Introduction

The El Dorado Project (Project), identified as Project No. 184 by the Federal Energy Regulatory Commission (FERC), is owned by El Dorado Irrigation District (EID). The Project includes four storage reservoirs (Echo Lake, Silver Lake, Caples Lake and Lake Aloha), water diversion and conveyance facilities, and hydropower generating facilities (Figure 1). The Project is operated for hydropower generation and for consumptive use water supply for El Dorado County.   As part of the FERC process for the relicensing of Project 184, EID is developing operation models of the Project 184 facilities. EID and the collaborative participants have identified a need for a daily timestep model which will be used to investigate system reservoir storage and instream flows for water years 1972 - 1996. EID is also interested in being able to investigate the system capabilities for water supply and hydroelectric generation using a monthly time step over the longer period from water year 1922 through 1996.

A key part of the modeling effort is the development of the hydrology which will be used to drive the operation of the model. This report summarizes the development of the hydrology for the daily model and that developed for the monthly model.

Hydrology Data Requirements

The collaborative participants , EID and its consultants have identified several stream locations in the Project 184 area where daily flow data for the 1972-1996 period are required. The identified stream locations are listed on Table 1 along with the contributing drainage area for each location. The map presented as Figure 1 shows each drainage area of interest, identified by the map number listed on Table 1. Table 1 also identifies the node number which represents the downstream end of each stream reach. The schematics for both models, daily and monthly, are presented as Figures 2 and 3 respectively.

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Table 1

Hydrology Data Requirements

Unimpaired Flow Locations

Map No.	Location	Drainage Area (Sq. Mi.)	Daily Model Node	Monthly Model Node
1	Caples Creek inflow to Caples Lake	13.5	150	150
2	Silver Fork American River inflow to Silver Lake	15.2	175	175
3	Pyramid Creek Inflow to Lake Aloha	3.4	125	125
4	Echo Creek Inflow to Echo Lake	N/A	100	100
5	South Fork American River near Kyburz	193	200	200
6	South Fork American at Echo Conduit	.75	115	
7	South Fork American at Aspen Creek	6.1	117	
8	South Fork American at Sayles Canyon	17.8	120	
9	Pyramid Creek at Twin Bridges	8.8	127	
10	South Fork American River at Pyramid Creek	28.3	130	
11	South Fork American at Strawberry Creek	36.6	133	
12	South Fork American at Silver Fork	79	190	
13	Upper Caples Creek below Kirkwood	8.4	152	
14	Unknown Tributary to Upper Caples Creek	6.4	153	
15	Caples Creek above confluence with Silver Fork	31.6	154	
16	Silver Fork American River at Silver Meadow	15.7	178	
17	Silver Fork American River below Oyster Creek	16.2	178	
18	Silver Fork American River above Caples Creek	23.7	179	
19	Silver Fork American River below Sherman Canyon	72	183	
20	Silver Fork American River at Girard Creek	90	184	

Map No.	Location	Drainage Area (Sq. Mi.)	Daily Model Node	Monthly Model Node
21	Silver Fork American River below Long Canyon	98	185	
22	Silver Fork American River at China Flat	101	187	
23	Silver Fork American River below Beanville Creek	109	188	
24	Silver Fork American River at South Fork American	110	189	
25	Carpenter Creek above the canal	2.17	201	201
26	No Name Creek above the canal	.45	205	205
27	Alder Creek above the canal	22.1	208	208
28	Mill Creek above the canal	3.26	215	215
29	Bull Creek above the canal	.90	225	225
30	Plum Creek above the canal	8.3	240	240
31	Ogilby Creek above the canal	1.22	237	237
32	Esmeralda Creek above the canal	.74	239	239
33	Northside Tributaries	48		
34	Pilot Creek above Stumpy Meadows Lake	11.7	N/A	

Figure 1

To Upper Truckee River

Natural Drainage

997

Echo Lake

100

115 — SF Amer @ Echo Conduit

Echo Lake Diversion

117 — SF Amer @ Aspen Creek

Lake Aloha

125

127

120 — SF Amer @ Sayles Canyon

Pyramid Creek @ Twin Bridges

130 — SF Amer @ Pyramid Creek

Strawberry Creek Accr.

133 — Silver Fk @ SF Amer

SF Amer @ Silver Fork

190

SF Amer. Rvr

Kyburz Diversion

200

EID Canal

203

Carpenter Creek

207

No Name Creek

210

Alder Creek

SF below Alder

220

Mill Creek

SF Below Mill

230

Bull Creek

SF below Bull

240

245

Ogilby Creek

310

SF American

Esmeralda Creek

320 — El Dorado PP

Power Plant Return Flow

330

Folsom Rediversion

999 — Terminal Node

Caples Outlet

151

150 — Caples Lake

Caples Spillway

152 — Upper Caples Crk

Unknown Trib to Upper Caples Crk

153

Caples Crk above confl

Silver Lk Leakage

154

177 — Spillway

175

180 — Silver Lake

179 — Silver Lk Outlet

183

Long Canyon Accr.

184

185

Silver Fork above Caples Crk

187

188

189

Sherman Crk Accr.

Girard Crk Accr.

China Flat Accr.

Beanville Accr.

Carpenter Creek

201

202

No Name Creek

205

206

Alder Creek Inflow

208

212 — Alder Div to EID Cnl

Mill Creek

215

217

Bull Creek

225

227

Plum Creek

Ogilby Creek

237

238

Esmeralda Creek

239

241 — Esmeralda Div

Forebay

300 — EID Forebay Del

900 — Res 1 WTP

910 — El Dorado Hills WTP

EID Project 184 Daily Schematic

Figure 2

Figure 3

Data Inventory

Analysis of Project 184 will be based upon historic streamflow and reservoir data of the South Fork watershed. Many of these records are published by the U.S. Geological Survey (USGS). No historic records have been compiled at some of the study sites. As a consequence, it is necessary to estimate historic streamflow at these locations from existing hydrologic records. Where sufficient data exist, unimpaired estimates were made with mass balance calculations. Where partial records existed, the unimpaired estimates were made using correlations with long term gages. Where no historic information had been recorded, the estimates of unimpaired flow were made by using area/precipitation relationships.

Existing Long Term Recording Gages

Flow and lake levels in the Project 184 area are measured at twelve gaging stations historically maintained by PG&E (now maintained by EID) in cooperation with the U.S. Geological Survey. A thirteenth gage, Pilot Creek above Stumpy Meadows Dam, is included because it correlates well with gages within the Project 184 area. The location of these stations are shown on Figure 4 and identified as follows:

USGS gage no. 11336608 (Echo Lake near Phillips, CA). This station is located in Echo Lake, in a concrete block gage house located near the inlet to the Echo Lake conduit. Data is recorded using a Fluid-Gage bellows type manometer connected to a Stevens A-71 graphic recorder, an Acro Systems Data Logger, and a potentiometric output. These devices input into a Remote Terminal Unit (RTU) for compliance with the Emergency Action Plan dam failure monitoring program as required by the FERC. This station measures water surface elevation in Echo Lake.

USGS gage no. 11434500 (Echo Lake Conduit, near Phillips, CA). This station is located in the Echo Lake Conduit. Data is recorded using an Acro Systems data logger and Stevens A-71 recorder. This station measures and records flows released from Echo Lake, into the SFAR, through the Echo Lake Conduit.
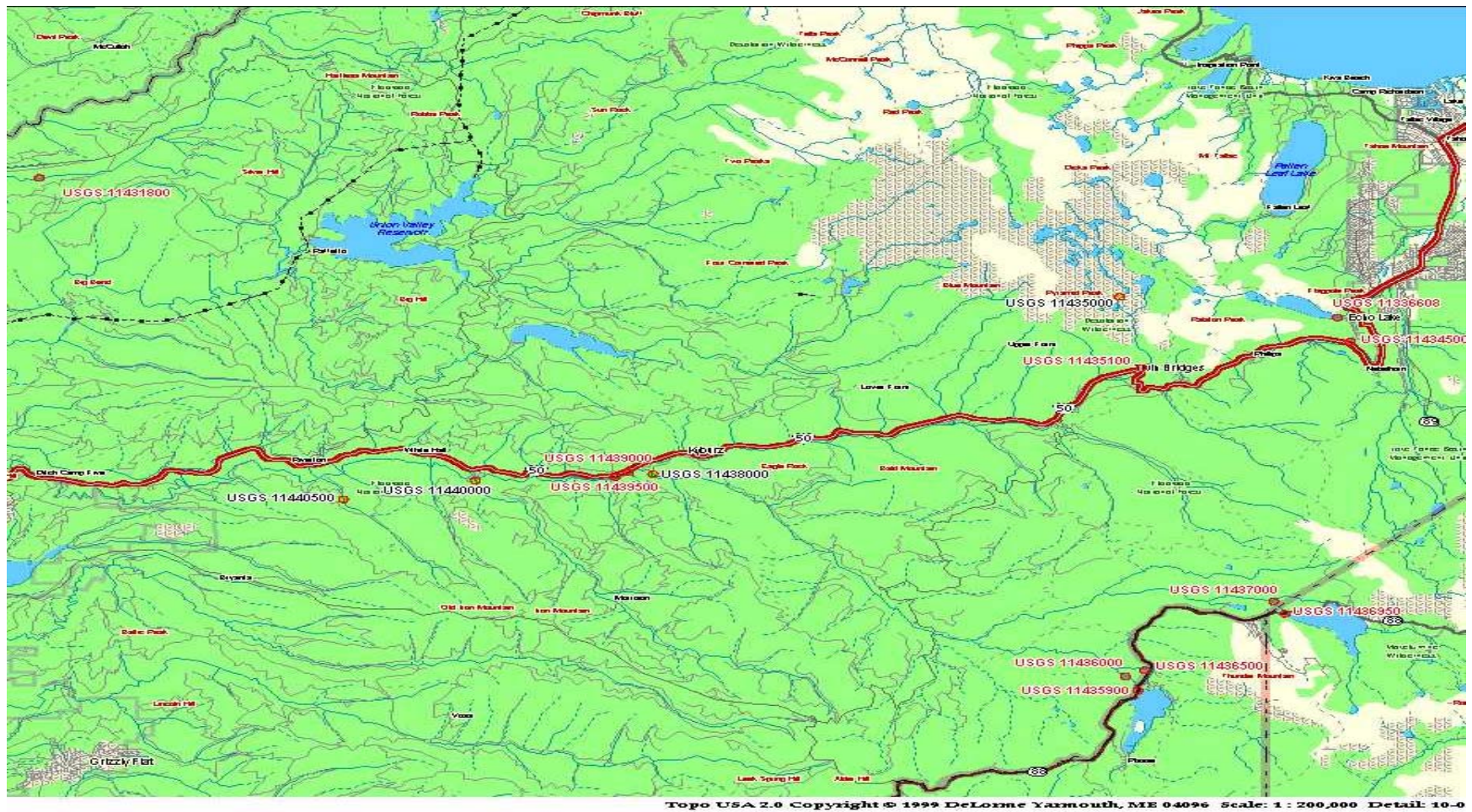
Figure 4

USGS gage no. 11435100 (Pyramid Creek at Twin Bridges, CA). This station is located on the right bank of Pyramid Creek, 0.5 miles northeast of Twin Bridges and 2.2. miles west of Phillips in the northwest (NW) quarter of the southwest (SW) quarter of Section 9, Township 11N, Range 17E. Data is recorded using an Acro Systems data logger and a Stevens A-71 recorder on separate floats. This station measures and records flows released from Lake Aloha into Pyramid Creek.

USGS gage no. 11436950 (Caples Lake near Kirkwood, CA). This station is located on Caples Lake dam near the center of the earthfill portion, 1.3 miles east of Kirkwood, in the SW quarter of the SW quarter of Section 18, Township 10N, Range 18E. Data is measured using a Stevens A-71 recorder driven by a Fluid Gage in a large wood box located just inside the gage house. An Acro Systems data logger and RTU are attached. This station measures water surface elevations at Caples Lake.

USGS gage no. 11437000 (Caples Creek Release below Caples Dam, near Kirkwood, CA). This station is located on the right bank of Caples Creek, 500 feet downstream from the main dam and 1.3 miles east of Kirkwood. Data is recorded using a Stevens A-71 recorder and an Acro Systems data logger and RTU on separate floats. This station measures and records flows released from Caples Lake into Caples Creek.

USGS gage no. 11435900 (Silver Lake near Kirkwood, CA). This station is located on the outlet structure in Silver Lake in the NW quarter of the SE quarter of Section 32, Township 10N, Range 17E. Data is recorded using an Acro Systems data logger connected to a Stevens A-71 recorder. This station measures water surface elevation in Silver Lake.

USGS gage no. 11436000 (Silver Lake Outlet near Kirkwood, CA). This station is located on the right bank of the Silver Fork of the American River downstream from Silver Lake Dam and 3.5 miles southwest of Kirkwood in the NE quarter of the SW quarter of Section 32, Township 10N, Range 17E. Data is recorded using a Stevens A-71 recorder and an Acro Systems data logger and RTU on separate floats. This station measures and records flows released from Silver Lake into the Silver Fork of the American River.

USGS gage no. 11436500 (Silver Lake Leakage No. 1 near Kirkwood, CA). This station is located on the left bank of a small stream at the culvert in the campground on the south side of Highway 88, in the SW

quarter of the NE quarter of Section 32, Township 10N, Range 17E. Data is measured using a staff gage.
This station measures leakage from Silver Lake.

USGS gage no. 11439500 (South Fork American River near Kyburz, CA). This station is located on the
right bank of the SFAR, 0.8 miles downstream from the Silver Fork American River confluence, 1.9
miles southwest of Kyburz in the SW quarter of the SW quarter of Section 29, Township 11N, Range
15E. Data is recorded using an Acro Systems data logger, with a stand-alone encoder and Stevens A-71
recorder on separate floats. There is also a Sierra Control Systems remote radio transmitting recorder on
another float. This station measures flow in the SFAR, below the El Dorado Diversion Dam.

USGS gage no. 11439000 (El Dorado Canal near Kyburz, CA). This station is located on the left bank of
the El Dorado Canal, 400 feet downstream from the intake and 1.5 miles southwest of Kyburz in the SW
quarter of the SE quarter of Section 29, Township 11N, Range 15E. Data is recorded using an Acro
Systems data logger and Stevens A-71 recorder on the same float. There is also a radio transmitter gage
on a separate float. This station measures flow diverted from the SFAR into the El Dorado Canal.

USGS gage no. 11439501 (Total River Flow). No actual station exists at this location. Data from this
gage represents total flow in the SFAR, upstream of the Kyburz Diversion Dam. Flow is computed by
summing the data collected at stations 11439500 and 11439000.

El Dorado Main Canal: This station is located in EID's main water supply canal. Data is recorded using
an A-18 Recorder. This station measures the amount of water discharged from Forebay Reservoir into
the EID's main water supply canal.

USGS gage no. 11431800 (Pilot Creek Above Stumpy Meadows Lake, CA.) This station is located on
the right bank of Pilot Creek, 2.1 miles upstream from Stumpy Meadows Dam and 12.5 miles east of
Geaorgetown in the NE quarter of the NW quarter of Section 18, Township 12N, Range 13E.   With a
drainage area of 11.7 square miles, this station has runoff characteristics which are similar to the area
tributary to SFAR downstream of Kyburz and upstream of the confluence of Silver Creek.

Discontinued USGS Recording Gages

In addition to the existing recording gages in the Project 184 area, there are four discontinued gages which were used to provide flow information about the basin. These gages are:

USGS gage no. 11438000 (Silver Fork of the South Fork American River near Kyburz, CA) This gage was located at approximately Latitude 38° 46' 20" Longitude 120° 16' 50" on the Silver Fork just upstream of the confluence with the South Fork American River. The gage measured the runoff from a drainage area of 107 square miles and was operated from October 1, 1924 through September 30, 1944 by the USGS.

USGS gage no. 11435000 (Pyramid Creek near Philips, CA) This gage was located at approximately Latitude 38° 50' 55" Longitude 120° 07' 40" on Pyramid Creek just downstream from Lake Aloha. Drainage area above the gage is 3.73 square miles. The gage was maintained at this location from October 1, 1960 through September 30, 1970.

USGS gage no. 11440000 (Alder Creek near White Hall, CA) This gage was located on the right bank of Alder Creek, 0.9 of a mile upstream of the mouth and 2.2 miles SE of White Hall in the NE quarter of the SE quarter of Section 35, Township 11N, Range 14E. Alder Creek, with a drainage area of 22.1 square miles, is the largest stream tributary to the El Dorado Canal. The USGS operated the gage from October 1, 1922 until September 30, 198. Recently, EID has reestablished a recording gage at this location.

