach for Developing Unimpaired Hydrology at the Project Facilities in the Upper Sub-basins; and
- Approach for Estimating Accretion Flows.

A complete hydrologic record, including both Project and unimpaired flows, developed in accordance with the agency-approved approach will be provided to the agencies for review and comment. All raw data and analyses files will be provided to the agencies on CD. Following agency review, the next key decision is the selection of a water-type classification for the watershed. PCWA proposes to collaborate with the agencies to select the appropriate water-type classification based on review of the existing and unimpaired hydrologic record.

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

- Describe the Project and unimpaired hydrology through a series of hydrologic analyses;
- Perform an Indicators of Hydrologic Alteration Analysis (IHA);
- Determine if additional data are needed to support the upcoming relicensing; and

- Provide a complete hydrologic data set and corresponding analyses to support the geomorphology, riparian and aquatic habitat, and water temperature studies.

Results of the hydrologic analyses will be provided to the resource agencies in a draft report for review and comment. A final report will be distributed summarizing all work completed as part the Hydrology Study Plan for use during the relicensing of the MFP.

TABLES

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Table 1. Flow Data Locations

Site Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
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
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

Table 1. Flow Data Locations (continued)

Site Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
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
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

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Table 1. Flow Data Locations (continued)

Site Number	Site Name	Latitude	Longitude	Drainage	Elevation	Start Date	End Date
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
20000001	UNIMPAIRED Rubicon River below Rubicon Reservoir	ND	ND	ND	ND	10-1-1974	9-30-2001
20000002	UNIMPAIRED Little Rubicon River at Buck Island Reservoir	ND	ND	ND	ND	10-1-1974	9-30-2001
20000003	UNIMPAIRED Gerle Creek at Loon Lake	ND	ND	ND	ND	10-1-1974	9-30-2001
20000004	UNIMPAIRED Gerle Creek at Gerle Creek Reservoir	ND	ND	ND	ND	10-1-1974	9-30-2001
20000005	UNIMPAIRED SF Rubicon River at Robbs Peak Diversion Dam	ND	ND	ND	ND	10-1-1974	9-30-2001
20000006	ACCRETION Gerle Creek above Basin Creek	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000007	ACCRETION Gerle Creek above SF Rubicon excl Gerle Creek Abv Gerle Res	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000008	ACCRETION Gerle Creek at Gerle Reservoir	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000009	ACCRETION Gerle Creek below Barts & Deller Creek	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000010	ACCRETION Gerle Creek below Jerret Creek excl inflow to Loon	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000011	ACCRETION Gerle Creek below Rocky Basin Creek	N/A	N/A	ND	ND	10-1-1974	8-30-2001
20000012	ACCRETION Little Rubicon River outflow from Rockbound Lake (excluding diversions)	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000013	ACCRETION Rubicon River at Rubicon Springs	N/A	N/A	ND	ND	10-1-1974	9-29-2001
20000014	ACCRETION Rubicon River below Little Rubicon	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000015	ACCRETION Rubicon River blw Miller Creek excluding above Rubicon Springs	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000016	ACCRETION SF Rubicon u/s of Rubicon River	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000017	UNREGULATED Rubicon River Inflow to Rubicon Reservoir	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000018	UNREGULATED Highland Creek Inflow to Rockbound Reservoir (Inflow at Rockbound Reservoir)	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000019	UNREGULATED Ellis Creek Inflow to Loon Lake	N/A	N/A	ND	ND	10-1-1974	9-30-2001
20000020	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. Accretions on MF American, Area A, Sub-Watershed Contribution

Larger Watershed Or accretion area	Basin Number	Area (acres)	% of Total Basin Area	Mean Annual Precipitation (in.)	Total Mean Annual Precip. Volume (ac-ft)	**Weight** % of Basin's Total Contribution
Accretions on MF from French Meadow to Interbay	13	3687	19%	67	20,585	19.5%
	15	8640	45%	67	48,241	45.8%
	16	4688	24%	63	24,610	23.4%
	17	2240	12%	64	11,947	11.3%
Total		19255	100%		105,384	100%

Table 3. Accretions of MF American, Area B, Sub-Watershed Contribution

Larger Watershed Or accretion area	Basin Number	Area (acres)	% of Total Basin Area	Mean Annual Precipitation (in.)	Total Mean Annual Precip. Volume (ac-ft)	**Weight** % of Basin's Total Precip.
Accretions on MF from Interbay to Foresthill	9a	432	2%	50	1,798	2%
	9b	3570	19%	50	14,874	16.5%
	10	3469	19%	54	15,609	17.3%
	12	11193	60%	62	57,830	64.2%
Total		18663	100%		90,112	100%

Table 4. Accretions of Rubicon, Area C, Sub-watershed Contribution

Larger Watershed Or accretion area	Basin Number	Area (acres)	% of Total Basin Area	Mean Annual Precipitation (in.)	Total Mean Annual Precip. Volume (ac-ft)	**Weight** % of Basin's Total Precip.
Accretions on Rubicon from HH to Foresthill	11	3511	5.2	54	15,801	4.6%
	22	5977	8.8	65	32,378	9.5%
	23	8258	12.2	62	42,664	12.5%
	24	5118	7.6	61	26,016	7.6%
	25	660	1	56	3,079	.9%
	27	5717	8.5	63	30,012	8.8%
	28	8888	13.2	60	44,439	13.1%
	29	6244	9.2	62	32,260	9.5%
	30	9889	14.6	61	50,269	14.8%
	31	7584	11.2	58	36,657	10.8%
	33	5736	8.5	56	26,767	7.9%
Total		67582	100%		340,343	100%

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Table 5. Accretions of NF & MF American, Area D, Sub-watershed Contribution

Larger Watershed Or accretion area	Basin Number	Area (acres)	% of Total Basin Area	Mean Annual Precipitation (in.)	Total Mean Annual Precip. Volume (ac-ft)	**Weight** % of Basin's Total Contribution.
Accretions on NF and MF from NF Dam and Foresthill to Auburn	1	3550	5%	36	10,651	4.1%
	2	24634	35%	39	80,062	30.4%
	4	9857	14%	51	41,890	15.9%
	5	3788	5%	40	12,628	4.8%
	6	11359	16%	53	50,170	19.1%
	7	8228	12%	46	31,542	12.0%
	8	8389	12%	52	36,354	13.8%
Total		69807	100%		263,298	100%

Table 6. Accretions of Long Canyon, Area E, Sub-watershed Contribution

Larger Watershed Or accretion area	Basin Numbe r	Area (acres)	% of Total Basin Area	Mean Annual Precipitation (in.)	Total Mean Annual Precip. Volume (ac-ft)	**Weight** % of Basin's Total Precip.
Long Canyon	19	2458	21%	59	12,084	21.6%
	20	4661	41%	55	21,362	38.2%
	21	4343	48%	62	22,440	40.2%
Total		11462	100%		55,886	100%

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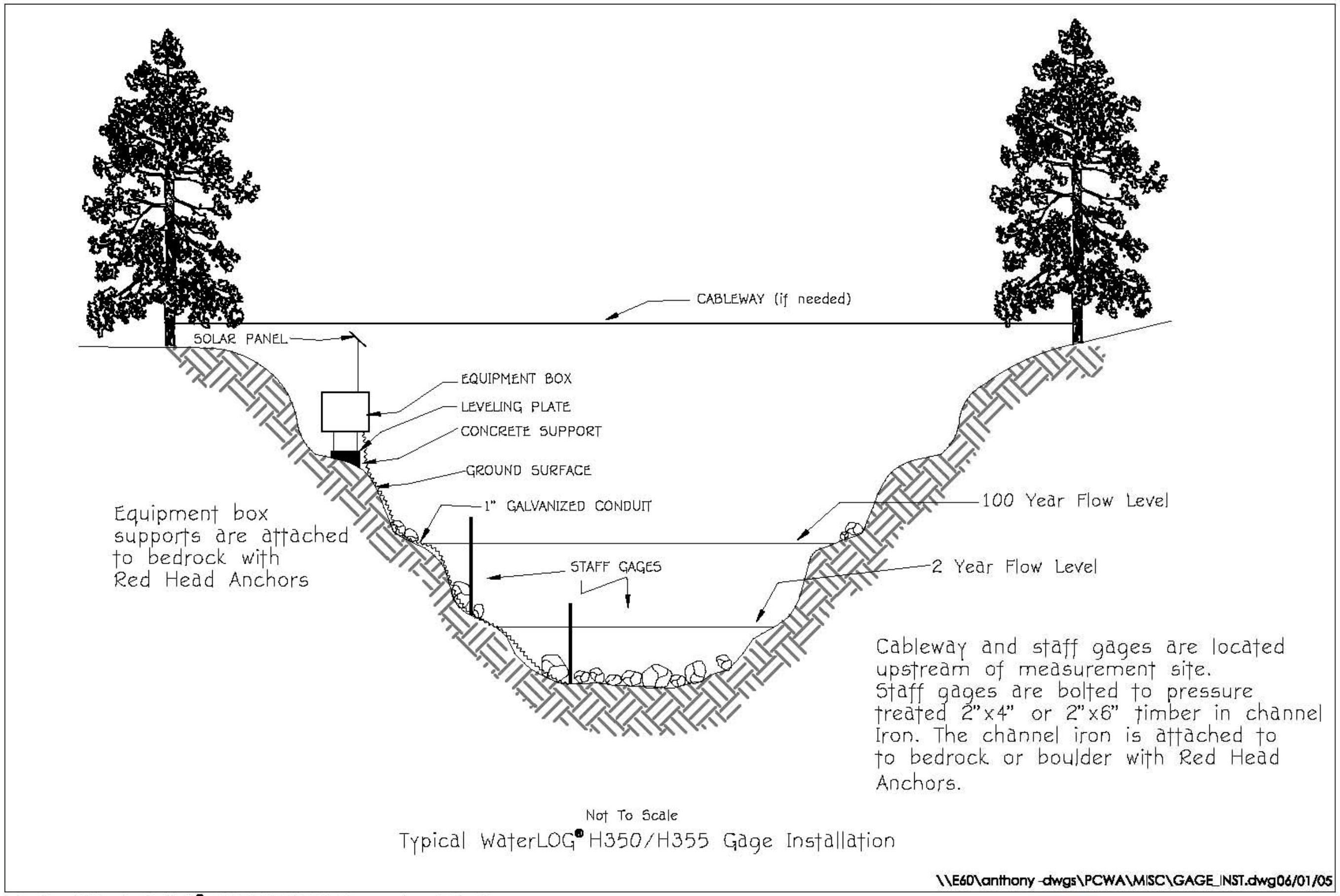
FIGURES

