RECLAMATION
Managing Water in the West

Natural Flow And Salt Computation Methods

Calendar Years 1971-1995

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Regional Office
Technical Services and Dams Division
Water Quality Group
Salt Lake City, Utah

U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Regional Office
Boulder Canyon Operations Office
River Operations Group
Boulder City, Nevada

December 2005

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by

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Introduction

This paper documents the steps taken to compute natural flow and salt in the Upper and Lower Colorado River Basins from 1971-1995. Natural flow and salt data are hydrologic input data required in the CRSS planning model. The methods used to compute natural flow and salt described in this paper have changed from previous methods as a result of recent research. This research found data and methodological inconsistency in past methods to compute natural flow and salt was compared to data and methods used in the CRSS planning model (Prairie and Fulp, 1999). To assure the computation of natural flow and salt is consistent with the use of natural flow and salt in the CRSS planning model, the new methods to compute natural flow and salt throughout the Colorado River Basin as described in this paper were adopted by the Bureau of Reclamation.

Nothing in this report is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994; 59 Stat. 1219), the Decree entered by the Supreme Court of the United States in Arizona vs. California, et al. (376 U.S. 340), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act, (70 Stat. 105; 43 U.S.C. 620), or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501).

An overview of methods used to compute natural flow and salt mass in both the Upper and Lower basin is first provided. The overview is followed by detailed explanations of

1. the data required to compute natural flow in the Upper Basin and the source of the data,
2. the data required to compute natural salt mass in the Upper Basin and the source of the data,
3. the development of regressions to model natural salt in the Upper Basin and,
4. the data required to compute natural flow and salt in the Lower Basin and the source of the data.

This report concludes with a discussion of the methods used to verify that the data and methods to compute natural flow and salt are consistent with those in the CRSS planning model.

Overview of Methods in Upper and Lower Basin

Natural flow and salt concentration are computed for the Upper and Lower Colorado River basin in a new RiverWare model. RiverWare is the generalized river basin modeling software that was used to develop models used for both medium (24 months study model) and long-term (CRSS planning model) policy planning on the Colorado River. The new model is based on the CRSS planning model. RiverWare was used to ensure algorithms to compute natural flow and salt concentration are consistent with the algorithms used in the CRSS planning model.

The new RiverWare model, which is named the *Natural Flow and Salt Calculation Model,* was designed to easily load historic data. These historic data include consumptive uses and losses in the Upper Basin that are loaded at a monthly temporal and USGS hydrologic unit code (HUC) spatial scale. In the Lower Basin, Decree Accounting records are entered monthly for each reported diverter. Currently, the CRSS planning model accepts future consumptive uses and losses estimates at a project level or reach level in the Upper Basin and by schedules for limited diverters and states in the Lower Basin.

Additional historic data required to compute natural flow includes historic gauged streamflow and historic reservoir pool elevations and outflows (reservoir regulation). For computing natural salt concentration, additional historic data includes initial reservoir salinity levels, salt contributed with agricultural return flows and salt removed with exports.

As stated earlier, the natural flow computed for the Upper and Lower Basin and the natural salt concentrations computed for the Lower Basin are used to drive the CRSS planning model. The natural salt concentration in the Upper Basin computed by the Natural Flow And Salt Calculation Model cannot be directly used to drive the CRSS planning model. Because of the uncertainty associated with salt mass pickup (loading) attributed to agricultural return flows, a statistical technique is used to model the relationship between natural flow and salt mass in the Upper Basin.

In order to quantify this uncertainty and display it in model output, the relationship between natural flow and salt mass are modeled with monthly regressions in the Upper Basin. It is well documented that a relationship between natural flow and salt mass exists. Generally, a plot of flow versus salt mass displays a proportional relationship. As flow increases salt mass increases. The rate of increase is not always linear and varies from one location to another. A scatter plot of natural flow and salt mass displays this relationship as seen in Figure 1. After a regression is fit to the data it is evident there is scatter around the regression. The scatter is reduced during high flow months but greatly increased during low flow months. The increased scatter during low flow months indicates that the relationship between flow and salt mass is not as strong or evident during low flow months.