USGS gage no. 11440500 (Plum Creek near Riverton, CA) This gage was located at approximately Latitude 38° 45' 15" Longitude 120° 25' 35" on Plum Creek just upstream of the El Dorado Canal. Its drainage area of 7.32 square miles at the gage, make it the second largest steam crossed by the canal. Plum Creek, unlike Alder Creek, can not be diverted into the canal. The gage was maintained from October 1, 1922 through September 30, 1939.

EID Data

As part of the Project 184 FERC relicensing process, EID has installed 26 continuous recording gages and 20 staff gages. Beginning in October 1999, EID has collected gage readings and recorded staff gage readings weekly. Much of this data has been used to develop unimpaired flow estimates which will be used in the modeling process.

 Some of the recording gages were previously operated by PG&E in cooperation with USGS and are part of the long term data base of the Project. The operation of these gages was assumed by EID when they acquired Project 184. Other recording gages were installed to aid in the analysis of the Project 184 impacts.

Name	EID Station ID	Established
Aloha Lake	A-1	
Echo Creek	A-3	10/01/99
Echo Conduit	A-4	10/01/99
Caples Lake	A-5	10/01/99
Caples Creek at Caples Lake outlet	A-6	10/01/99
Silver Lake	A-8	10/01/99
Silver Creek at Silver Lake outlet	A-9	10/01/99
El Dorado Canal at diversion	A-11	10/01/99
South Fork American River below diversion	A-12	10/01/99
Oyster Creek at Silver Lake outlet	A-24	05/05/00
Pyramid Creek above Hwy 50	A-40	10/01/00
Medley Lake outlet	A-2	
Alder Creek below diversion	A-13	01/11/00
Alder Creek diversion above canal diversion	A-14	
El Dorado Forebay	A-17	
Forebay outlet to EID	A-18	10/01/99

Forebay outlet to penstock	A-19	
Echo Spill to Tahoe	A-43	10/01/99
At flume 52A	A-45	
At Camp 5	Camp 5	
Caples Creek 0.4 mi upstream	A-6-A	10/09/99
Caples wing dam spill	A-7	
Silver Creek upstream of Caples confluence	A-9-A	10/09/99
Mill Creek above diversion	A-10	10/01/00
South Fork American River above Silver Fork	A-10-A	04/01/00
Oyster Creek downstream Hwy 88	A-24-A	07/29/00

In addition to the recording gages operated by EID, the district has installed 20 staff gages at the locations listed below. The gages are non-recording and are generally read once a week.

Name	EID Station ID	Established
Esmeralda Creek above Hwy 50	T-1	10/08/99
Esmeralda Above Diversion	T-2	10/08/99
Esmeralda Creek below Canal	T-3	01/24/00
Ogilby Creek above confluence	T-4	10/19/99
Ogilby Diversion Flume	T-5	10/18/00
Ogilby Creek above diversion	T-6	11/16/99
Bull Creek above confluence	T-7	10/08/99
Bull Creek above diversion	T-8	10/08/99
No Name Creek above diversion	T-9	10/04/99
Carpenter Creek above diversion	T-10	10/04/99
Strawberry Creek 0.5 mi. above confluence	T-11	12/01/99
South Fork American River above Pyramid Creek	T-12	10/04/99
South Fork American River above Echo Conduit	T-13	10/08/99
Long Canyon Creek near confluence	T-14	10/04/99

Sherman Canyon Creek near confluence	T-15	10/04/99
Mill Creek above confluence	T-16	04/11/99
Bull Creek diversion flume	T-17	
Mill Creek above canal	T-18	
No Name feeder	T-19	12/20/00
Carpenter feeder	T-20	

Unimpaired Flow Estimates

In the past, unimpaired data for the South Fork American River has been developed by Borcalli and Associates with further development by Resource Insights (daily time step for 1972-1996), California Department of Water Resources (monthly time step for 1922-1996), and Sierra Hydrotech (monthly timestep for 1922-1978). Each of these data sets were developed by slightly different methodologies for different purposes. While each data set covers some different stream locations, all the data sets have three common locations; Caples Lake Inflow, Silver Lake Inflow and South Fork American River near Kyburz. In this section of the report, we look at each data set, its derivation and determine their usefulness in FERC Project 184 process.

Borcalli and Associates / Resource Insights Data

The original unimpaired flow data for Project 184 was developed by Borcalli and Associates and was published in a report dated 1999.   Resource Insights used the data from the Borcalli report and adjusted the data to remove negative flows by dissipating the errors on a monthly basis. Resources Insights then used Blackwood Creek data to parse the monthly data into simulated daily flows for some of the locations of interest. The following, presented in italics, is a description of the methodologies used by Resource Insights, Inc. excerpted from a draft report prepared by Resource Insights, Inc.

Mean daily unimpaired streamflow are estimated for the following Project study sites. The primary methodology used to estimate unimpaired flow at the location is noted in parenthesis.

- *Streamflow below Silver Lake (Mass balance)*

- *Streamflow of Silver Fork of the South Fork American River at Confluence with Caples Creek, not including Caples Creek (Area/precipitation)*

- *Streamflow below Caples Lake (Mass balance)*

- *Streamflow of Caples Creek at confluence with Silver Fork of South Fork American River, not including Silver Fork   (Area/precipitation)*

- *Streamflow of Silver Fork of South Fork of the American River at China Flat (Area/precipitation)*

- *Streamflow of Silver Fork near confluence with South Fork of the American River (Area/precipitation)*

- *Streamflow of upper South Fork of the American River at confluence with Aspen Creek (does not include Aspen Creek) (Area/precipitation)*

- *Streamflow of Pyramid Creek below Lake Aloha (Mass balance)*

- *Streamflow of Echo Creek below Echo Lake*

- *Streamflow of South Fork of the American River near Kyburz diversion (Mass balance)*

Methodology

The mean daily unimpaired streamflow is the historic impaired streamflow adjusted to reflect impacts of upstream reservoir operation and diversions. Unimpaired streamflow is not measured directly and must be estimated. Theoretically, mean daily unimpaired streamflow can be calculated using a mass balance approach. Because of data measurement error, incomplete and missing data, and data inconsistencies, this approach does not provide adequate results for the intended use of this streamflow information. To better estimate the mean daily unimpaired streamflow below each reservoir, a paired basin approach is used. A gaged unimpaired

watershed similar to our study watersheds is used to estimate the streamflow at study sites.

Several unimpaired basins in the area were investigated to find the most suitable for estimating streamflow on the upper South Fork American River watersheds. Blackwood Creek near Tahoe City, CA (USGS No. 10336660) was chosen as the most suitable basin. Blackwood Creek is located on the east side of the Sierra Nevada Mountains north of the South Fork of the American River basin and drains into Lake Tahoe. The 11.2 square mile basin ranges in elevation of about ???? feet down to about 6200 feet at the gage site. The USGS lists no known diversion or regulation above this gage.

On a monthly basis, a mass balance approach provides an accurate method to estimate monthly unimpaired streamflow. Data errors associated with streamflow and reservoir storage measurement on a daily basis are dissipated on a monthly basis. For Silver Lake, Caples Lake and Lake Aloha monthly unimpaired flow is calculated using a mass balance technique including an estimate of evaporation using historic evaporation data from the Tahoe City evaporation pan gage.

Blackwood Creek mean daily unimpaired flow is then adjusted based on the ratio of monthly Blackwood Creek unimpaired streamflow and the Project basin unimpaired streamflow being estimated. Monthly adjustments are then modified, when necessary, to provide an adequate estimate of mean daily streamflow. Monthly adjustments are converted into daily adjustments to provide continuous daily adjustment factors. Blackwood Creek mean daily unimpaired data are adjusted by the daily adjustment factors to estimate mean daily unimpaired streamflow at each study site. Detailed methodology used to develop mean daily unimpaired flow at each study site is presented below.

Silver Lake

Mean daily unimpaired streamflow below Silver Lake was calculated using the releases and spills from the reservoir, the change in storage of the reservoir and the leakage from the reservoir. A portion of Silver Lake leakage is gaged on Oyster Creek. The USGS publishes the station Silver Lake Leakage No. 1 Near Kirkwood Ca (11436500). Oyster Creek originates near Oyster Lake and is described by the USGS as leakage from Silver Lake. The leakage can be detected by witnessing the relatively rapid reservoir stage decrease through the summer months with little or

no releases from the reservoir. Review of leakage indicates that the gage does not measure all of the leakage occurring from Silver Lake. For this analysis it is necessary to estimate the total leakage from Silver Lake.

Because leakage is not directly gaged and no subsurface investigations have been completed, a water-budget is used to estimate the order of magnitude of leakage from Silver Lake. Several parameters must be known or assessed in order to estimate leakage volumes. These parameters include; precipitation, reservoir surface inflow, surface outflow, storage, and evaporation. Using these hydrologic parameters, Equation 1 can be used to estimate leakage from Silver Lake.

Equation 1

SILVER LAKE MONTHLY LEAKAGE WATER-BUDGET

$$LEAKAGE = (STORAGE_1 - STORAGE_2) + SURFACE\ INFLOW + PRECIPITATION - SURFACE\ OUTFLOW - EVAPORATION$$

This approach is simple in theory, but application rarely produces reliable results since all errors in measuring or estimating surface inflow, surface outflow, changes in storage and evaporation are reflected directly in the computed leakage. However, for this analysis this approach should give adequate results.

The hydrologic parameters used in Equations 1 for Silver Lake are as follows:

STORAGE: Silver Lake storage data is available from the USGS.

SURFACE INFLOW: The inflow to Silver Lake is unknown. For this analysis, only dry periods were investigated (July through October). This coincides with times when the inflow to Silver Lake is very small or near zero. This analysis assumes inflow is zero.

PRECIPITATION: Only dry periods were investigated (July through October). This corresponds to periods when precipitation is zero or near zero. This analysis assumes precipitation is zero.

SURFACE OUTFLOW: Silver Lake outflow data are available from the USGS. No in lake

diversions from the reservoir are known and assumed to be zero for this analysis.

EVAPORATION: Evaporation from the reservoir surface is estimated using evaporation pan data and techniques published in the State Department of Water Resources Bulletin 73-79, Evaporation from Water Surfaces in California. Transpiration is relatively small and is considered zero for this analysis.

Total monthly leakage was estimated using Equation 1 for Silver Lake. The leakage is substantially larger than the USGS data on Oyster Creek indicating that Silver Lake leaks in addition to that recorded at the Oyster Creek gage location. Results indicate that Silver Lake could leak up to approximately 1,000 acre-feet per month, if the reservoir were to remain full. Equations used to estimate total monthly leakage from Silver Lake corresponding to reservoir stage are shown below.

Silver Lake Equations used to Estimate Leakage

If reservoir stage > 15.0 feet,	*Leakage = 74.03 × reservoir stage – 680.45*
15.0 ≥ reservoir stage > 13.0,	*Leakage = 66.0 × reservoir stage – 560.00*
13.0 ≥ reservoir stage > 10.0,	*Leakage = 42.1 × reservoir stage – 252.60*
10.0 ≥ reservoir stage > 8.0,	*Leakage = 28.57 × reservoir stage – 114.29*
8.0 ≥ reservoir stage > 0,	*Leakage = 14.28 × reservoir stage – 0.00*

Table 2 lists estimated Silver Lake leakage volumes for a range of reservoir stages.

TABLE 2
ESTIMATED MONTHLY SILVER LAKE LEAKAGE

SILVER LAKE STAGE	ESTIMATED TOTAL MONTHLY LEAKAGE	
(feet)	(acre-feet)	(average CFS)
5	71	1
7	100	2
10	171	3
13	295	5
15	430	7
18	652	11
20	800	13
22.7	1,000	17

The summertime stage of Silver Lake depends highly on its leakage and the timing and volume of surface inflow to the reservoir. By Labor Day, the stage at Silver Lake can be as much as 6 feet below the normal operating maximum of 22.7 feet with no releases in excess of the minimum streamflow maintenance requirement. The reservoir storage is drawn down due to evaporation, streamflow maintenance requirements and leakage.

Monthly unimpaired streamflow below Silver Lake is calculated using a relationship including reservoir releases, spill, leakage, and change in storage .

Silver Lake Unimpaired Streamflow = 11436000 + Leakage + Change in Storage of 11435900 + Evaporation

Silver Lake mean daily unimpaired streamflow is then estimated using Blackwood Creek historic data adjusted using Silver Lake daily adjustment factors determined as described in Section 3.2.

Caples Lake

Mean daily unimpaired streamflow is estimated using the historic release, spill, estimate of evaporation and storage data from the reservoir. The following equation, expressed in USGS identification numbers, is used to estimate the monthly unimpaired streamflow below Caples Lake.

Caples Lake Unimpaired Streamflow = 11437000 + Change in Storage of 11435900 + Evaporation

Caples Lake mean daily unimpaired streamflow is then estimated using Blackwood Creek historic data adjusted using Caples Lake daily adjustment factors determined as described in Section 3.2.

Lake Aloha

Mean daily unimpaired streamflow below Lake Aloha is estimated using the streamflow at Pyramid Creek, representing the reservoir outflow, estimate of evaporation and the change in

storage of the reservoir. The following equation, expressed in USGS identification numbers, was used to calculate the unimpaired streamflow on Pyramid Creek below Lake Aloha.

Pyramid Creek Unimpaired Streamflow at Twin Bridges =
11435100 + Change in Storage of 11434900 + Evaporation

Lake Aloha mean daily unimpaired streamflow is then estimated using Blackwood Creek historic data adjusted using Lake Aloha daily adjustment factors determined as described in Section 3.2.

3.2.10 South Fork of the American River near Kyburz Diversion
In order to estimate the mean daily unimpaired streamflow of the South Fork American River near Kyburz at the El Dorado diversion dam first, the "accretions" below the upper reservoirs and above the South Fork streamflow gage is estimated. The equation below is used to calculate the South Fork of the American River accretions.

South Fork Accretions = 11439501 – 11436000 – Silver Lake Leakage – 11437000 – 11435100 - 11434500

The accretions represent the unimpaired streamflow originating above the gage South Fork American River Near Kyburz (USGS No. 11439501) and below Silver Lake, Caples Lake and Lake Aloha. Import from Echo Lake is subtracted out to provide only flow originating from the South Fork of the American River watershed.

The total mean daily unimpaired streamflow of the South Fork of the American River near Kyburz is the sum of the South Fork accretions and the unimpaired flow below each of the upper reservoirs.

S. F. American River Near Kyburz = South Fork Accretions + Streamflow below Silver, Caples and Aloha

The South Fork of the American River near Kyburz mean daily unimpaired streamflow is a combination of the estimated streamflow below each project reservoir and the calculated accretions below the reservoirs. Blackwood Creek information is not used to estimate South Fork of the American River accretions.

Silver Fork Near Confluence with South Fork American River

A discontinued gaging station, Silver Fork of South Fork American River near Kyburz (USGS No. 11438000) was established in October 1924 and discontinued in September of 1944. This 107 square mile watershed provides the necessary information to estimate the unimpaired streamflow of the Silver Fork for the study period.

A double mass analysis between Silver Fork and the South Fork of the American River, excluding Silver and Caples Lakes, indicates a possible break in slope in 1929. All flows prior to the 1930 water year are increased by 15 percent to make the record compatible with the South Fork of the American River near Kyburz.

A relationship was derived between the monthly unimpaired Silver Fork streamflow below Silver and Caples Lakes and the unimpaired South Fork of the American River near Kyburz streamflow below Silver and Caples Lakes on the basis of the 1925 through 1944 coincident record. Monthly unimpaired streamflow for Silver Fork below Silver and Caples Lakes is then calculated for the study period, water years 1972 through 1996 based on the estimated South Fork of the American River unimpaired streamflow.

Silver Fork mean daily unimpaired streamflow below Silver and Caples Lakes is then estimated using Blackwood Creek historic data adjusted using Silver Fork daily adjustment factors determined as described above. The unimpaired streamflow below Silver and Caples Lakes is then added to obtain the full unimpaired mean daily flow of the Silver Fork of the South Fork of the American River.

Silver Fork at Confluence with Caples Creek

Silver Fork unimpaired streamflow near the confluence with the South Fork of the American River originating below Silver and Caples Lakes is calculated as described above. This intermediate area is used to estimate the Silver Fork at the confluence with Caples Creek by distributing the streamflow based on tributary drainage area adjusted to reflect average annual precipitation distribution in the watershed.