Figure 1. A Typical Cross-Section of the Planned Gage Installations.



Typical WaterLOG® H350/H355 Gage Installation.

2004-005 PCWA-FERC

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS

Figure 2. Data Gaps to be Filled In.

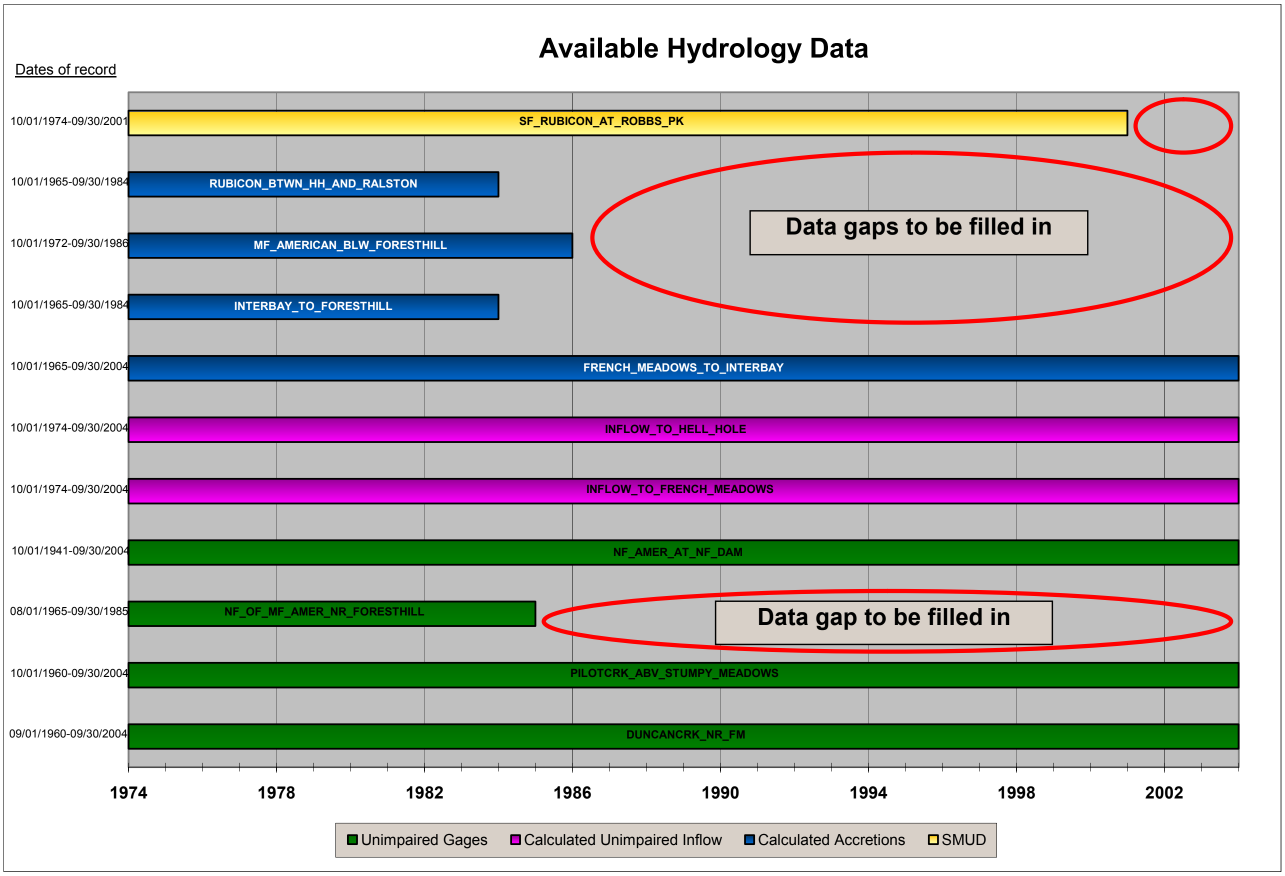


Figure 3. French Meadows and Duncan Creek Regression Analysis.

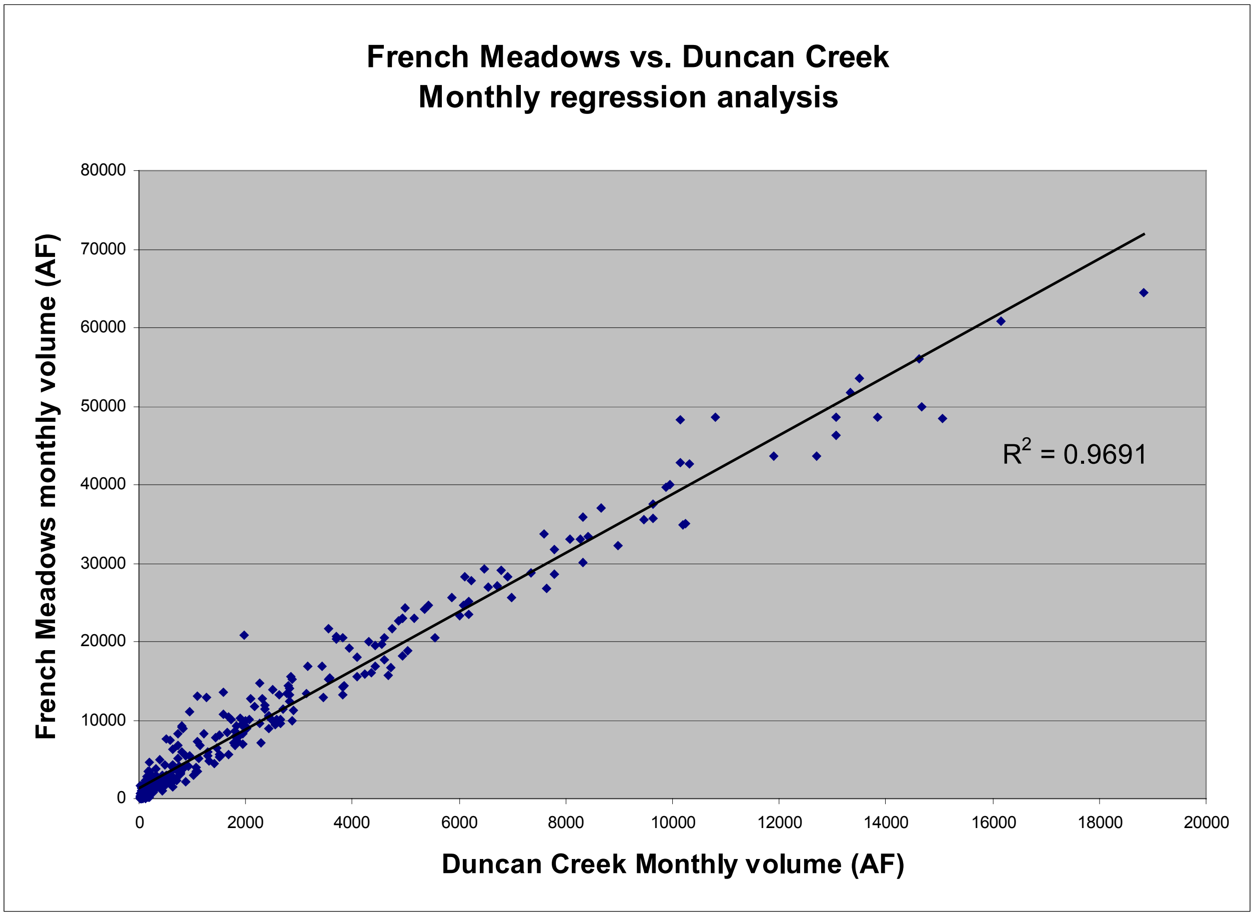


Figure 4. Comparison of Developed Unimpaired French Meadows Record to Originally Calculated Values.