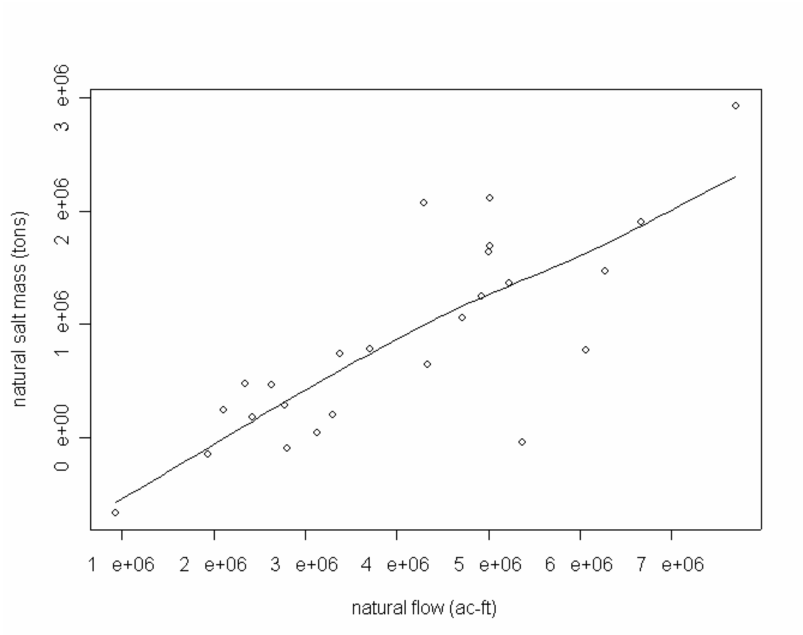

Figure 1. June's natural flow and salt relationship Colorado River at Lees Ferry, Arizona

In order to capture the uncertainty in the flow and salt mass relationship, a new natural salt model was developed with the statistical software package R. The new natural salt model generates a regression between natural flow and salt mass and incorporates the uncertainty around the regression. The details of the new salt model are explained in later sections of this documentation.

Figure 2 displays a flowchart with the sequence of steps required to compute both natural flow and salt concentration in the Upper and Lower Basin.