Caples Creek at Confluence with Silver Fork of South Fork of the American River

The Silver Fork unimpaired flow near the confluence with the South Fork of the American River originating below Silver and Caples Lakes is calculated as described above. This intermediate area is used to estimate Caples Creek at the confluence with Silver Fork of the South Fork of the American River by distributing the streamflow based on tributary drainage area adjusted to reflect average annual precipitation distribution in the watershed.

Silver Fork of South Fork of the American River at China Flat
The Silver Fork unimpaired flow near the confluence with the South Fork of the American River originating below Silver and Caples Lakes is calculated as described above. This intermediate area is used to estimate Silver Fork of South Fork of the American River at China Flat by distributing the streamflow based on tributary drainage area adjusted to reflect average annual precipitation distribution in the watershed.

Although we haven't seen the Borcalli and Associates calculations, we do know the data has been derived using mass balance. Mass balance calculations using daily data usually generate negative flows into a reservoir. This happens because gage readings at a reservoir can be influenced by wind, rain, and evaporation. Errors may also be generated because of data measurement errors. The data contained in the Borcalli and Associates report contained negative daily flow data. Resource Insights used the data from the Borcalli report and adjusted the data to remove negative flows by dissipating the errors on a monthly basis.

The method used to dissipate the error was to sum the daily data generated by Borcalli and Associates into monthly data. The monthly data was used to develop an adjustment factor based on the Blackwood Creek flow. The adjustment factor was made on a monthly basis by a ratio of monthly sub-basin flow to Blackwood Creek flow. Further adjustments are made on a daily basis to disaggregate monthly flows to daily flows. The final daily adjustment factor is used to multiply the Blackwood Creek flow to arrive at a flow that is representative of an unimpaired flow that could be expected at each flow location. The daily data is consistent throughout the South Fork American River basin because Blackwood Creek was used on each flow location.

The following example is presented to illustrate the methodology used by Resource Insights to develop daily flow values from the monthly unimpaired flow estimates.

Pyramid Creek at Twin Bridges Example

Monthly adjustment factor = Pyramid Creek @ Twin Bridges Unimpaired flow / Blackwood Creek flow

The Daily adjustment factor is developed using an empirically derived smoothing technique to develop daily data that preserves the monthly relationship but reduces the large changes in relationship from one month to another. (Figure 1)

The daily adjustment factors are multiplied by the daily Blackwood Creek flow to get the resulting Pyramid Creek flow below Lake Aloha at Twin Bridges. The resulting monthly flows are the sum of the daily flows for each month.
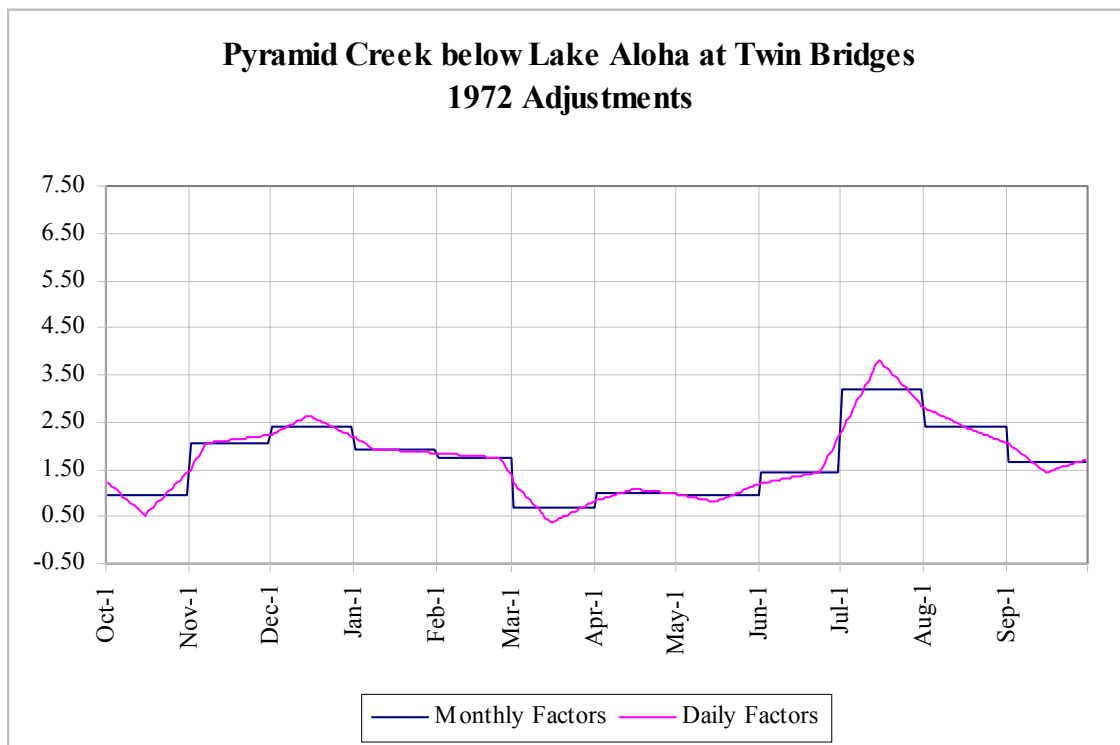
Figure 5

Another method of generating data must be used when no gaged data is available for the area of interest. For example, the Pyramid Creek inflow to Lake Aloha is an area of interest. There is no gage at the location, but the flows of Pyramid Creek at Twin Bridges is gaged, has been unimpaired, and is nearby. The method used for calculating the inflow to Lake Aloha is to develop areal relationships between the gaged location and the ungaged location. For example the drainage area at Pyramid Creek at Twin

Bridges gage is 8.76 square miles. The drainage area between Lake Aloha Dam and the Pyramid Creek at Twin Bridges gage is 5.36 square miles. The estimated accretions between Lake Aloha Dam and the Pyramid Creek at Twin Bridges gage = Pyramid Creek at Twin Bridges Unimpaired gage * 5.36 / 8.76. This resulting estimate for the accretion was then subtracted from the Unimpaired Pyramid Creek flow at Twin Bridges to estimate the unimpaired inflow to Lake Aloha. The map on the following page illustrates the areas used in this calculation.

3.4 sq. mi.

5.36 sq. mi.
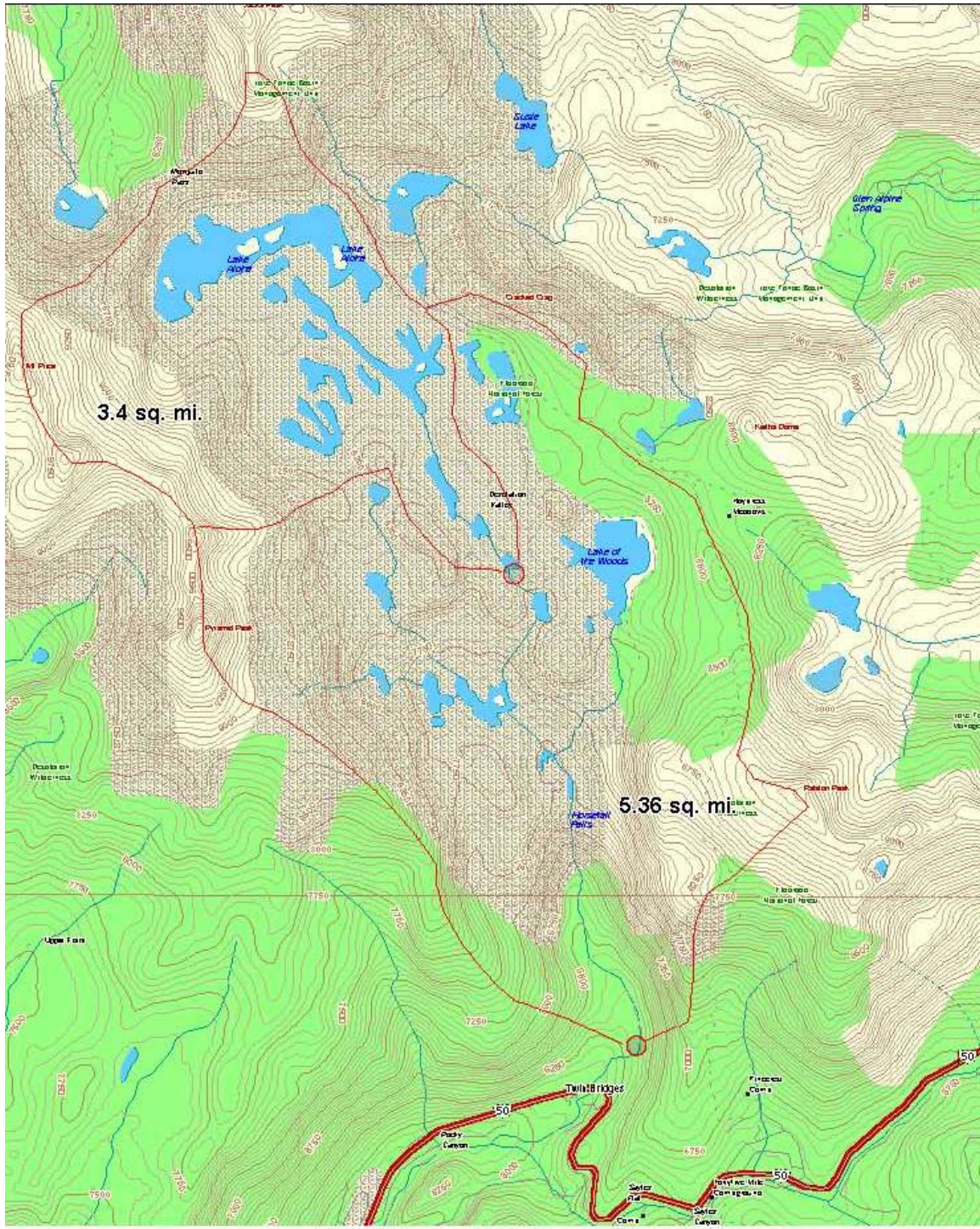
Topo USA 2.0 Copyright © 1999 DeLorme Yarmouth, ME 04096 Scale: 1 : 40,625 Detail: 12–3

Figure 6

The map above shows the 8.76 square mile Pyramid Creek drainage area. The area is divided into two regions. The upper area represents the 3.4 square mile drainage area that contributes to the inflow to Lake Aloha. The area between Aloha Dam and the Pyramid Creek at Twin Bridges gage is represented by the lower 5.36 square mile area.

California Department of Water Resources (DWR) Data

DWR has developed a model of the American River Basin using the Hydrologic Engineering Center model HEC3. The model runs on a monthly time step using the period of record from 1922 - 1996. The South Fork American River is represented in the model, but the level of detail is such that only a few of the hydrologic traces could be used in the Project 184 OASIS modeling process. The useful traces include Caples Lake Inflow, Silver Lake Inflow, Alder Creek Damsite Inflow and Sherman Damsite Accretions. These could be very helpful for developing hydrology that spans the 1922 - 1996 period of record.

The development of the data computed by DWR is documented in the 1984 American River Watershed Model report. In 1984 the period of record was from 1922 through 1980. Values beyond 1980 calculated after 1984 are currently undocumented. The following is excerpted from that report.

Caples Lake Inflow

Inflow to Caples Lake was computed as the sum of the historic outflow, "Caples Lake Outlet near Kirkwood", plus the change in Caples Lake storage. Records for the outlet are available for the period 1923 thru 1980 from USGS. End of year storages only are available for Caples Lake for the period 1922 thru 1948 from USGS. End of month storages for Caples Lake are available for the period 1949 thru 1980 from Snow Surveys.

Caples Lake inflow was first computed by combining the flow at Caples Lake outlet with the Caples Lake change in storage. The results produced some negative flows for the period 1949 thru 1980. These negative flows were assumed to be unmeasured releases and were added to the first cut inflow to produce the final unimpaired inflow. Annual inflow for the year 1922 was estimated by correlation with the "South Fork Silver Creek near Ice House". Monthly flows for the period 1922 thru 1948 were distributed by S-curve distribution with "Alder Creek near Whitehall".

Silver Lake Inflow

The unimpaired inflow to Silver Lake was computed as the sum of the estimated and historic outflow plus the change in storage of Silver Lake. The historic outflow used the gage "Silver Lake Outlet near Kirkwood", plus unmeasured seepage escaping the lake through porous rock formations. Historic outflow records are available for the period 1923 thru 1980. The combined outflow plus seepage records are also available in USGS Water Supply Papers for the period 1930-45. End of year storages for Silver Lake are available in USGS WSP's for the period 1922 thru 1946. End of month storages from Snow Surveys data are available for the period 1947 thru 1980. Monthly seepage was computed for the period 1930 thru 1945 as the difference between the combined and uncombined records. The periods 1922 thru 1929 and 1946 were estimated as the 1930-45 average.

A first cut unimpaired inflow was computed as the historic outflow 1923-80 plus seepage 1922-46 plus end of year change in storage 1922-46 plus end of month change in storage 1947-80. The results show negative monthly flows which are assumed to be unmeasured seepage for the period 1947-80. These are added to the first cut unimpaired inflow to obtain a second cut inflow. The second cut inflow covers the period 1923-80. The year 1922 was estimated by correlation with "South Fork Silver Creek Near Ice House Reservoir". Since the unimpaired inflow for the period 1922-46 could only be adjusted for end of year Silver Lake changes in storage, monthly values did not reflect an unimpaired distribution. Monthly values were, therefore, redistributed by S-curve distribution with "Alder Creek near Whitehall". End of month Silver Lake storages for the period 1922-46 are then estimated as the beginning of month storage plus inflow minus outflow. The resulting storages exceeded the maximum 8,600 acre-feet in some months. To stay within the maximum storage, inflow values were redistributed by reducing those months when the reservoir was filling and increasing those months when the reservoir was emptying.

South Fork American River near Kyburz

The unimpaired flow of the gage "South Fork American River near Kyburz" was calculated by adding the historic change in storage for Caples and Silver Lakes (the evaporation was ignored for these two reservoirs); subtracting the import from Echo Lake Conduit; and adding the diversion to the El Dorado Canal. This unimpaired flow covers the period 1923-80. Water year 1922 was taken from "Surface Water Hydrology of the American River Unit". The accretions were found by subtracting the upstream inflows to Forni damsite Sherman damsite, Caples Lake and Silver Lake.

Sierra Hydrotech

Sierra Hydrotech also developed data for the South Fork American River described in a June 1979 report. The report is hydrologic investigation entitled *Development of Basic Hydrologic Data for SOFAR Operational Studies*. The period of record contained in the report is 1921 through 1978. The following are excerpts from that report describing the methodology for developing data for Caples Lake inflow, Silver Lake inflow and unimpaired flow at the South Fork American River near Kyburz.

Caples Lake Outlet near Kirkwood

PG&E furnished historic storage values for Caples Lake (Twin Lakes) estimated monthly and sometimes observed on a daily basis, for the entire period of record. Unfortunately the outflow records and reservoir stage records are not always compatible. It was necessary to adjust storages in many years, particularly when observations were sparse. The total change for each year was set equal (within approximately 100 acre-feet) to the annual change in storage published by USGS which was based on observations as of September 30 of each water year. It was assumed that the published USGS figure would be reasonably accurate, since physical observations are possible and have been made as of this date each season. To hold minimum flows to zero, a "dummy" change in storage was calculated, representing small changes in the time-distribution of change in storage during the water year.

Plots were made of the calculated unimpaired runoff of Caples Lake Outlet against Silver Lake Outlet and against South Fork near Kyburz. Only in 1928 were flows adjusted in October, November and December to reflect a major deviation from the average plot. The rest of the figures appear realistic on an annual and monthly basis.

Silver Lake Outlet near Kirkwood

As at Caples Lake, records of historic storage values for Silver Lake were furnished by PG&E. These records were subject to many of the same problems of lack of adequate data, usually during periods of no actual observations.

When Silver Lake is filled a substantial flow bypasses the Silver Lake Outlet gage as

seepage and at least the major portion of this water returns as definable surface flow to Silver Fork below the Silver lake Outlet gage. This flow represents drainage from the Silver Lake basin and should be included on analysis of flows of Silver Lake Outlet.

From 1930 through 1945, measurements were made of the definable Silver Lake seepage. A plot was made of measurable Silver Lake seepage by months versus reservoir storage. A reasonably good relationship was developed. For the periods prior to and after the observed Silver Lake seepage measurements, seepages were estimated by months utilizing the relationship between reservoir storage and seepage.