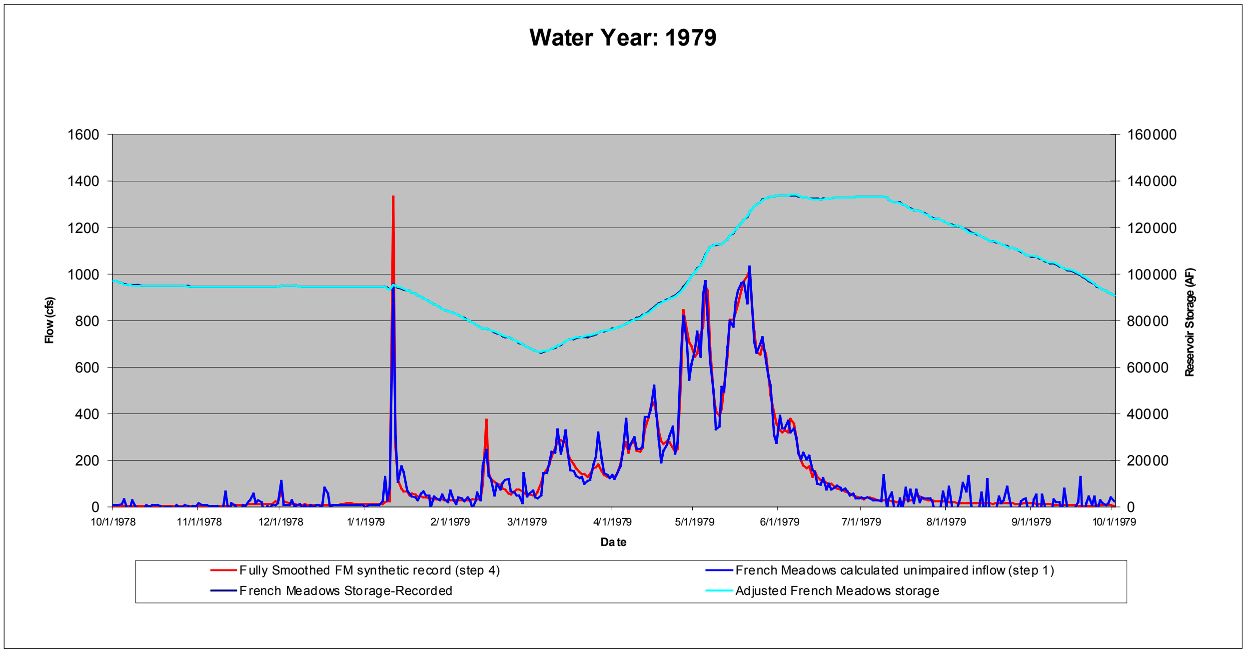


Figure 5. Hell Hole and Duncan Creek Regression Analysis.

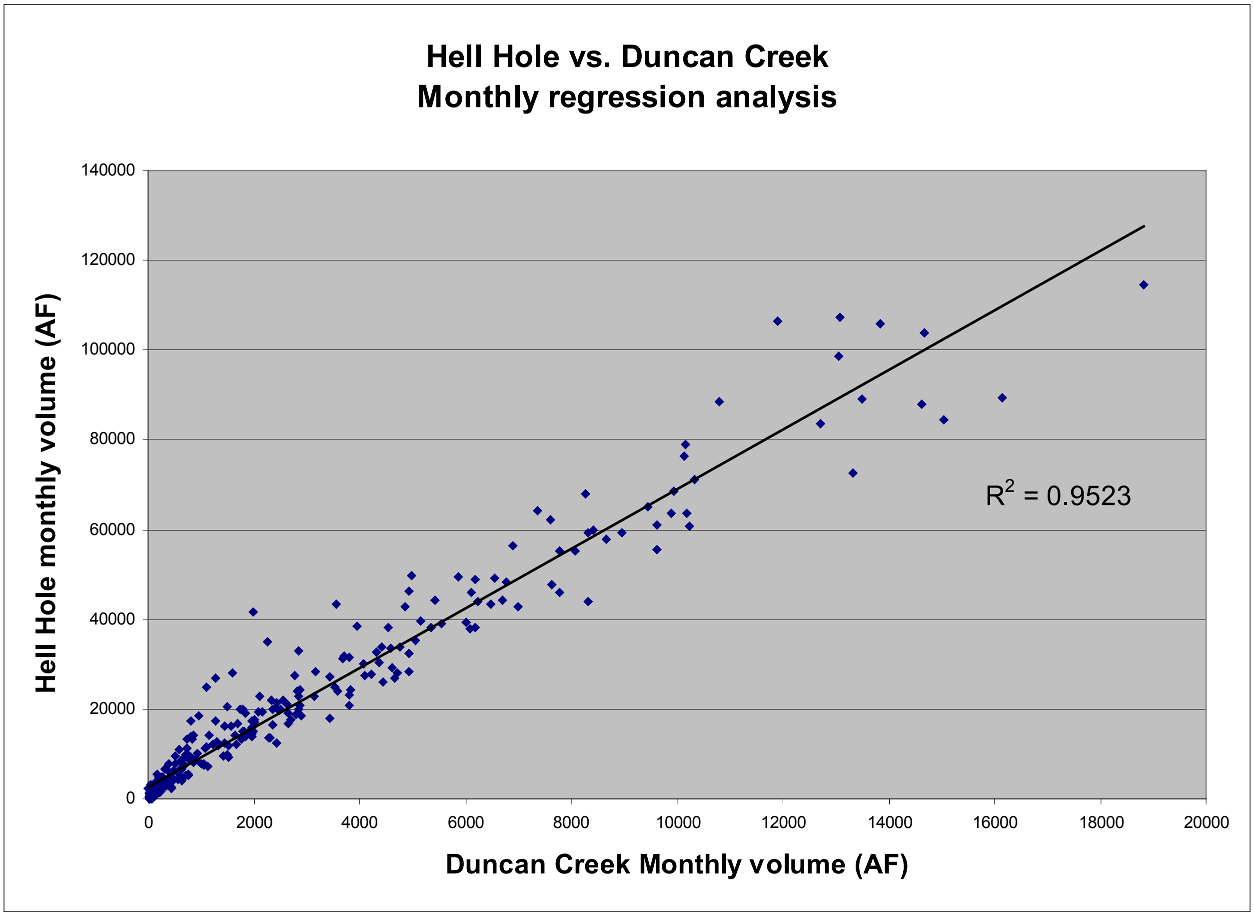


Figure 6. Comparison of Developed Unimpaired Hell Hole Record to Originally Calculated Values.

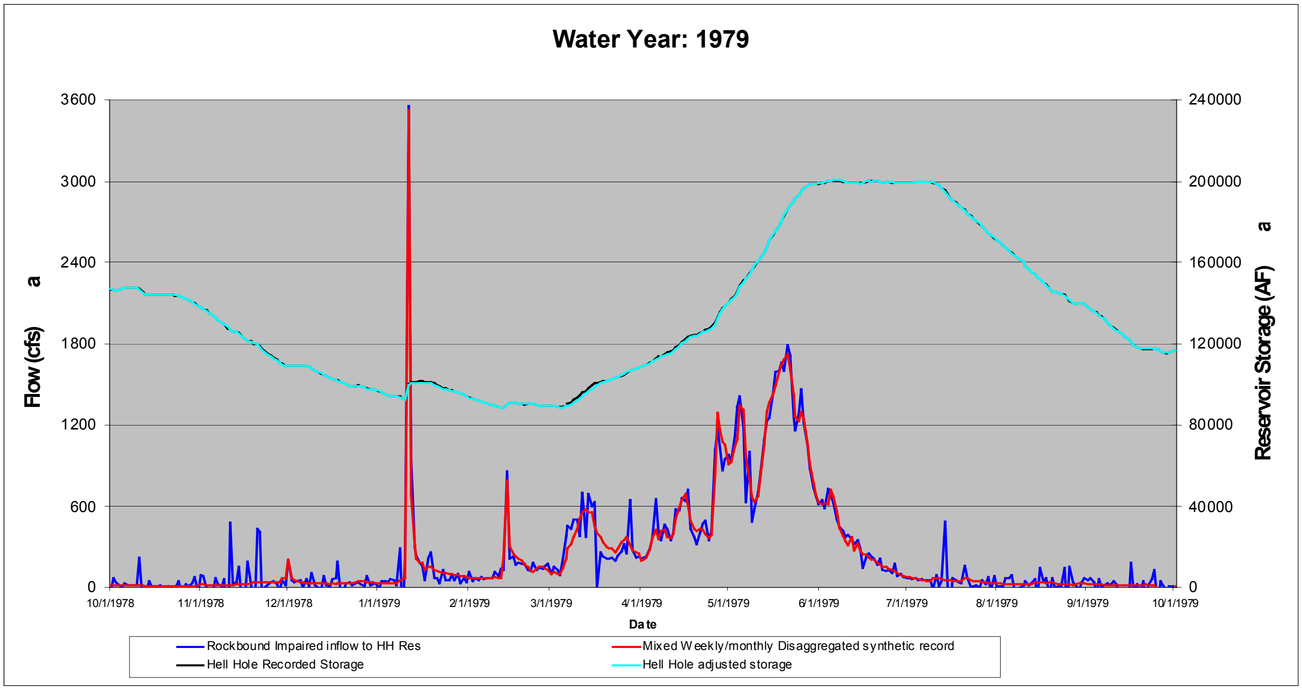


Figure 7. Long Canyon Watershed, Area E.

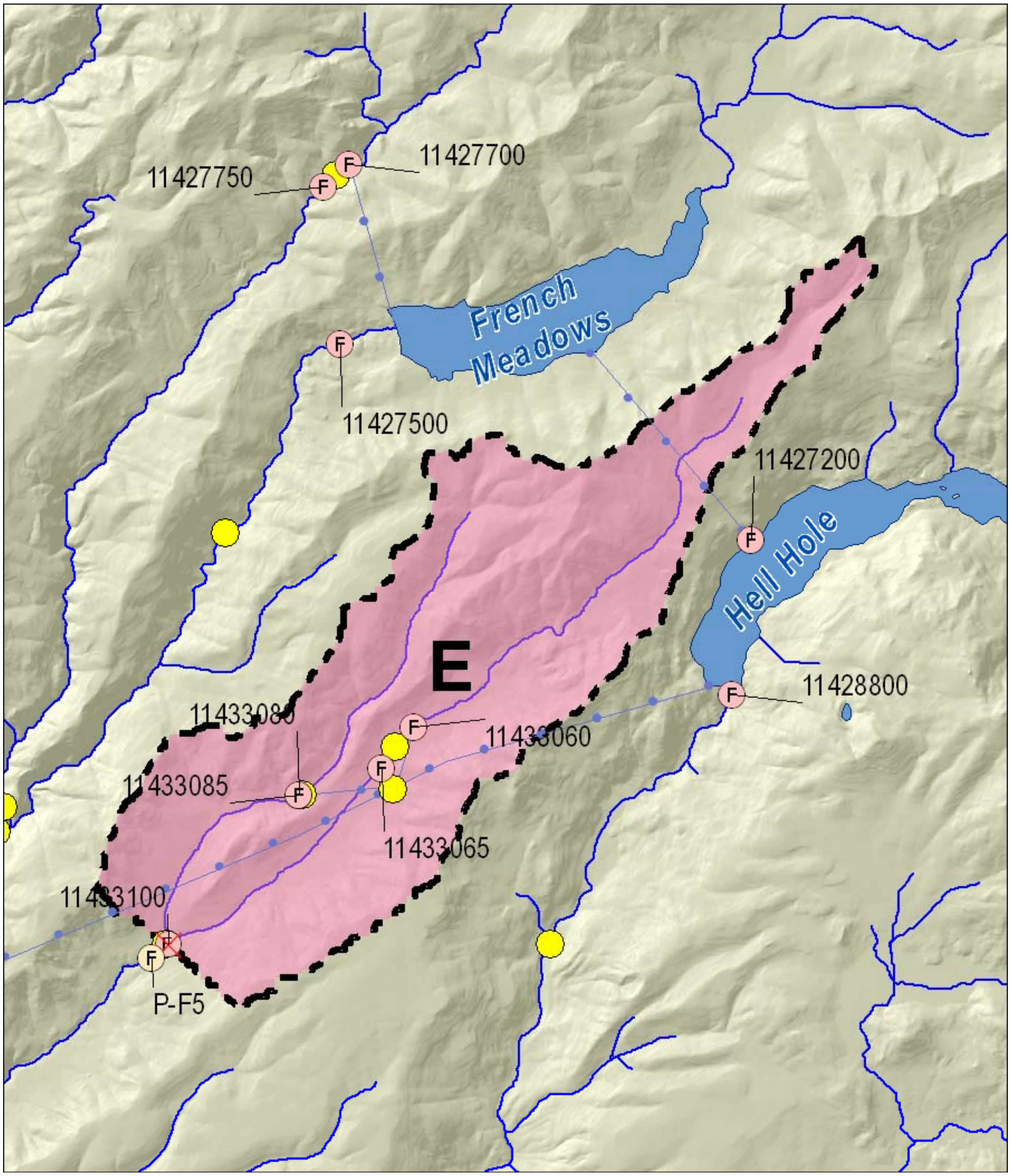


Figure 8. Long Canyon Creek and Pilot Creek Regression Analysis.

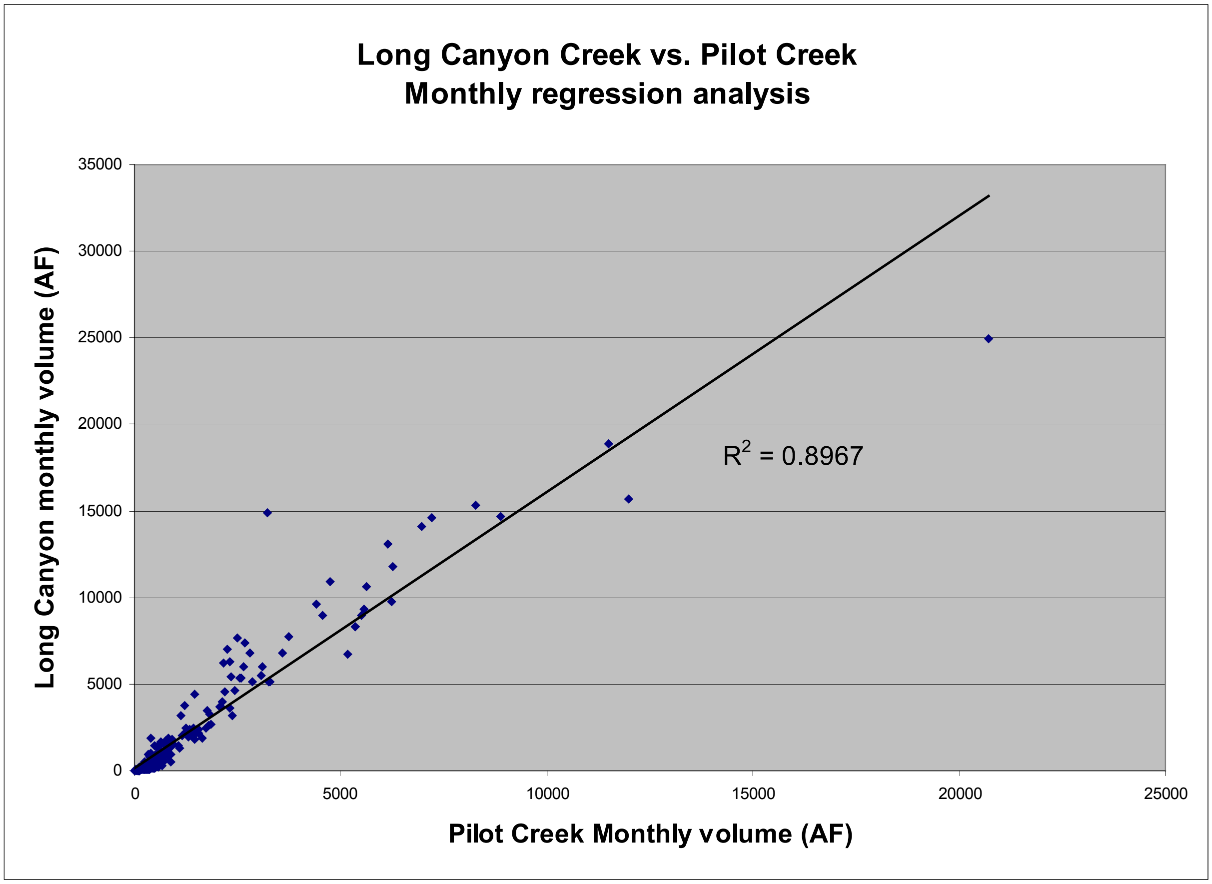


Figure 9. Middle Fork American Watershed, Area A.