As in the case of Caples Lake, a "dummy" change in storage was calculated of Silver Lake. Unlike the data for Caples Lake, however, this data represents primarily what is thought to be unmeasured seepage by the gaging station, Silver Lake Outlet. Analysis of evaporation from the lake surface, measured reservoir outflow, and measured seepage suggested that the change in storage was somewhat greater than might be anticipated unless there were additional ungaged seepage around the gaging station. Review of the topographic maps suggested that any major seepage out of the Silver Fork basin would be unlikely. It was assumed that an additional unmeasured seepage returned to Silver Fork below the gaging station. On and annual basis this seepage was estimated to be (.600 + .015(Caples Lake Unimpaired runoff)). All flows are in 1000 acre-feet. The unimpaired runoff at Caples Lake Outlet was used in this calculation since it is very similar in magnitude to that at Silver Lake and it was available at the time the calculation was made. The distribution of this incremental runoff during the season was made in such a manner to reduce negative flows. In addition, some small changes in the distribution of change in storage were made similar to those at Caples Lake. During several of the earlier years this calculated amount of incremental seepage was increased to make the unimpaired runoff apparently more compatible with observed conditions later in the record.

South Fork American River Near Kyburz

South Fork American River near Kyburz was considered as one of the most important records in the watershed for calculation of flows pertinent to SOFAR sites. The record began in 1923 and has continued to date. The 193 square mile watershed has approximately 30 square miles controlled by PG&E operated reservoirs and the import from Echo Lake which averages approximately 1600 acre-feet annually. The calculations of unimpaired flows for South Fork

near Kyburz (including El Dorado Canal) include adjustment for import from Echo Lake and change in storage for Lake Aloha, Caples Lake and Silver Lake.

Calculated unimpaired runoff of South Fork American River near Kyburz was plotted as a double mass diagram against a DWR (Snow Surveys Branch) calculation of American River near Fair Oaks to determine if any breaks had possibly occured in the Kyburz record. Results appeared satisfactory. There appeared to be no reason to suspect any major change in the measurement or calculation of flows at Kyburz, although some specific observations could certainly be subject to question. Calculation of unimpaired discharge at Kyburz agrees very well with estimates prepared by Snow Surveys Branch of DWR for that gage. Flows for 1921 and 1922 were estimated from correlation analysis. Estimates of South Fork near Kyburz, the major station upon which SOFAR flows have been based are as accurate as practicable with data available, and appear adequate for the analysis intended.

DWR vs. Resource Insights

Within the unimpaired data developed by DWR for the South Fork American River Basin, there are three locations common with that developed by Resources Insights: Caples Lake Inflow, Silver Lake Inflow and South Fork American River near Kyburz.

We reviewed and compared both estimates for each of these locations to identify any possible inconsistencies and to determine if the DWR estimates could be used to develop unimpaired estimates for the long term (1922-1996) studies.

Caples Lake Inflow

We have developed a scatter plot to evaluate the consistency between the DWR monthly data versus the data developed by Resource Insights. The data is strongly correlated, however there are a few outliers and at low flows many of the data points are estimated by DWR are lower than those estimated by Resource Insights.

Caples Inflow Scatter Plot
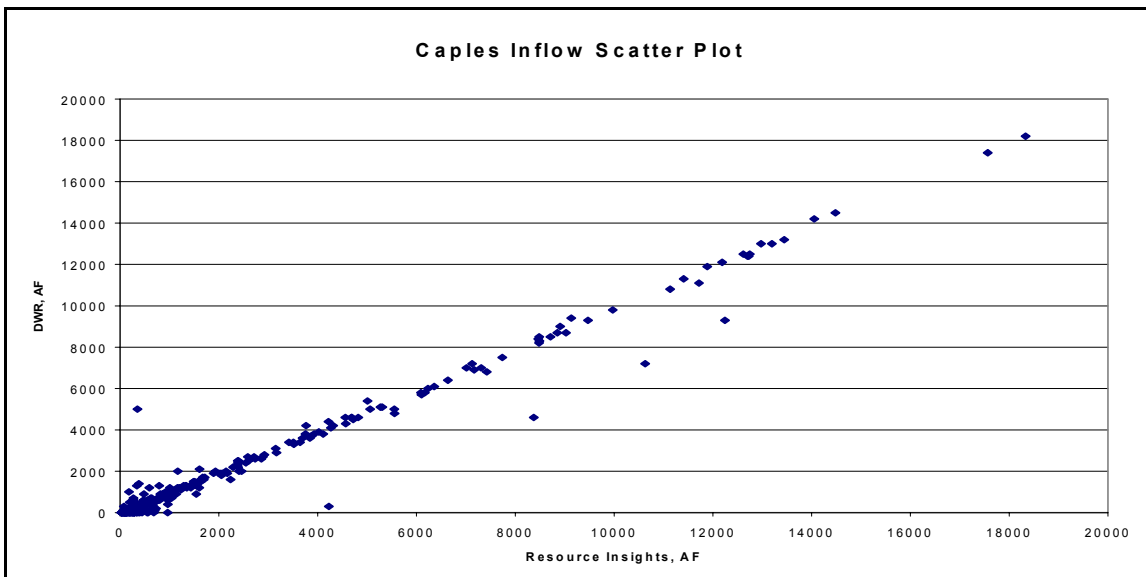
Figure 7

The following graph is a double mass diagram that shows the relationship between the Resource Insights Caples Lake inflow and the DWR Caples Lake inflow. Both the DWR dataset and the Resource Insights dataset cover the period from 1972 - 1996. Although the DWR documentation

was done in 1984, the graph indicates that the methods used for estimating the unimpaired flow were consistent throughout the period of record.

Caples Inflow
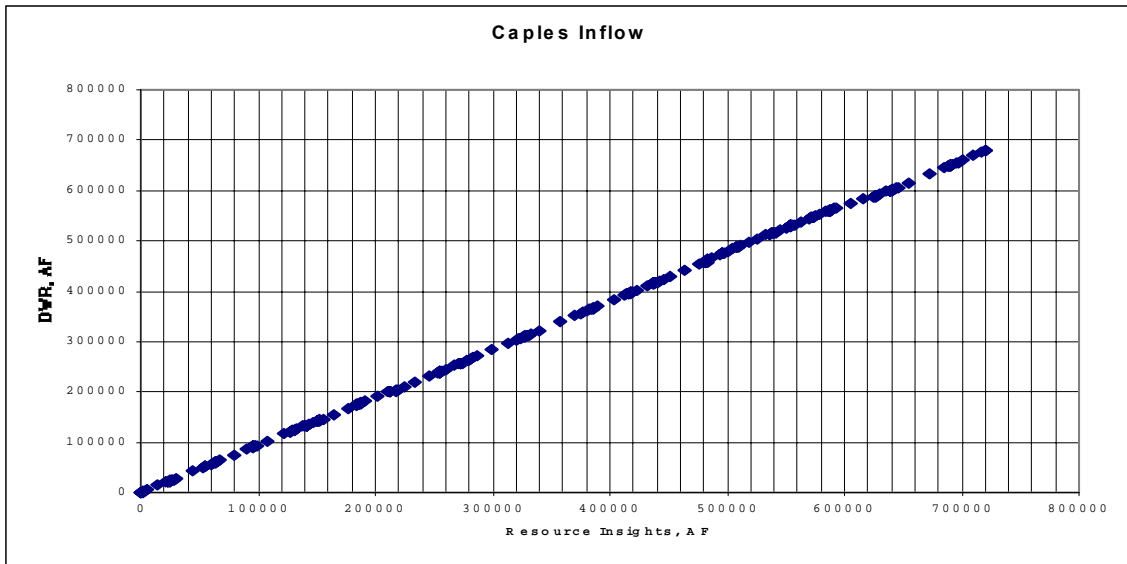
Figure 8

Silver Lake Inflow

We have developed a scatter plot to evaluate the consistency between the DWR monthly data versus the data developed by Resource Insights. The data is strongly correlated, however there are a few outliers and at low flows many of the data points are estimated by DWR are lower than those estimated by Resource Insights.
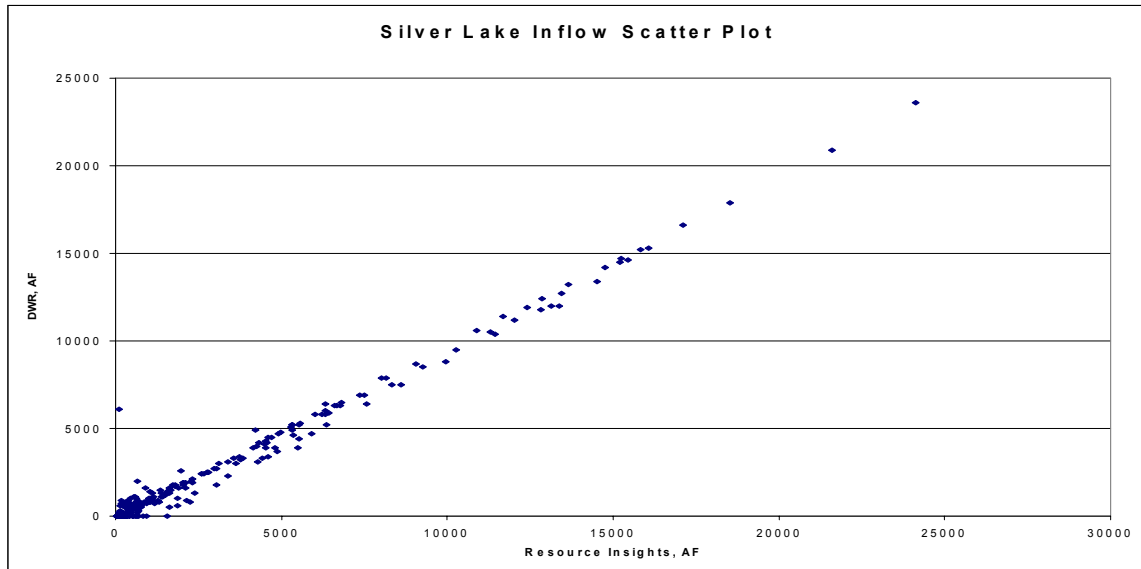
Figure 9

The double mass diagram below shows the relationship between the Resource Insights data and the DWR data appears consistent throughout the period of record. Resource Insights estimates higher Silver Lake inflows than DWR.
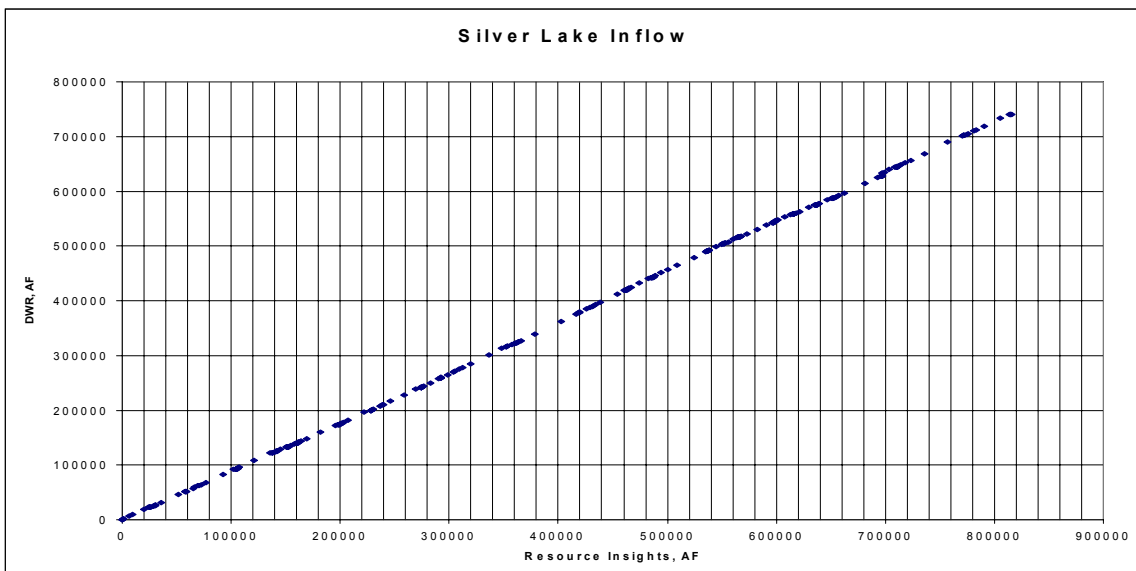
Figure 10

Kyburz Unimpaired Flow

We have calculated an unimpaired Kyburz flow from the DWR data and compared that to the data developed by Resource Insights. The scatter plot below indicates that the data are strongly correlated. The equation we used to calculate the unimpaired flow at Kyburz using DWR data is as follows:

Kyburz Unimpaired flow = South Fork American Plus Import + Caples Creek + Silver Fork American + Inflow to Sherman Diversion Dam site + Alder Creek + Kyburz Accretions.

Note: The Kyburz accretions subtracts the import from the Echo Lake Conduit.

Kyburz Unimpaired Scatter Plot
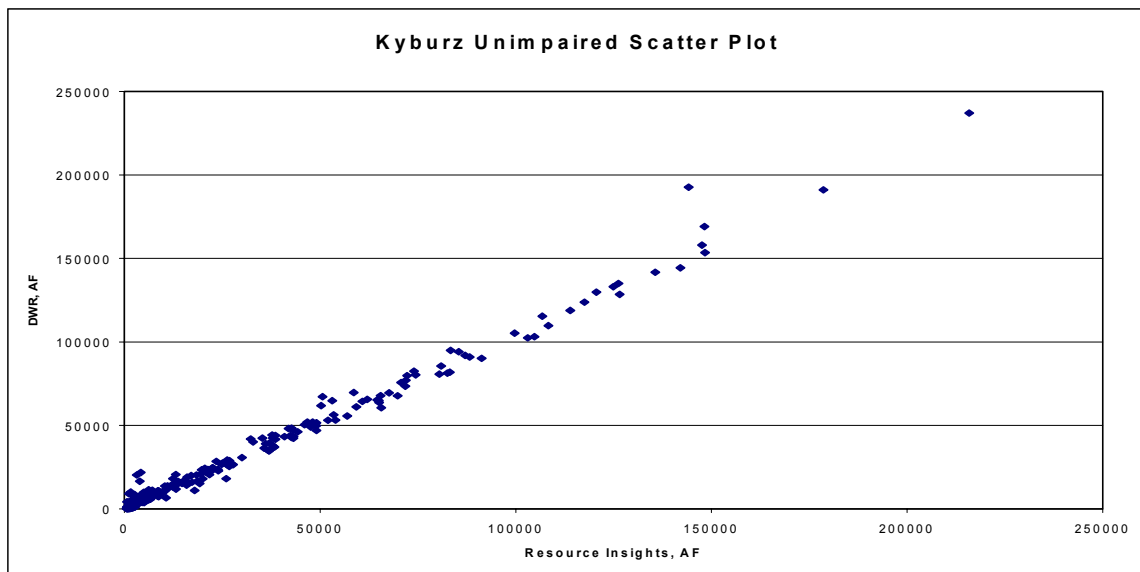
Figure 11

As with the other comparisons, the following double mass diagram shows that the relationship between the DWR data and the Resource Insights data is consistent through the 1972-1996 period of record.

Kyburz Unimpaired
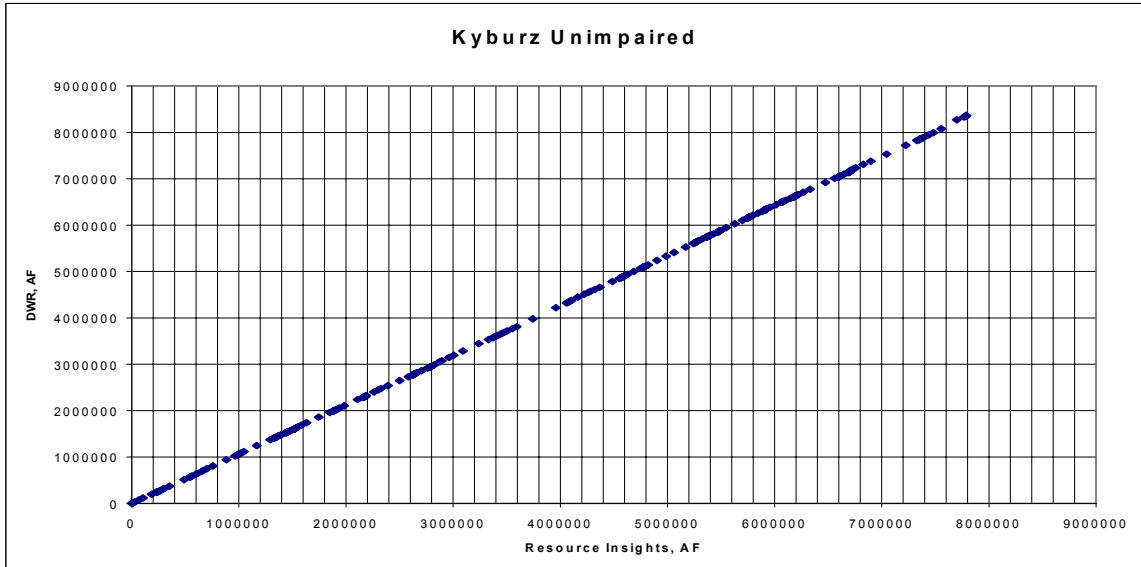
Figure 12

Resource Insights/DWR/Sierra Hydrotech

Sierra Hydrotech also developed data for the South Fork American River described in a June 1979 report. The report is hydrologic investigation entitled *Development of Basic Hydrologic Data for SOFAR Operational Studies*. The period of record contained in the report is 1921 through 1978.

The overlapping period for the three data sets is 1972 - 1979. Within that time period, we have compared a wet year(1974) a dry year(1972) and a critical year(1977) to determine if the three data sets agree in each of a wide variety of hydrologic conditions.
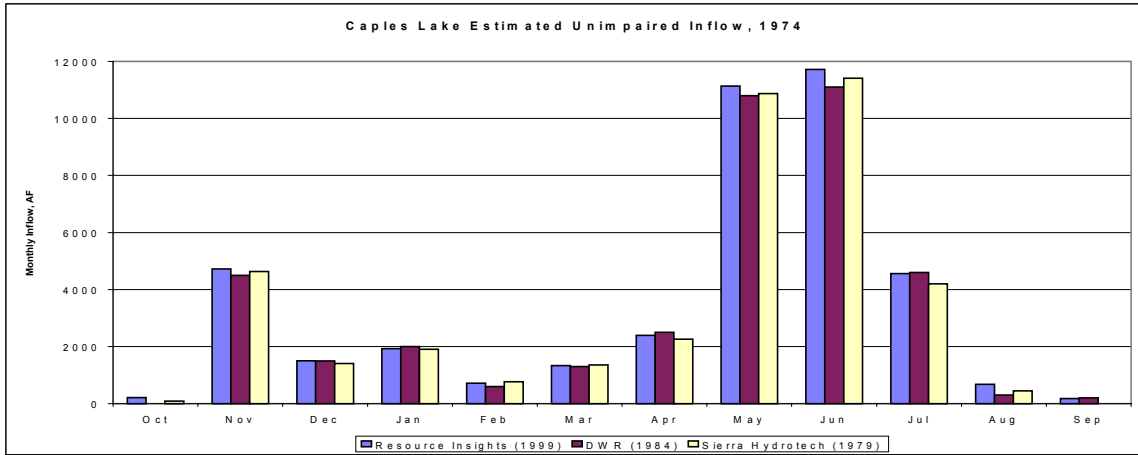
Figure 13 - Caples Lake Inflow, Wet Year Comparison
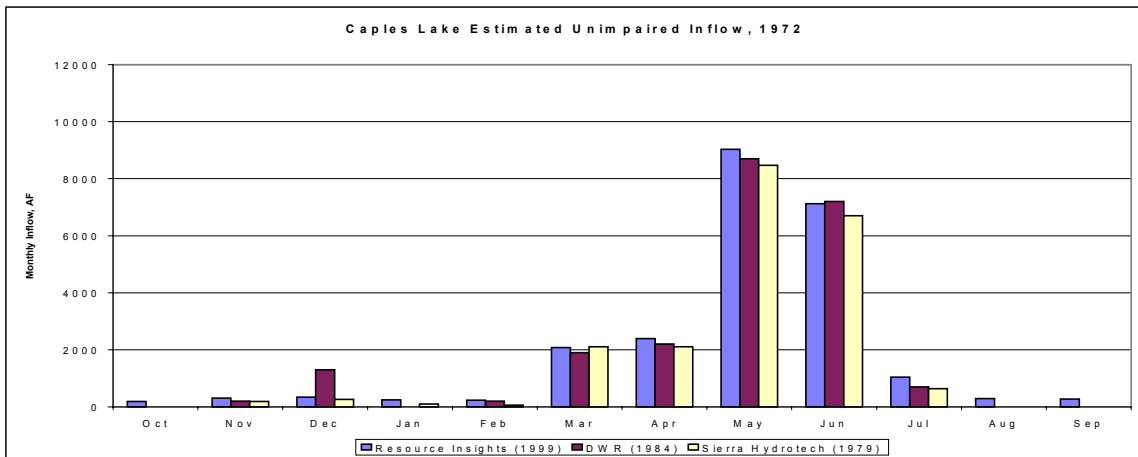
Figure 14 - Caples Lake Inflow, Dry Year Comparison
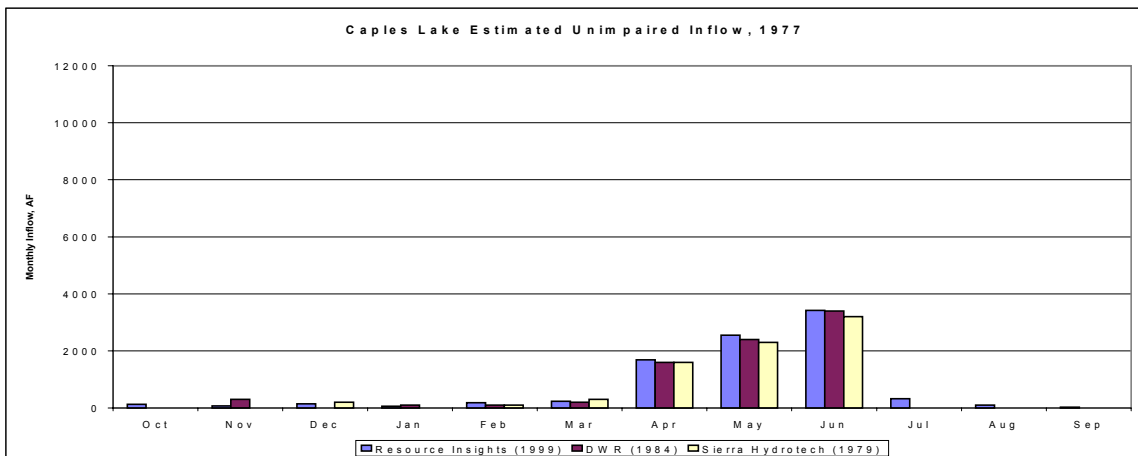
Figure 15 - Caples Lake Inflow, Critical Year Comparison
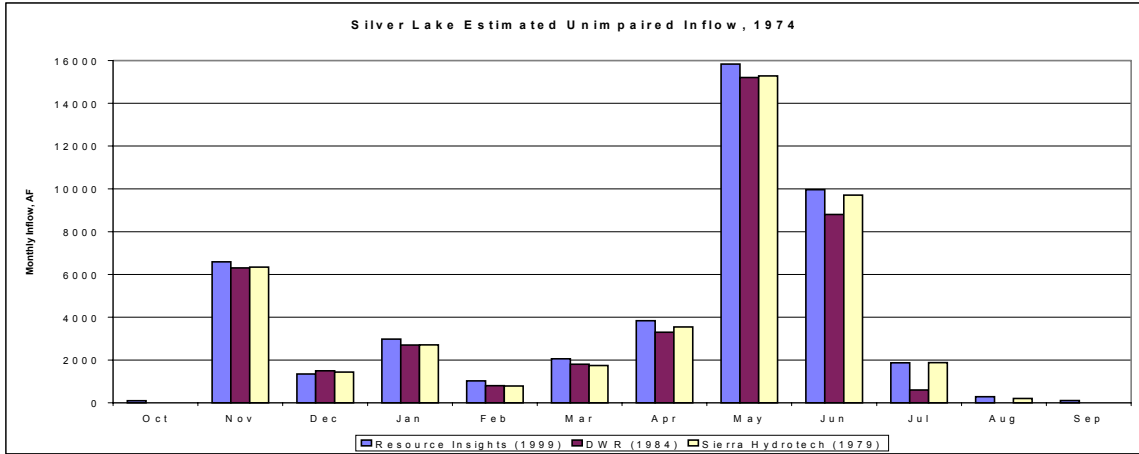
Figure 16 - Silver Lake Inflow, Wet Year Comparison
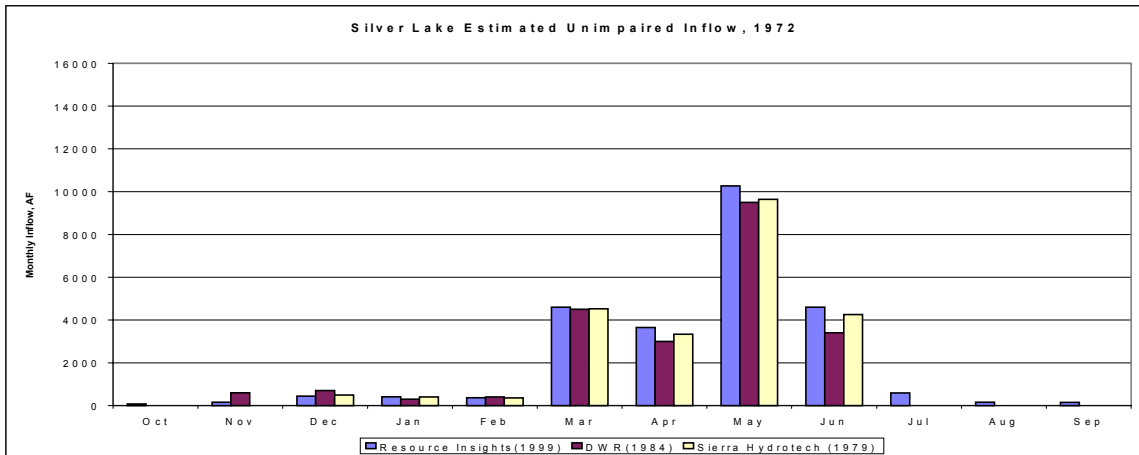
Figure 17 - Silver Lake Inflow, Dry Year Comparison
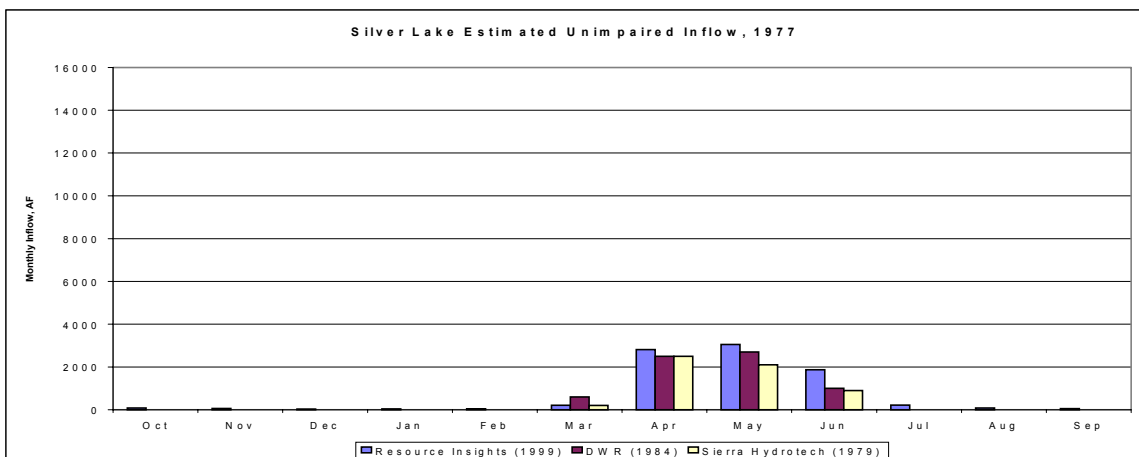
Figure 18 - Silver Lake Inflow, Critical Year Comparison
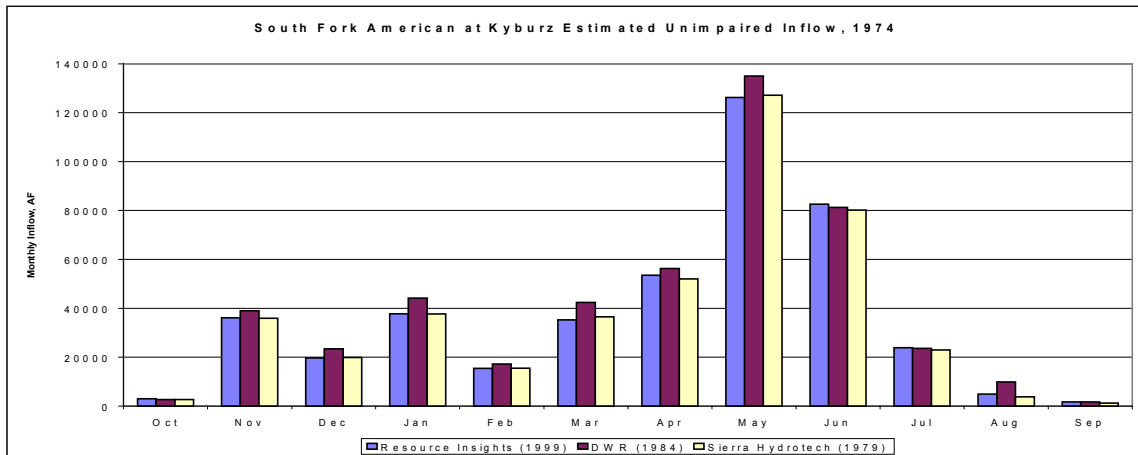
Figure 19 - South Fork American River near Kyburz, Wet Year Comparison
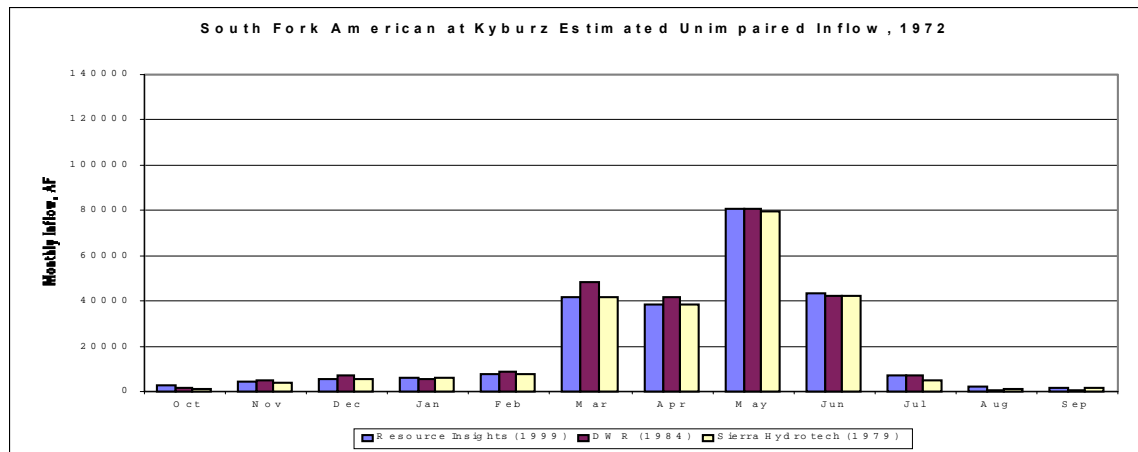
Figure 20 - South Fork American River near Kyburz, Dry Year Comparison
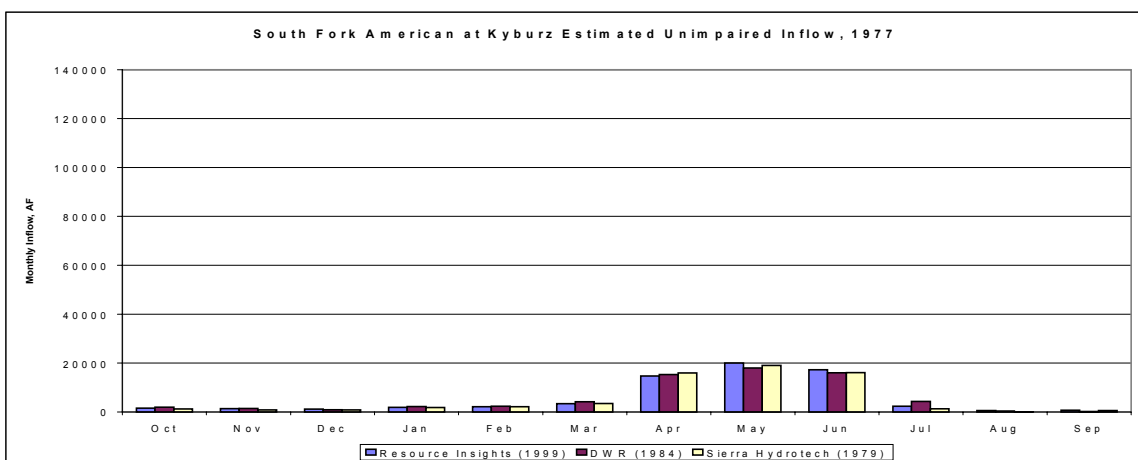
Figure 21- South Fork American River near Kyburz, Critical Year Comparison

After reviewing the calculations done by Resource Insights and descriptions of the calculations by DWR and Sierra Hydrotech, it is apparent that each developed data independently using three slightly different methodologies. Although the most rigorous development seems to have been done by Resource Insights and Sierra Hydrotech, all three have developed very similar results. The most critical comparison is that of the unimpaired South Fork American River flow near Kyburz. This record is often used as a basis to develop data in other areas of the basin. The Resource Insights and Sierra Hydrotech methods seem to develop very similar results, while the DWR method frequently estimates flows that are slightly higher. Worthy of note is that DWR does not account for the evaporation that occurs at Caples and Silver lakes nor does it account for the operations at Lake Aloha. The omission of the evaporation at Caples and Silver lake may be negligible because of the way they calculated seepage. Any negative flows are assumed to be unmeasured seepage and are added back into the flow in the second cut calculation. The unmeasured seepage could include evaporation. Resource Insights frequently has inflow to the reservoirs when DWR and Sierra Hydrotech do not. This is likely do to the more rigorous development of the data. In spite of all the differences, the results are generally very similar.