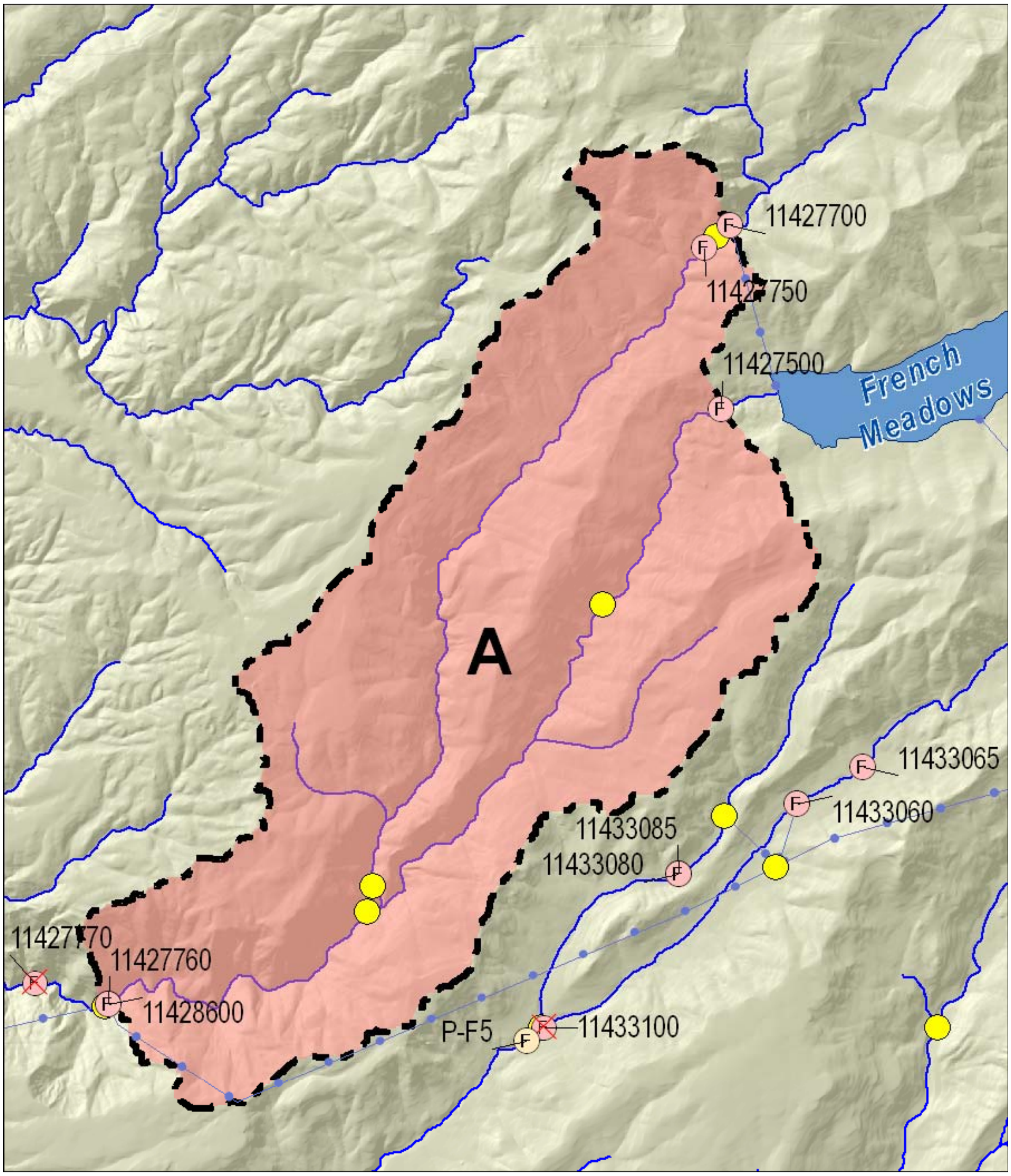


Figure 10. Middle Fork American, Area A, Sub-Watersheds.

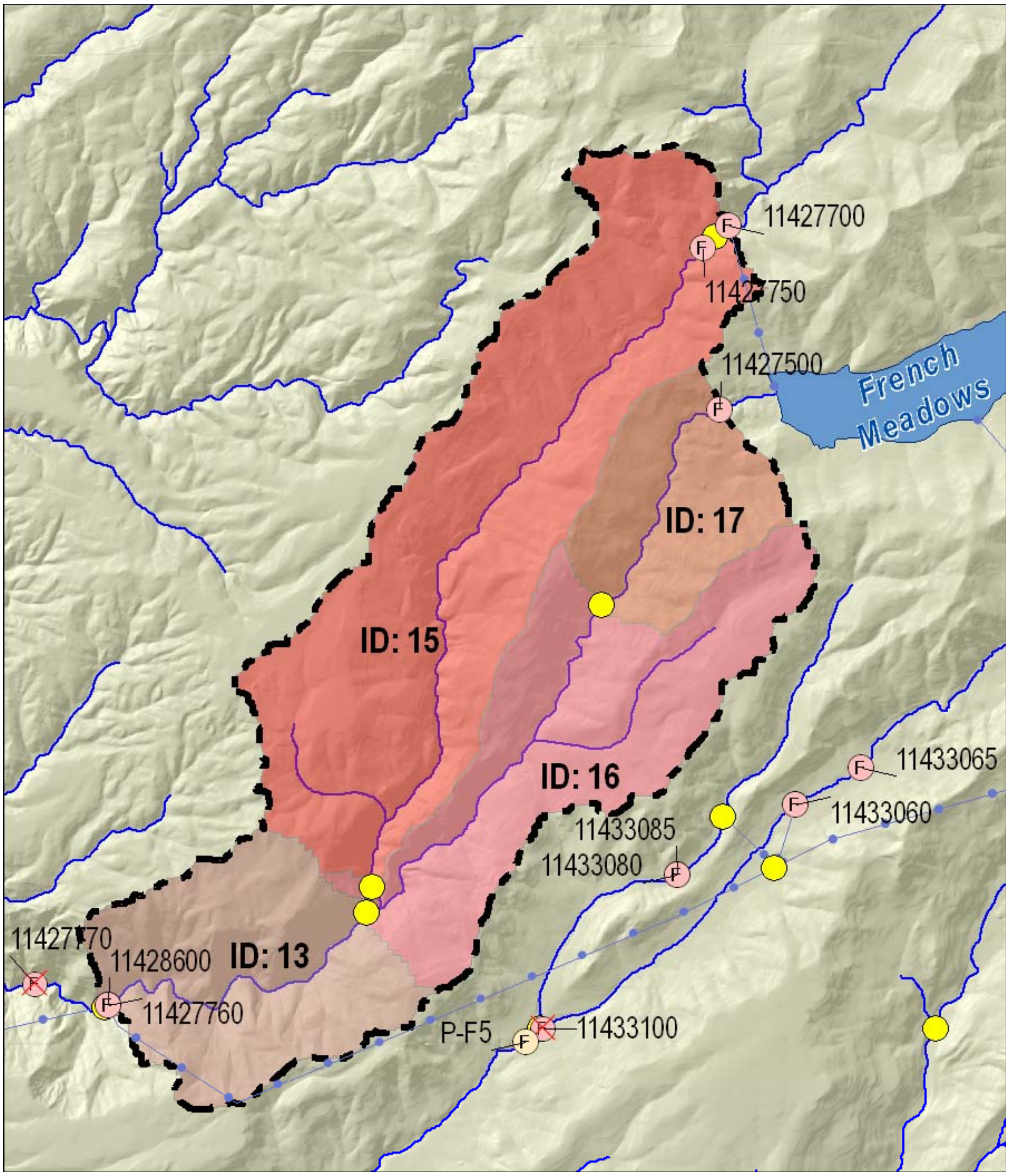


Figure 11. Middle Fork American Watershed, Area B.

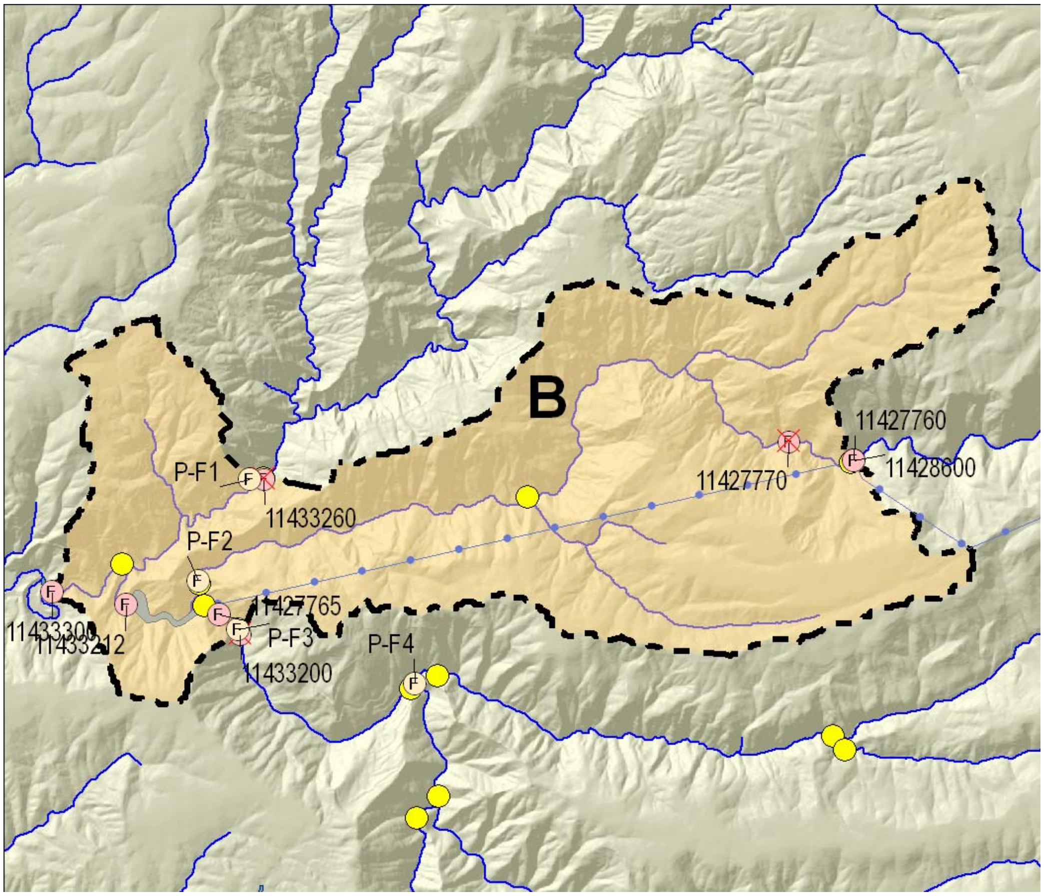


Figure 12. Middle Fork American Sub-Watersheds, Area B.

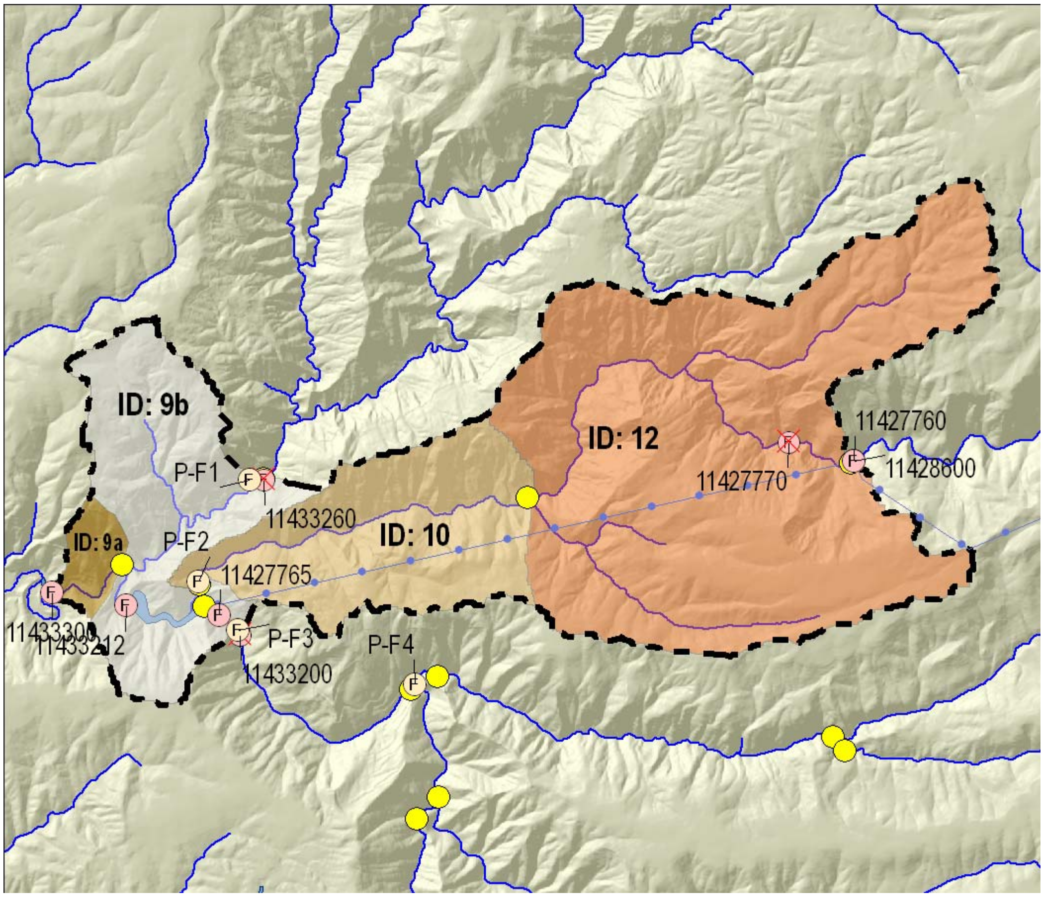


Figure 13. Rubicon, Sub-Watersheds, Area C.

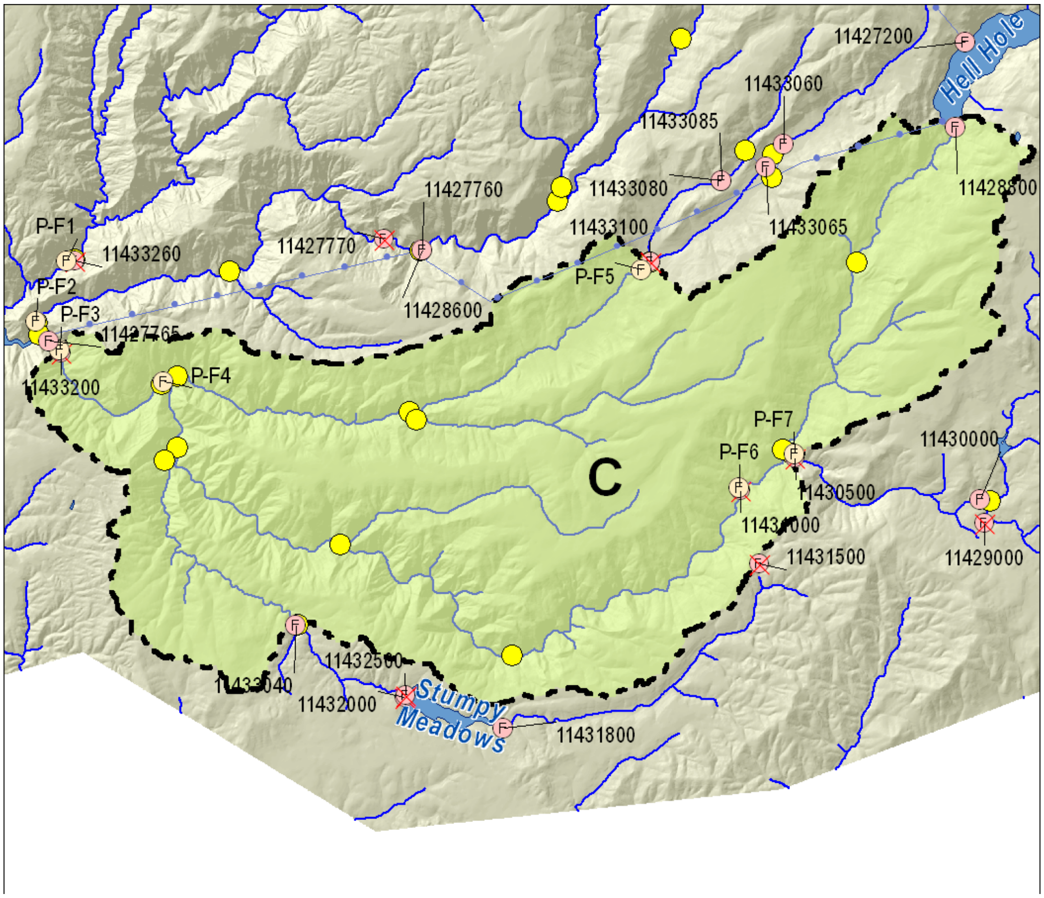


Figure 14. Rubicon, Sub-Watersheds, Area C.

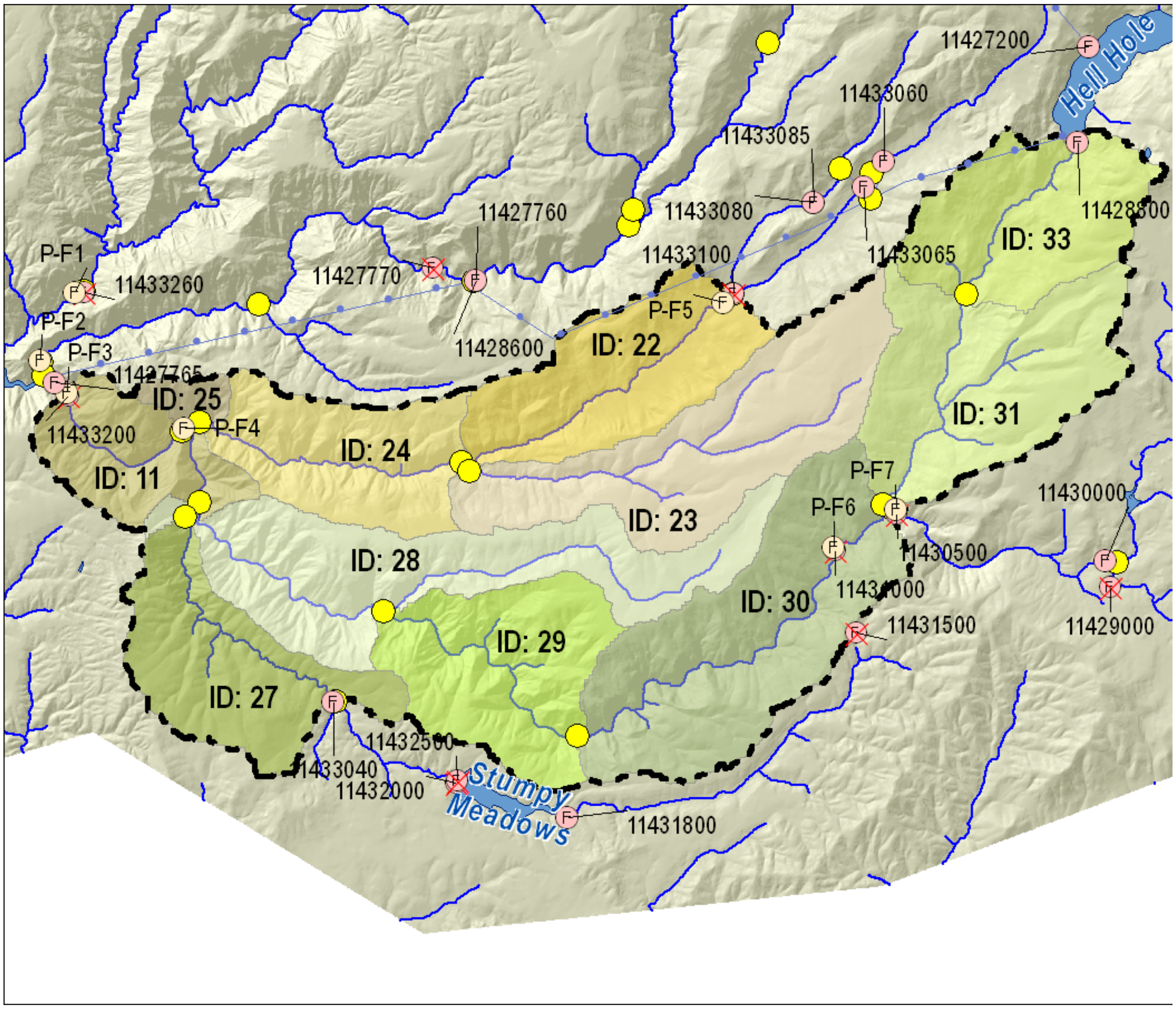


Figure 15. North Fork and Middle Fork American, Watershed Area D.