Hydrology Data Gaps

Our review of the unimpaired estimates completed by Resources Insights revealed that they had developed daily data sets for 19 of the 33 locations identified as stream reaches of interests by EID and the collaborative participants. These locations are:

 Caples Creek inflow to Caples Lake
 Silver Fork American River inflow to Silver Lake
 Pyramid Creek Inflow to Lake Aloha
 Pyramid Creek at Twin Bridges
 South Fork American River near Kyburz
 Echo Creek Inflow to Echo Lake

South Fork American at Echo Conduit

South Fork American at Aspen Creek

South Fork American at Sayles Canyon

South Fork American at Strawberry Creek without Pyramid Creek

South Fork American at Silver Fork without Pyramid Creek

Silver Fork American River at Silver Meadow

Silver Fork American River below Oyster Creek

Silver Fork American River Above confluence with Caples Creek

Caples Creek above confluence with Silver Fork American River

Silver Fork American River below confluence with Caples Creek

Silver Fork American River at Girard Creek

Silver Fork American River at China Flat

Silver Fork American River at South Fork American

The gaps in the hydrology daily data sets included five locations in the Silver Fork of the South Fork of the American River basin:

(1) Silver Fork American River below Sherman Canyon,

(2) Silver Fork American River below Long Canyon,

(3) Silver Fork American River below Beanville Creek,

(4) Upper Caples Creek below Kirkwood and

(5) Unknown Tributary to Upper Caples Creek

In addition, the daily 1972 - 1996 estimates of unimpaired flow for nine areas tributary to the South Fork American River downstream the El Dorado Diversion Dam and the intake of the El Dorado Canal were not developed by Resource Insights. These locations include:

(1) Carpenter Creek above the canal

(2) No Name Creek above the canal

(3) Alder Creek above the canal

(4) Mill Creek above the canal

(5) Bull Creek above the canal

(6) Plum Creek near Riverton

(7) Ogilby Creek above the canal

(8) Esmeralda Creek above the canal

(9) Northside Tributaries(3)

A third area of missing information was the extension of the monthly data to cover the 1922-1996 time period. These data needed to be extended for all the locations shown on the monthly model schematic.

Data Generated by HydroLogics

Daily Estimates Upstream of El Dorado Diversion Dam

The estimates of unimpaired daily flow for the five sites upstream of El Dorado Diversion Dam were made by HydroLogics using the same area ratio methodology used by Resources Insights. The Silver Fork unimpaired flow near the confluence with the South Fork of the American River originating below Silver and Caples Lakes is calculated as described above. This intermediate area is used to estimate the five additional locations of interest by distributing the streamflow based on tributary drainage area adjusted to reflect average annual precipitation distribution in the watershed. In all cases the precipitation adjustment was assumed to be 1.0

Tributaries to SFAR downstream of El Dorado Diversion Dam

There are several other diversions made into the El Dorado Canal along its length from tributaries to the South Fork American River: Alder Creek, Mill Creek, Carpenter Creek, Ogilby Canyon Creek, Bull Creek, Esmeralda Creek and an unnamed creek. There are only minor streamflow records available on these tributaries to the El Dorado Canal. The total flow of Alder Creek was recorded by the USGS during water years 1923-81.   Plum Creek was gaged from 1922 -1939 by the USGS. Recently EID reestablished a recording gage on Alder Creek at the

old USGS gage site. EID also established a recording gage on Mill Creek. In addition to these two recording gages EID has established and collected weekly data from staff gages on the streams tributary to the El Dorado Canal over the last two years. The gaged streams and the contributing drainage areas are listed in Table 1 below.

TABLE 3

**SOUTH FORK AMERICAN RIVER TRIBUTARY DRAINAGE AREA
AT POINT OF DIVERSION TO THE EL DORADO CANAL**

Tributary	Drainage Area (mi^2)
Alder Creek	22.1
Mill Creek	3.26
Carpenter Creek	2.17
Ogilby Creek	1.22
Bull Creek	0.90
Esmeralda Creek	0.74
Unnamed Creek	0.45

Of the model inflows below Kyburz, most had to be estimated using correlations from nearby gages which had flow records. The following USGS gages were identified as having similar elevation, locations near to the study area, and long periods of record.:

  11427700 Duncan Creek Near French Meadows

  11431800 Pilot Creek Above Stumpy Meadows

  11315000 Cole Creek Near Salt Springs Dam

When we plotted the hydrographs of these three gages with Alder Creek, it was clear that only the Pilot Creek gage would be useful for correlation.

The Alder Creek gage was ideal as a basis for correlation, but unfortunately that gage was discontinued in September 1981. Since Alder Creek flow was needed for input to the model, we would have to compute an estimate of Alder Creek, using correlation with Pilot Creek, for the years 1982-1996. Therefore, it would still be possible to estimate other streams using a

correlation with Alder Creek, even though the for the years 1982-1996 our estimate of the flow in those streams would really be based on the measured flow at Pilot Creek.

When developing correlations, we examined the effect of developing separate correlation functions for different periods of the year. For Mill Creek and Plum Creek this seasonal approach was found to be useful. At the rest of the gages, a distinct seasonal trend could not be found in the correlations.

Alder Creek

The period of record for USGS gage 11440000 on Alder Creek overlapped the Pilot Creek gage from October 1960 to September 1981. A nonlinear trend was visible in the correlation plot, so we empirically developed the following function:

```
x=Pilot Cr
y=Alder Cr

for x >= 25          y = -11.7 + 1.9 x
for x < 25           y = -1 + 0.164 x 1.68

                     y >= 0
```

R^2 for this correlation was computed to be 0.836.
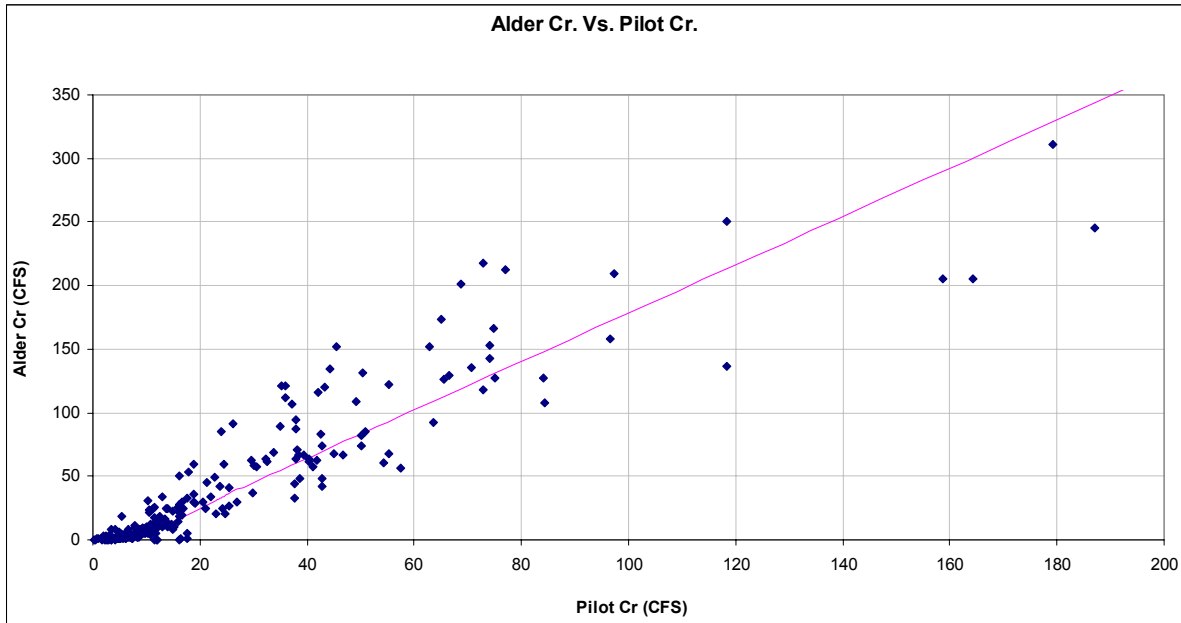
Figure 22

On Alder Creek, we were able to use the historical measured flow until September 1981. After that date, we used the estimated historical flow from the correlation.

Mill Creek

The period of record for EID gage A-10 on Mill Creek overlapped the Alder Creek gage A-13 from October 2000 to December 2001. We found that the months May-July seemed to be correlated differently than the other months, so we developed two separate correlation functions. Nonlinear trends were visible in the correlation plots, so we empirically developed the following functions:

```
x=Alder Cr
y=Mill Cr

May-July:
                              y = 1.7 LN( x + 5 ) - 2.8

August-April:
for x > 3                     y = 1.42 LN( 2x - 1.7 )
for x <= 3                    y = 0.69 x

                              y >= 0
```

R^2 for this correlation was computed to be 0.959 for May-July and 0.873 for August-April. During the months of August and April the estimate transitions from one correlation function to the other.
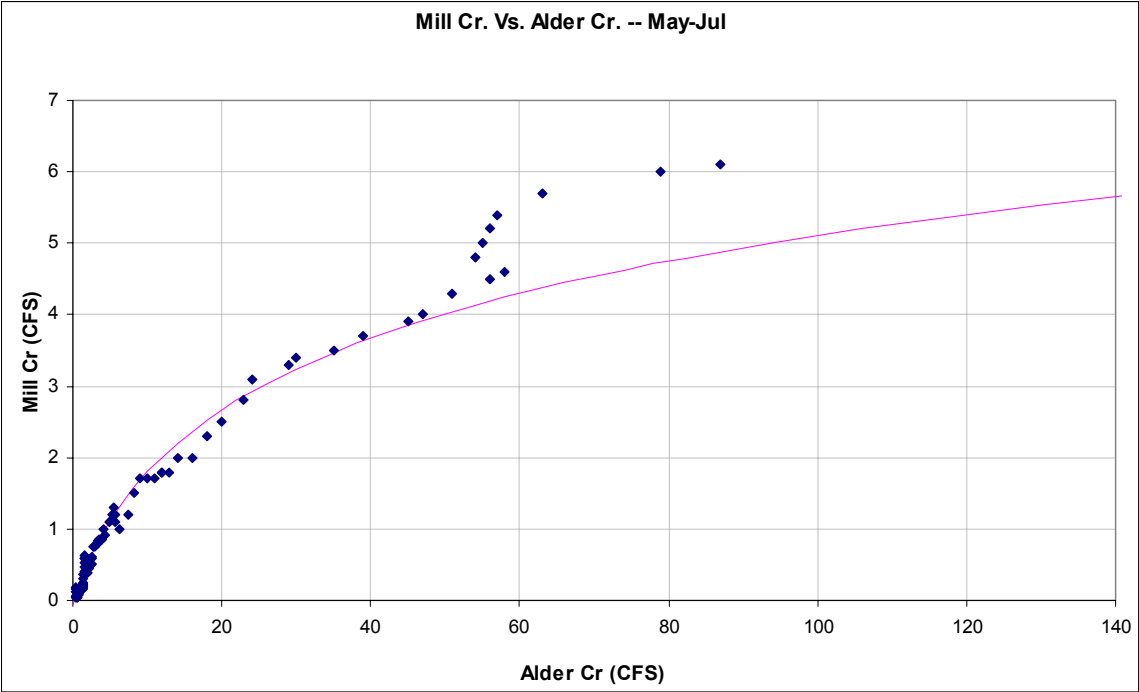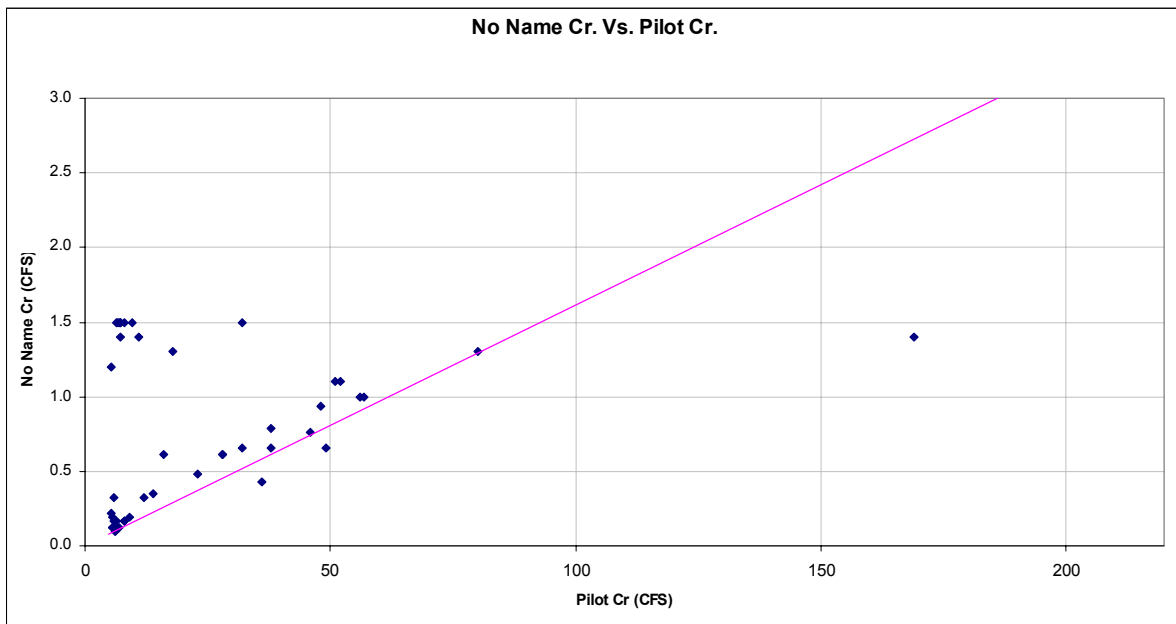

Figure 23
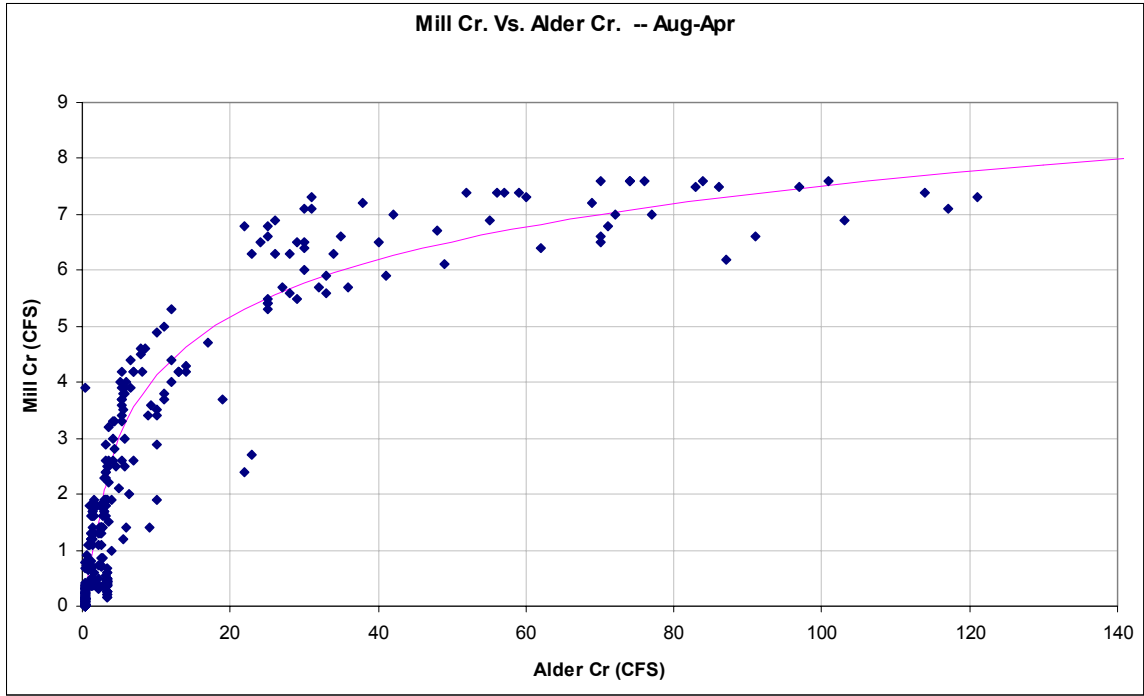
Figure 24

Carpenter Creek

The period of record for EID gage T-10 on Carpenter Creek overlapped the Pilot Creek gage from October 1999 to September 2000. Nonlinear trends were visible in the correlation plot, so we empirically developed the following function:

x=Pilot Cr
y=Carpenter Cr

$$y = 4.9 \, LN(2x + 55) - 20$$

$$y >= 0$$

R^2 for this correlation was computed to be 0.882.
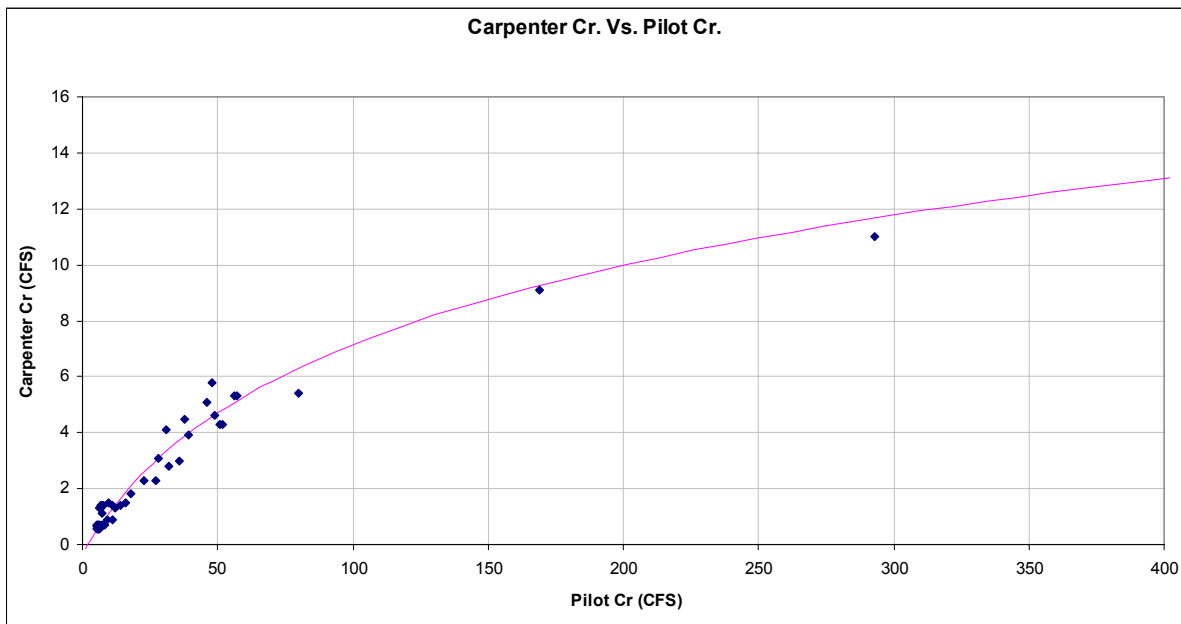
Figure 25

No Name Creek
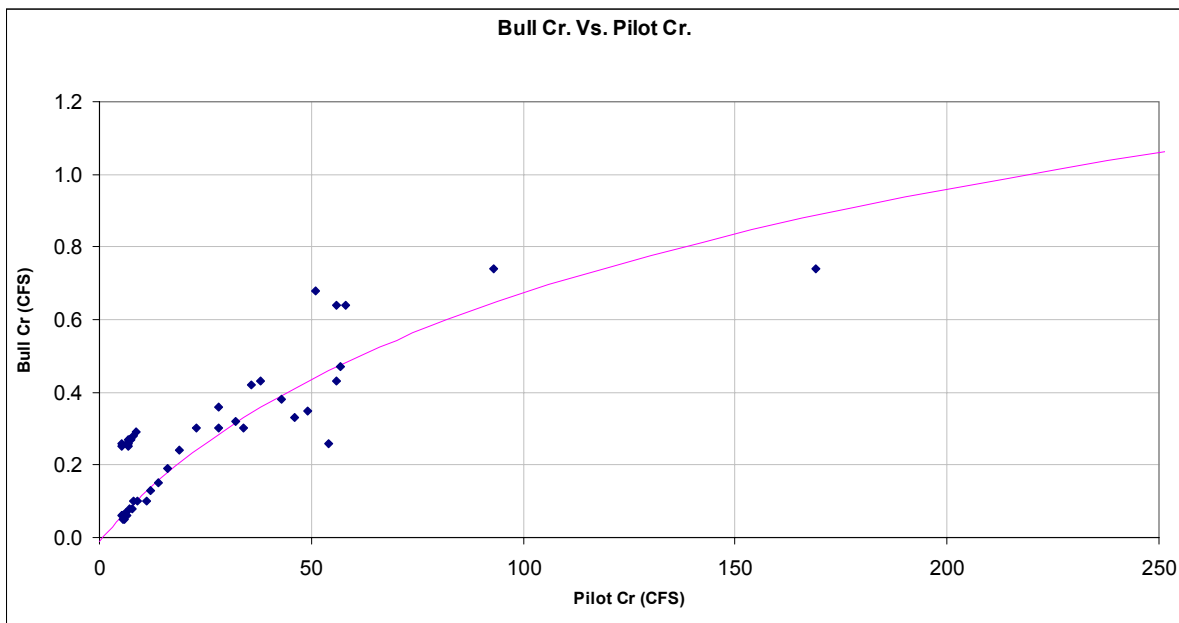
The period of record for EID gage T-9 on No Name Creek overlapped the Pilot Creek gage from October 1999 to September 2000. The correlation plot appeared to have a linear trend, so we used linear regression to derive this correlation function:

x=Pilot Cr
y=No Name Cr

$$y = 0.0161 \ x$$

R^2 for this correlation was computed to be 0.838.

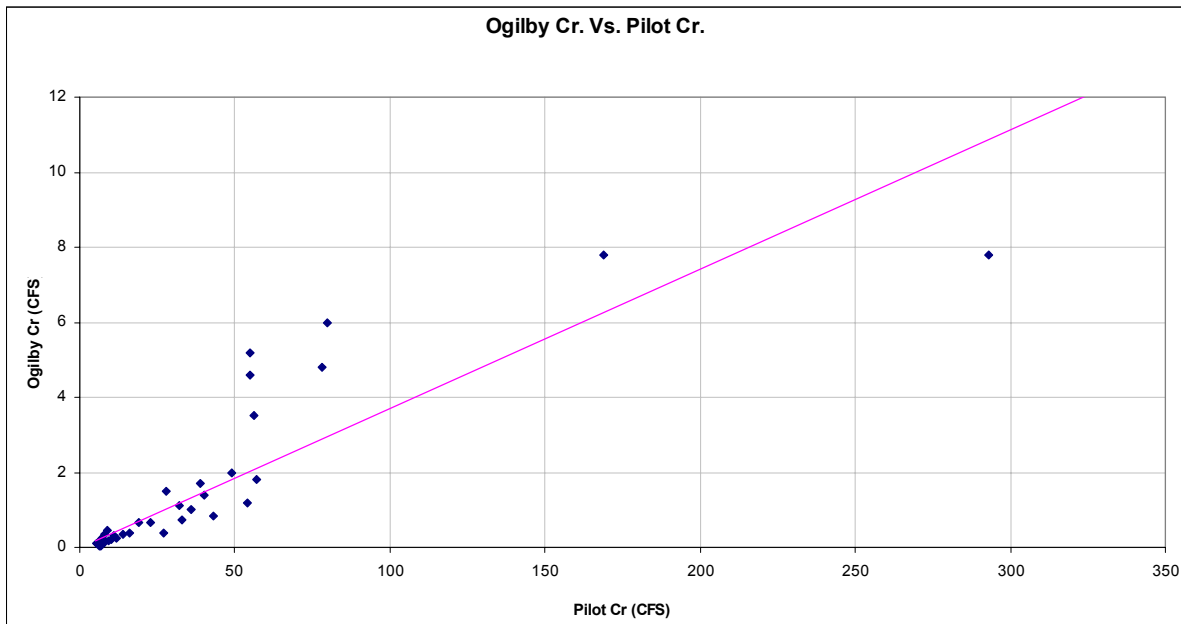**Figure 26**

Bull Creek

The period of record for EID gage T-8 on Bull Creek overlapped the Pilot Creek gage from October 1999 to September 2000. Nonlinear trends were visible in the correlation plot, so we empirically developed the following function:

x=Pilot Cr
y=Bull Cr

$$y = 0.523 \, LN(x + 37) - 1.9$$

$$y >= 0$$

R^2 for this correlation was computed to be 0.851.

Figure 27

Ogilby Creek

The period of record for EID gage T-6 on Ogilby Creek overlapped the Pilot Creek gage from October 1999 to September 2000. The correlation plot appeared to have a linear trend, although at times where the flow in Pilot Creek was above 55 CFS, there was no clear trend. We made the simplest assumption by using linear regression to derive this correlation function:

x=Pilot Cr
y=Ogilby Cr

$$y = 0.0371\ x$$

R^2 for this correlation was computed to be 0.752.

Figure 28

Esmeralda Creek

The period of record for EID gage T-2 on Esmeralda Creek overlapped the Pilot Creek gage from October 1999 to September 2000. The correlation plot appeared to have a linear trend, so we used linear regression to derive this correlation function:

x=Pilot Cr
y=Esmeralda Cr

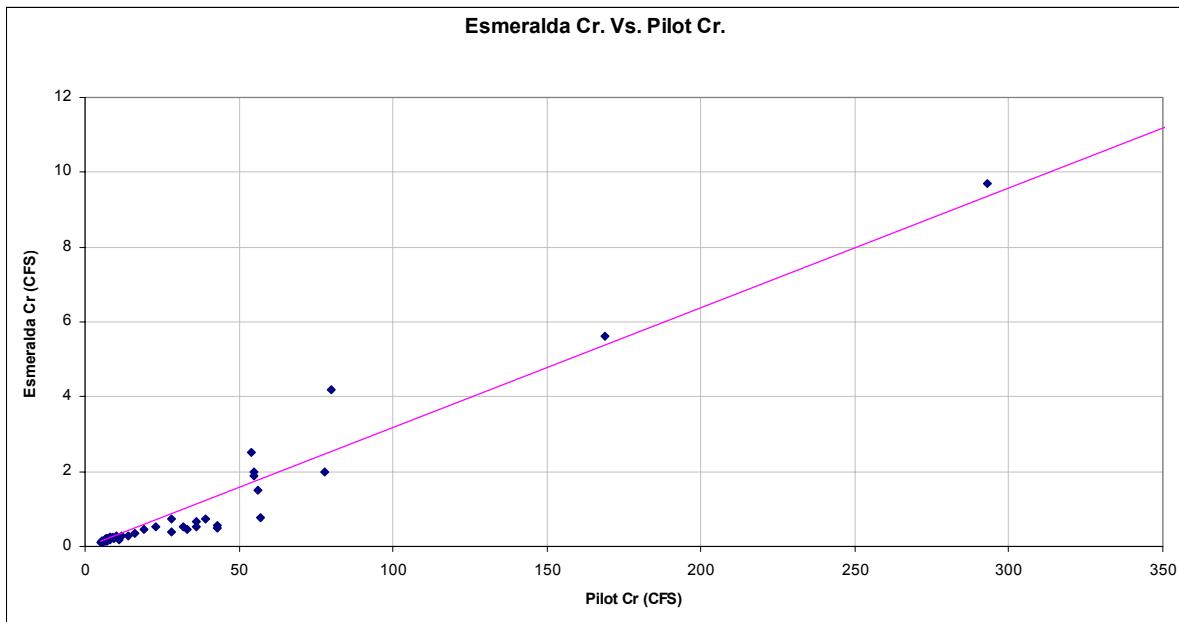$$y = 0.032\,x$$

R^2 for this correlation was computed to be 0.937.

Figure 29

Plum Creek

The period of record for USGS gage 11440500 on Plum Creek overlapped the Alder Creek gage from October 1922 to September 1939. We found that the months May-October seemed to be correlated differently than the other months, so we developed two separate correlation functions.

The correlation plots appeared to have linear trends, so we used linear regression to derive the following functions:

x=Plum Cr
y=Alder Cr

May-October:
$$y = 0.0989\ x$$

November-April:
$$y = 0.3132\ x$$

R^2 for this correlation was computed to be 0.870 for May-October and 0.705 for November-April. During the months of November and April the estimate transitions from one correlation function to the other.
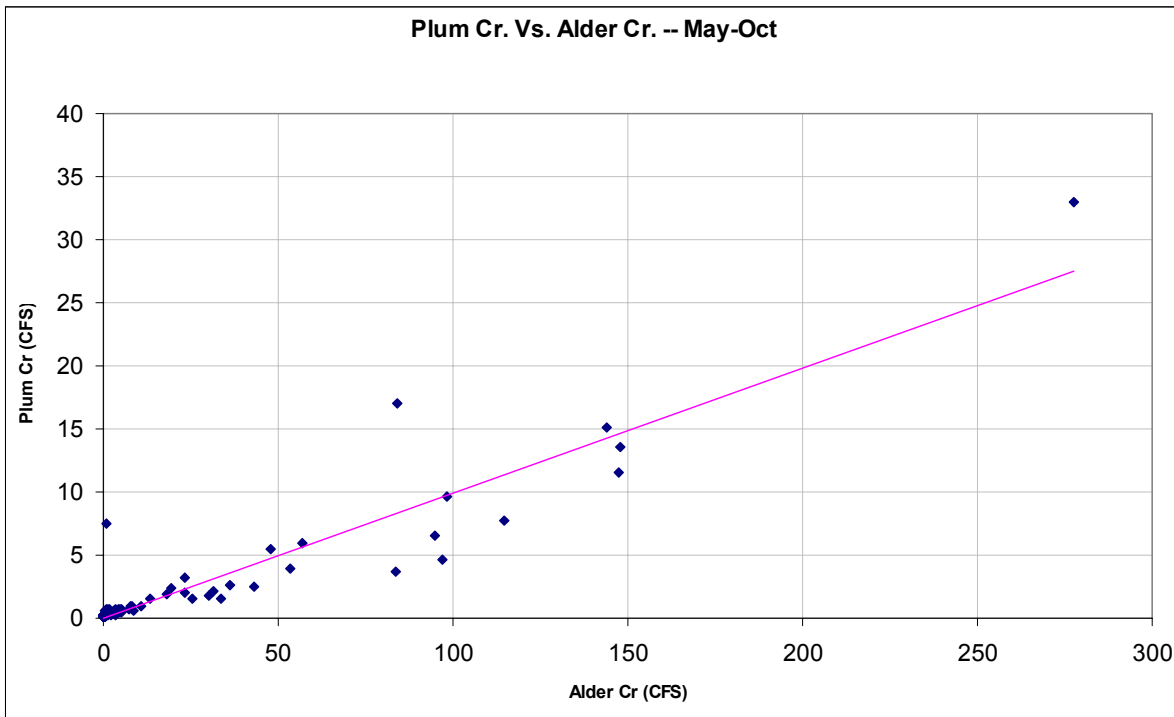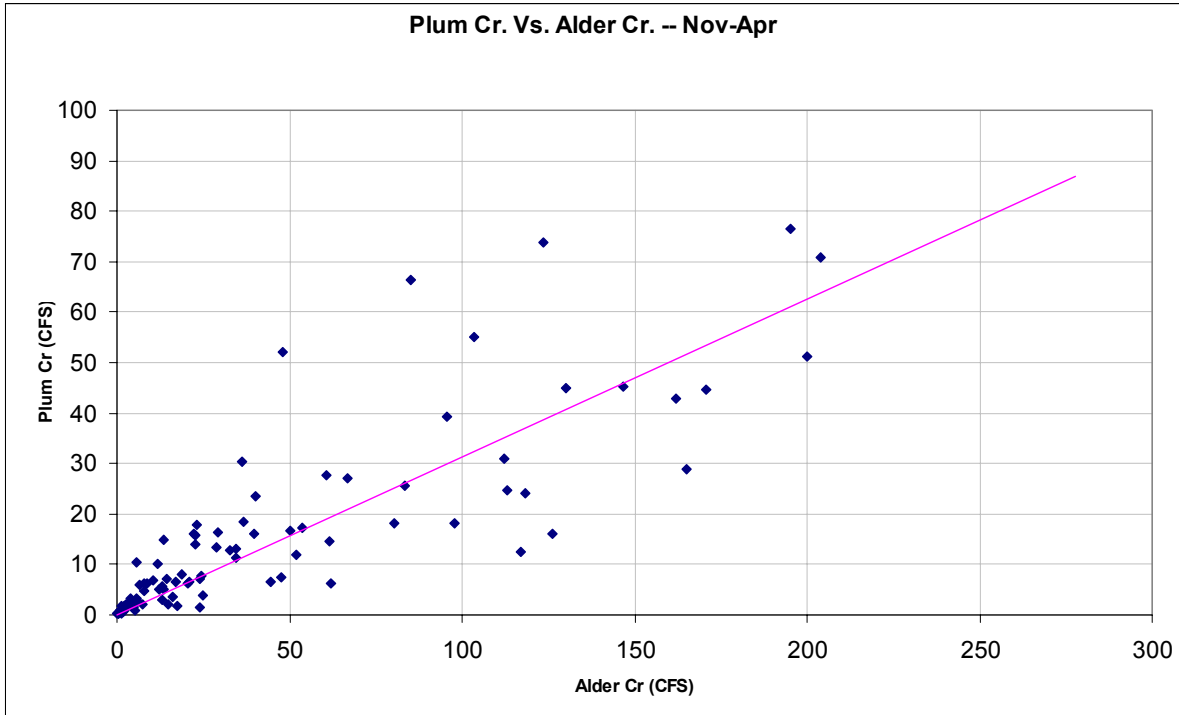