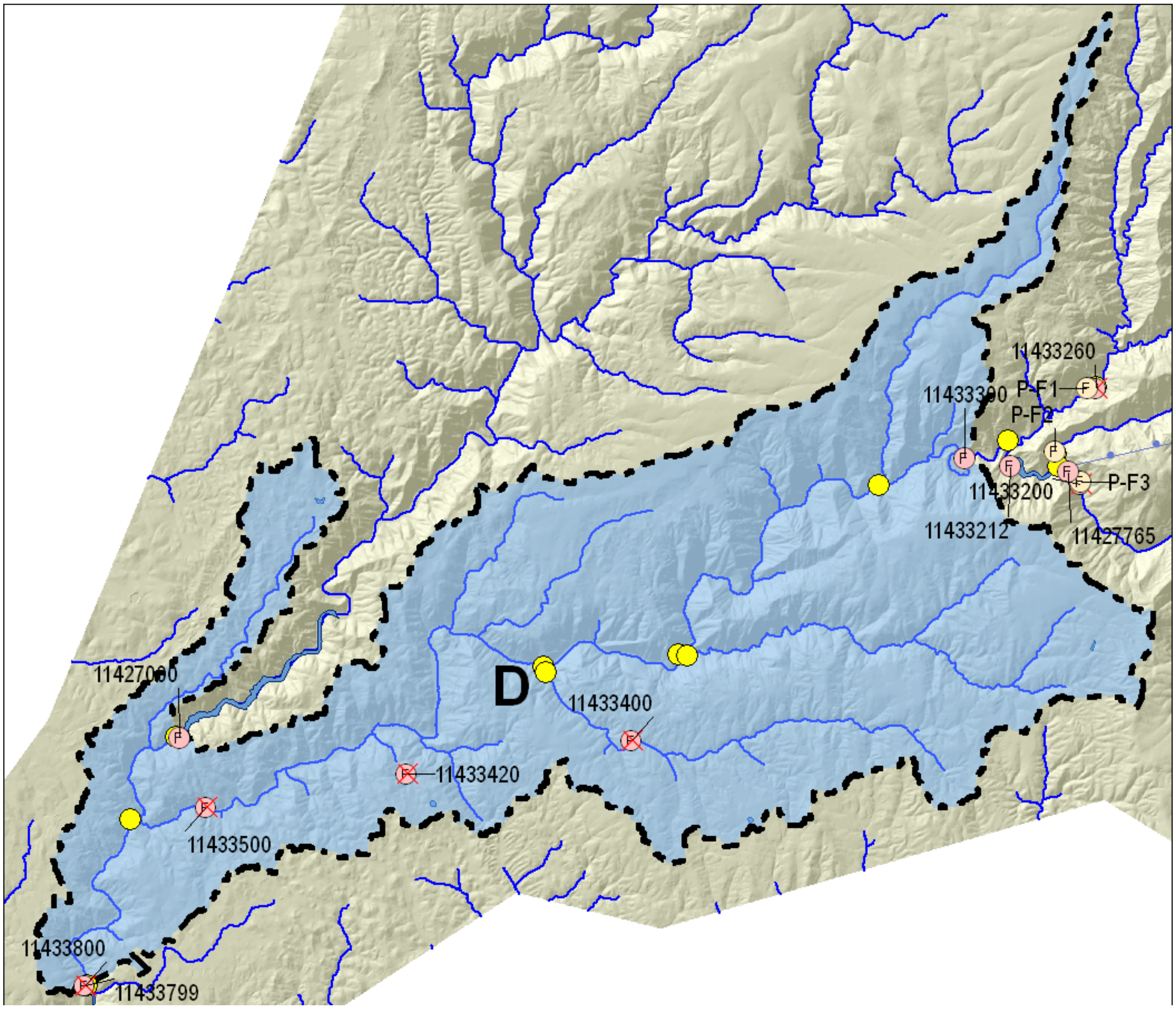


Figure 16. North Fork and Middle Fork American, Sub-Watershed, Area D.

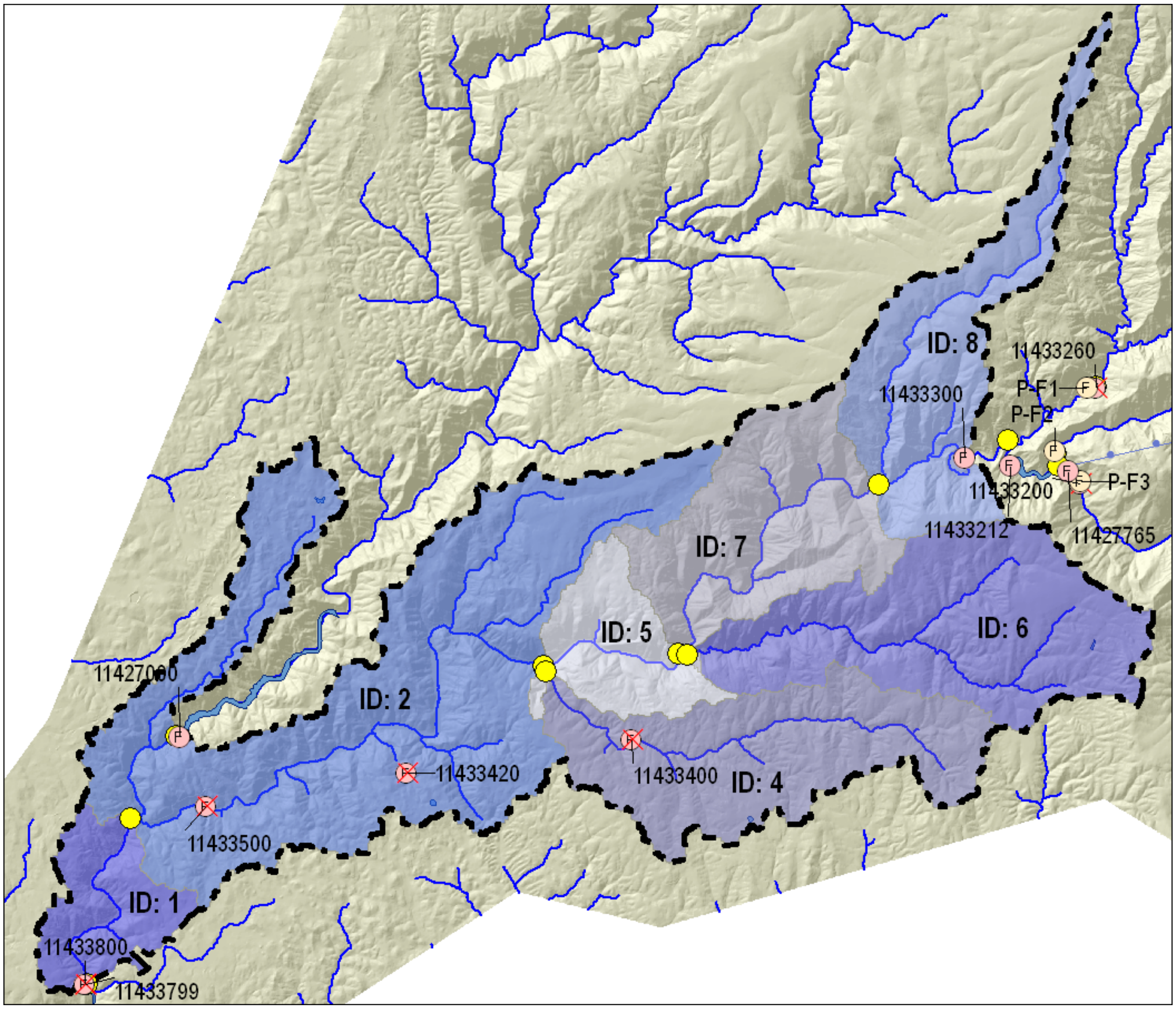


Figure 17. Long Canyon, Sub-Watersheds, Area E.

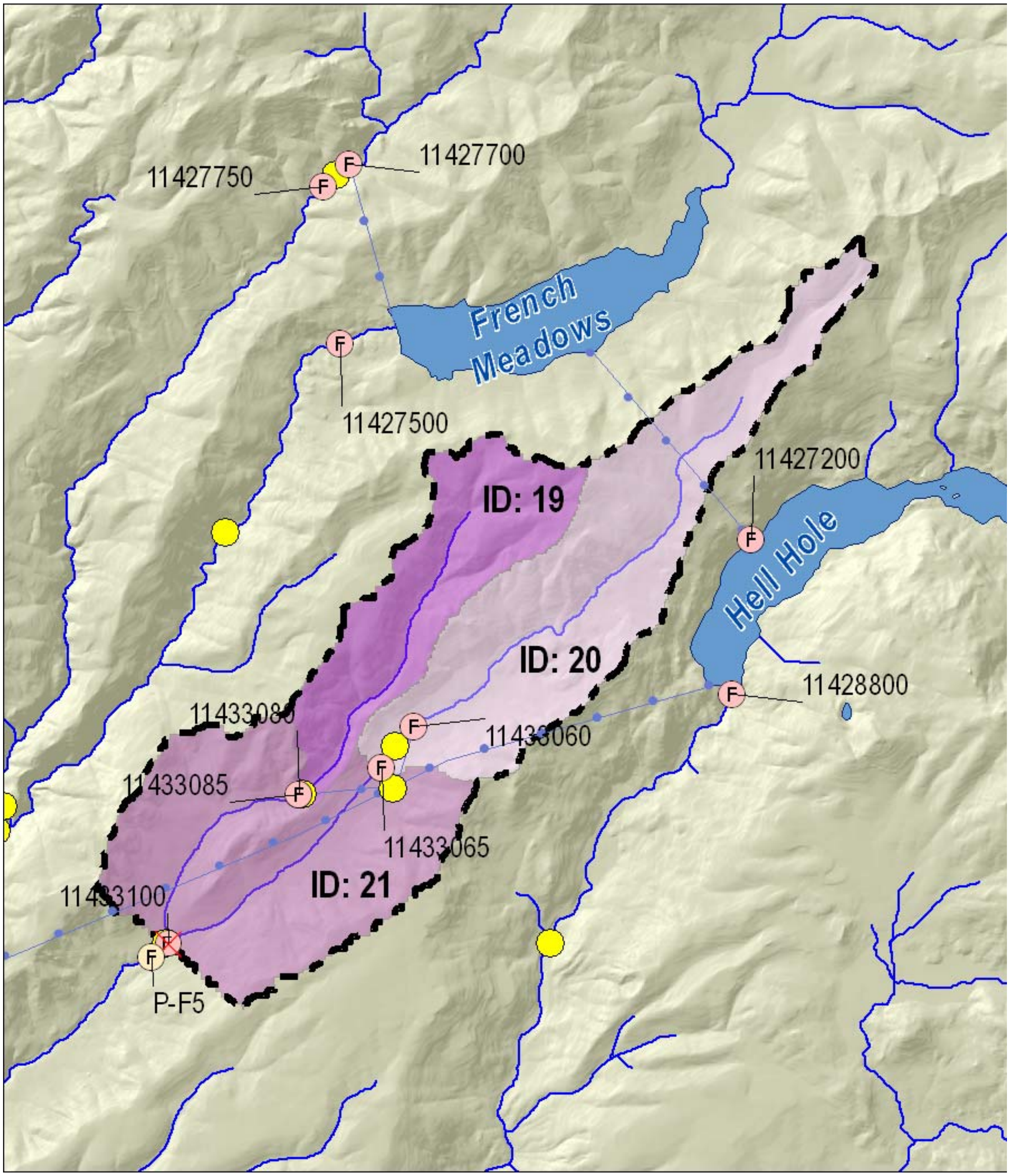


Figure 18. Comparison of daily flows at Pilot Creek above Stumpy Meadows to Flows on the North Fork of the Middle Fork Near Foresthill for Water Year 1983.

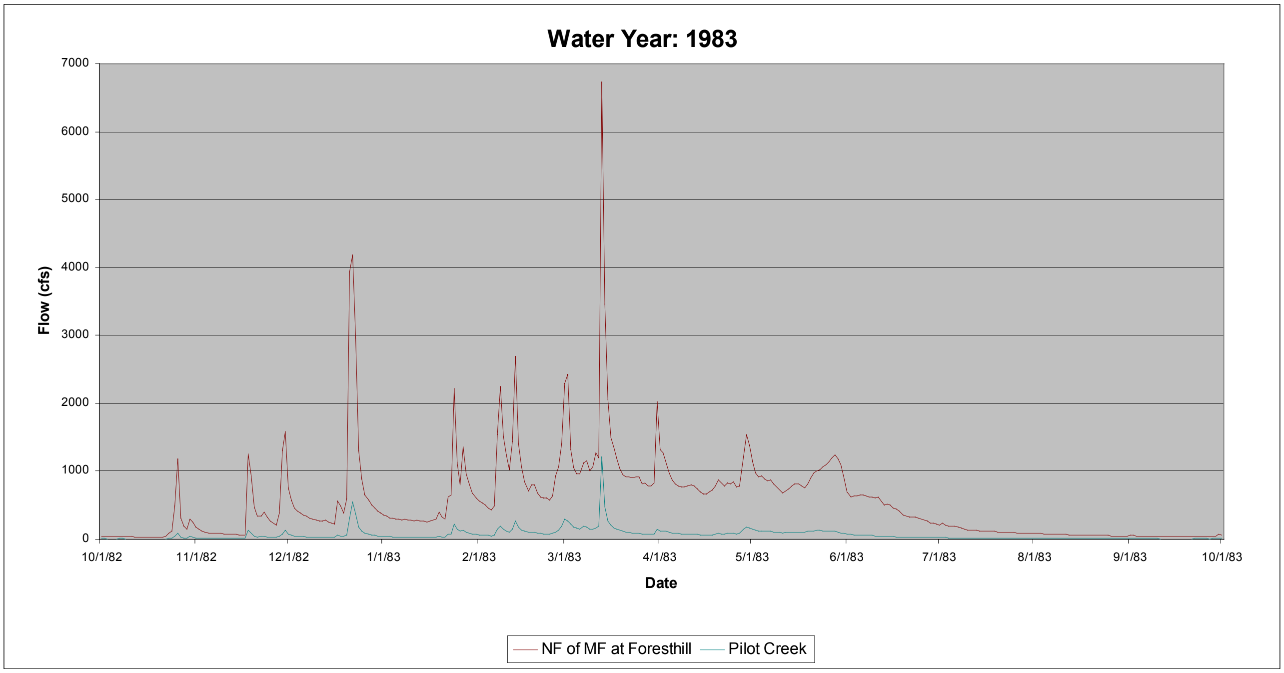
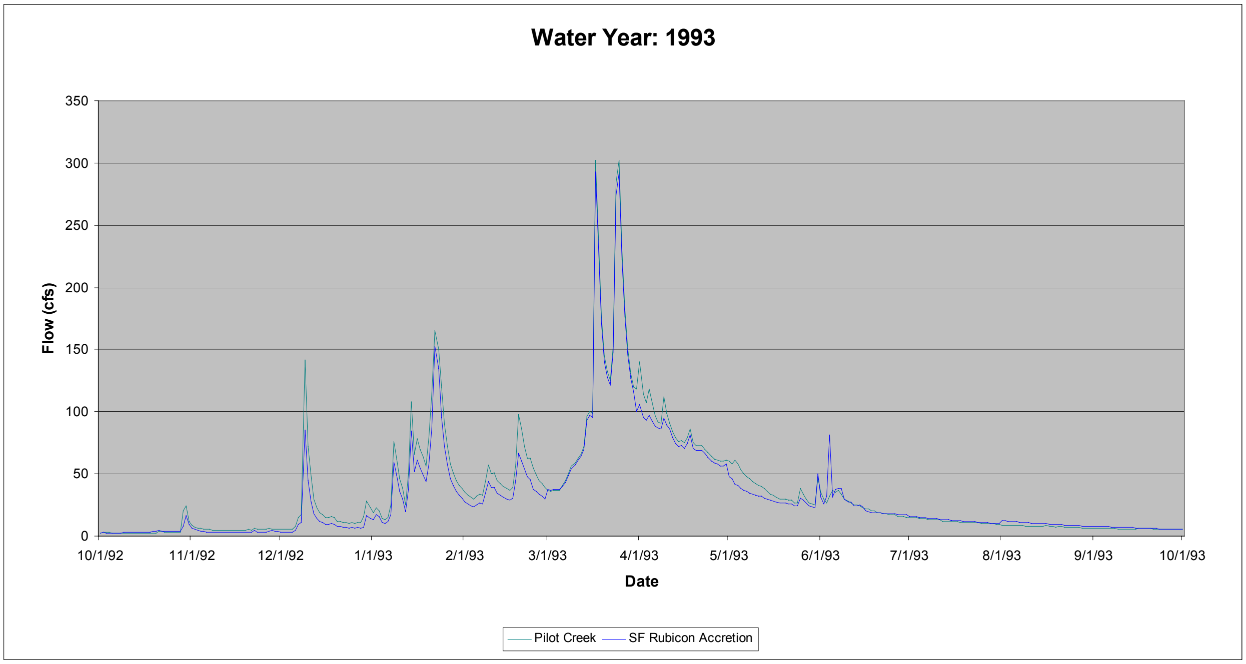


Figure 19. Comparison of Daily Flows at Pilot Creek with SMUD's SF Rubicon Accretion Data.



MAPS

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Placeholder for Map 1

Map 1: Flow Gage Locations

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Placeholder for Map 2

Map 2: Accretion Locations and Basins Map

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