Figure 30

Figure 31

Ungaged inflow below Kyburz

As described above, we obtained either historical measured flow data or estimated historical flow (from correlations with Pilot or Alder Creeks) for 8 tributaries on the South Fork American River below El Dorado Diversion Dam: Carpenter, No Name, Alder, Mill, Bull, Plum, Ogilby, and Esmeralda Creeks. Thus, we have flow values for input to the model at the locations of these 8 gages. However, to accurately model the reaches of the South Fork American River below El Dorado Diversion Dam, we still need estimates of the local inflow from locations where there are no flow gages. This includes all local inflows from the north bank of the South

Fork American River, as well as all local inflows from the south bank that are not upstream of the 8 gages.

To derive an estimate of the ungaged flow, we decided to do a flow balance. Refer to the following schematic diagram to help understand the flow balance. USGS gage 11442500 is located on the South Fork American River just above El Dorado Powerhouse. Silver Creek is a major tributary to the South Fork American River above this gage that must be considered in the flow balance. USGS gage 11441900 is located on Silver Creek about 5 miles above the South Fork American River. USGS gage 11439500 is located just downstream of the El Dorado Diversion Dam. When we combine these three USGS gages with the flow in the 8 tributaries, we can solve for the ungaged local flow. In the diagrams below, the gray shading represents the location of ungaged inflow that is counted by this balance. We assume that the distribution of the ungaged inflow is distributed proportionally to drainage area. The first diagram shows the entire region that may contribute local flow for the balance computation. The second diagram shows the region that contributes local flow that we are actually interested in for the model. This was further divided into three locations where the local inflow enters the model:

|	REPRESENTS ALL LOCAL FLOW ENTERING THE SYSTEM		Drainage Area
Point Location in Model	**above point:**	**below points:**	
Confluence of Alder Cr.	Confluence of Alder Cr.	El Dorado Diversion Dam Carpenter Cr. Diversion No Name Cr. Diversion Alder Cr. Diversion	?
Confluence of Bull Cr.	Confluence of Bull Cr.	Confluence of Alder Cr. Mill Cr. Diversion Bull Cr. Diversion	?
Confluence of Ogilby Cr.	Confluence of Ogilby Cr.	Confluence of Bull Cr. Plum Cr. Gage Ogilby Cr. Diversion	?
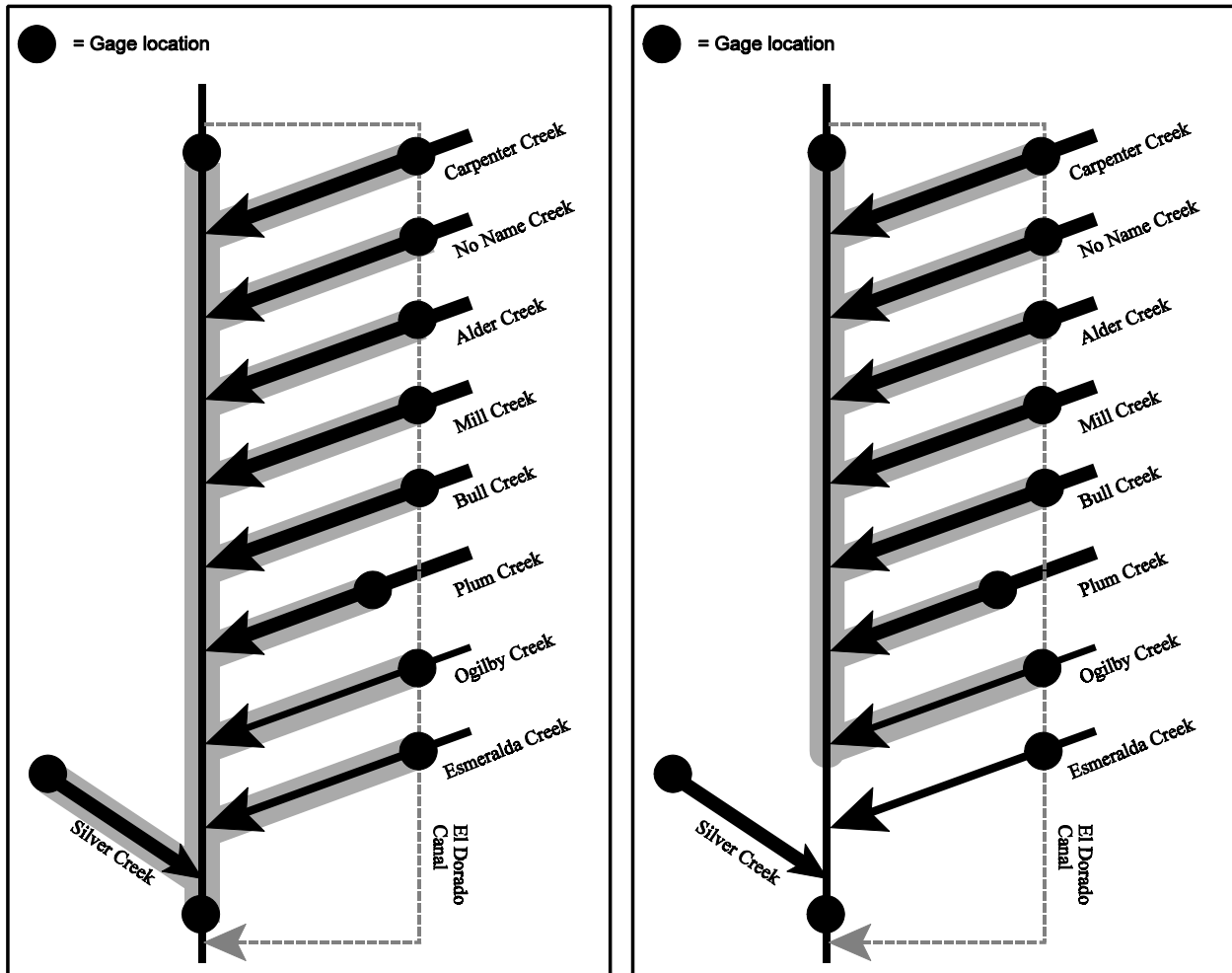
Figure 32

Unfortunately, the balance computation must account for the water diverted from the tributaries into the El Dorado Canal. We have no historical records of the water diverted into the canal except at Alder Creek. Therefore, we had to make assumptions about the historical diversion behavior. We assumed that historically PG&E diverted the entire flow of the tributaries up to the amount allowed by the water rights, and up to the amount of available canal capacity. Using historical records of the diversion at the El Dorado Diversion Dam and the delivery from El Dorado Forebay, we were able to estimate the historically available capacity for diversions.

Thus, we computed an estimate of the historical diversion which could be entered into the balance equation.

The balance can thus be stated:

Ungaged inflow　　　=　　　flow above Powerhouse (11442500),

　　　　　　　　minus　flow in Silver Creek (11441900),

　　　　　　　　minus　flow below Diversion Dam (11439500),

　　　　　　　　minus　flow below Alder Creek diversion (11439999),

　　　　　　　　minus　estimated flows in Carpenter, No Name, Mill, Bull, Plum, Ogilby, and Esmeralda Creeks,

　　　　　　　　plus　estimated diversions from Carpenter, No Name, Mill, Bull, Ogilby, and Esmeralda Creeks,

We only performed this computation for the portion of the historical record when there were measured flows for all 5 of the USGS gages in the balance. There is no overlapping record of flow for the 7 smaller tributaries. The period used for the computation was October 1970 through September 1971, and October 1975 through September 1981 – a total of seven years of record.

Unfortunately, the ungaged flow computed from this balance did not seem realistic. The most obvious problem was that we got frequent negative values during months of April, May, and June. When doing the balance computation, we often got negative values for the ungaged flow *before the estimates for the 7 small tributaries had been subtracted*. Thus, even if our estimates for the 7 small tributaries were highly inaccurate (which is doubtful), we computed a negative value for the ungaged flow using *only the measured data*, and when the flows of the 7 small tributaries were subtracted, the computed value could only become worse, no matter what those flows actually were.

It seems likely that there were problems with the rating curves at one or more of the gages used in the balance computation. This is surely one reason why the correlation of the computed

ungaged flow to gaged flows was not very strong. Nevertheless, we decided that while the ungaged flow computed in any given month might be inaccurate, the *central tendency* of the computed ungaged flow should still be reasonable. Therefore, we could use the results of the balance to correlate the ungaged flows with Pilot Creek. The correlation plot appeared to have a linear trend, so we used linear regression to derive the following function:

x=Ungaged inflow
y=Pilot Cr

$$y = 2.12 \, x$$

R^2 for this correlation was computed to be 0.571. Before doing the linear regression we discarded the data point for January 1980, when the computed value of ungaged accretion was 860 CFS. This is more than three times the next highest value, and we judged that that data point would exert undue bias on the regression.
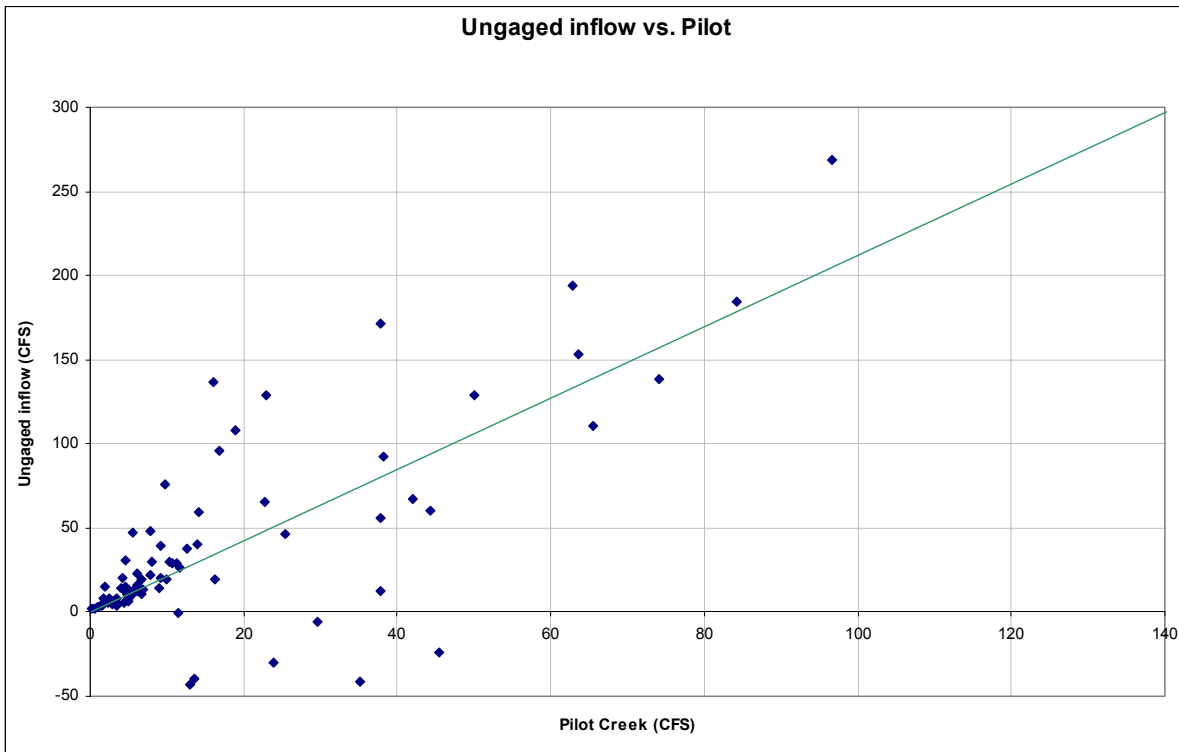

Figure 33

The equations present above can be used with the Pilot Creek record to generate a simulated daily record from 1972-1996. The same equations can be used to create a monthly simulated record for all the tributaries from 1922 - 1996.

Long Term Studies

Resource Insights developed unimpaired daily and monthly flow data for the 1972 - 1996 time period for several sites which could be used in the monthly Project 184 model. Those sites are:

>   Caples Lake Inflow
>   Silver Lake Inflow
>   Lake Aloha Inflow
>   Echo Lake Inflow
>   South Fork American River near Kyburz

While the time period covered by these data is adequate for the purpose of the FERC process, it is common practice to use water years 1922 - 1996 to evaluate water supply and hydroelectric projects in California. The California Department of Water Resources (DWR) has developed monthly unimpaired hydrology for the 1922 - 1996 time period for much of the Central Valley. Data of interest for Project 184, which has been developed by DWR, includes South Fork American River near Kyburz, Caples Lake Inflow and Silver Lake Inflow.

Data available from DWR is not sufficient by itself to evaluate Project 184 capabilities. As previously discussed, the data developed by DWR is closely correlated with the data developed by Resource Insights for Project 184. Therefore, the Resource Insights developed records for the above sites can be extended for the 1922 - 1971 period by correlation with the DWR monthly data. Table 4 below gives the parameters of those correlations.

Table 4

Project 184 Correlation Parameters

Resources Insights Data (Dependent Variable)	Constant	Coefficient	R^2	DWR Data (Independent Variable)
SFAR nr Kyburz	1.7	0.931	0.99	SFAR nr Kyburz
Caples Lake Inflow	115	1.01	0.98	Caples Lake Inflow
Silver Lake Inflow	166	1.03	0.98	Silver Lake Inflow
Lake Aloha Inflow	251	0.311	.091	Caples Lake Inflow
Echo Lake Inflow	311	0.385	.091	Caples Lake Inflow

Figure 34

Lake Aloha Inflow
1972-1996

$Aloha_{RI} = 251 + 0.3106*Caples_{DWR}$
$R^2 = 0.91$

Y-axis: Resource Insights Monthly Data, TAF
X-axis: DWR Caples Inflow Monthly Data, TAF

Figure 35

South Fork American River
near Kyburz -1972-1996

$Kyburz_{RI} = 1.7 + 0.931* Kyburz_{DWR}$
$R^2 = 0.99$

Y-axis: Resource Insights Monthly Data, TAF
X-axis: DWR Monthly Data, TAF

Figure 36

Echo Lake Inflow
1972-1996

$Echo_{RI} = 311 + 0.385*Caples_{DWR}$
$R^2 = 0.91$

Resource Insights Monthly Data, TAF (y-axis)
DWR Caples Inflow Monthly Data, TAF (x-axis)

Figure 37