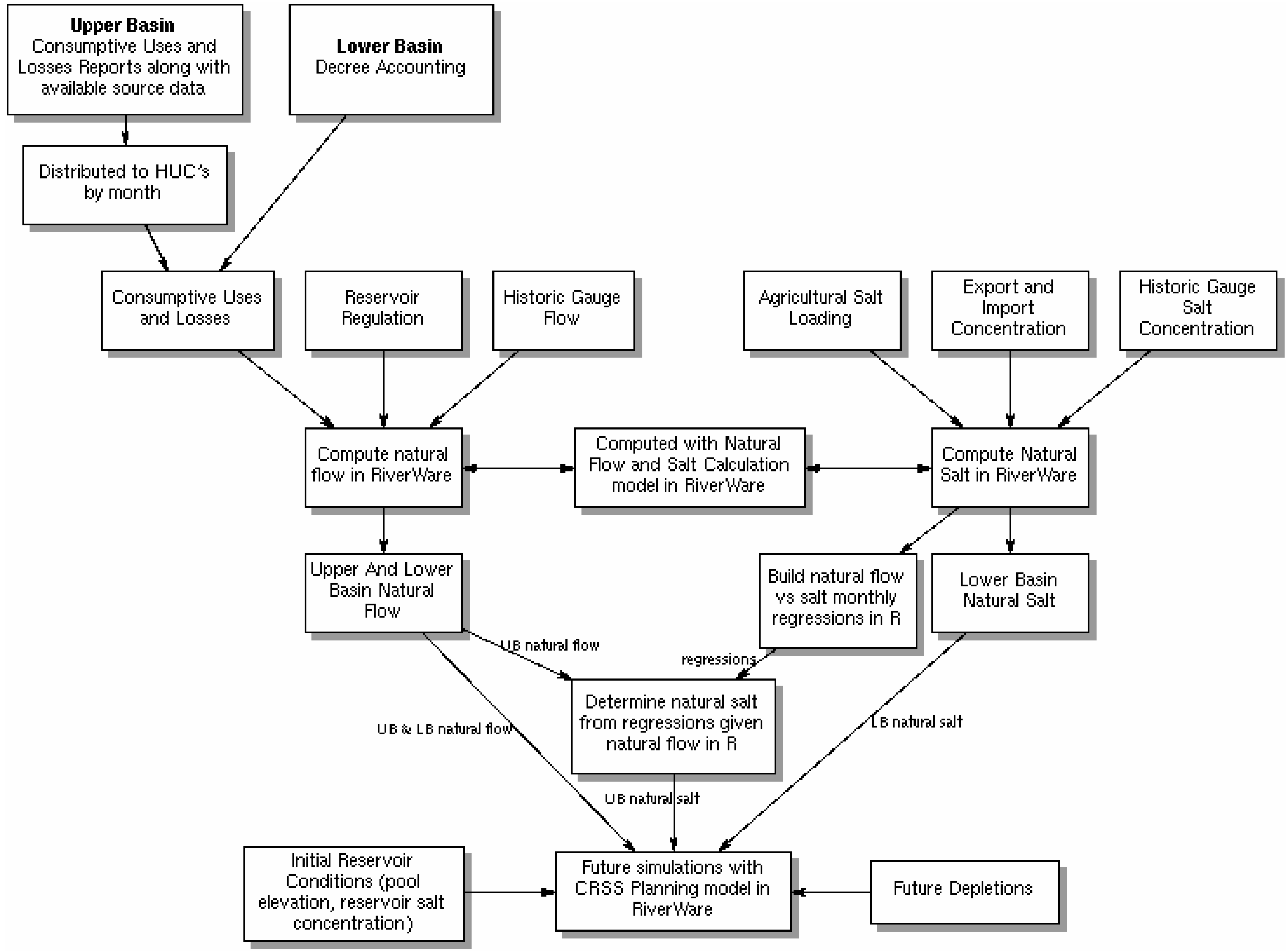

Figure 2. Flowchart of natural flow and salt computation.

Upper Basin

The Upper Basin is split into 20 reaches. Each reach terminates at the gauge listed in Table 1 and labeled with that gauge name. Natural flows are computed for each reach. The methods and data used to compute natural flow and salt mass in the Upper basin are explained in the following sections.

Table 1. Upper basin reaches for natural flow and salinity

	Gauge Number	Gauge Name
1	09211200	Green River below Fontenelle Reservoir, Wyoming
2	09217000	Green River near Green River, Wyoming
3	09234500	Green River near Greendale, Utah
4	09251000	Yampa River near Maybell, Colorado
5	09260000	Little Snake River near Lily, Colorado
6	09302000	Duchesne River near Randlett, Utah
7	09306500	White River near Watson, Utah
8	09315000	Green River at Green River, Utah
9	09328500	San Rafael River near Green River, Utah
10	09072500	Colorado River near Glenwood Springs, Colorado
11	09095500	Colorado River near Cameo, Colorado
12	09109000	Taylor River below Taylor Park Reservoir, Colorado
13	09124700	Gunnison River below Blue Mesa Reservoir, Colorado
14	09127800	Gunnison River at Crystal Reservoir
15	09152500	Gunnison River near Grand Junction, Colorado
16	09180000	Dolores River near Cisco, Utah
17	09180500	Colorado River near Cisco, Utah
18	09355500	San Juan River near Archuleta, New Mexico
19	09379500	San Juan River near Bluff, Utah
20	09380000	Colorado River at Lees Ferry, Arizona

Flow Methods

This section explains the methods used in the Upper Basin to compute natural flow. First the methodology is explained followed by a description of the data required to compute natural flow and the sources of these data.

Methodology

Natural flow is computed as

$$naturalFlow = historicFlow + totalDepeltion \pm resevoirregulation$$

Therefore, to compute natural flow several data sources are accessed and imported into the model. These data are loaded in the model with the data management interface in the RiverWare modeling environment.

Streamflow Gauge Data

Streamflow gauge data is taken from two sources. The first source is output from the SLOAD program. SLOAD is a program run by the USGS that computes salinity concentration from flow data and EC measurements collected by the USGS. The output from SLOAD provides flow in acre-feet/month, salt mass in tons/month, and salt concentration in mg/L. SLOAD produces output for sixteen stream flow gauges in the Upper Baisn. The streamflow gauges included in SLOAD are listed in Table 2. The remaining five streamflow gauges are taken from the USGS records available on their website. These are listed in Table 3.

Table 2. Upper Basin SLOAD stream gauging stations provided by USGS Grand Junction Office

SLOAD filename	Gauge Number	Gauge Title
Grwy	09217000	Green River near Green River, Wyoming
Gdale	09234500	Green River near Greendale, Utah
Yampa	09251000	Yampa River near Maybell, Colorado
Duch	09302000	Duchesne River near Randlett, Utah
White	09306500	White River near Watson, Utah
Grut	09315000	Green River at Green River, Utah
Sanraf	09328500	San Rafael River near Green River, Utah
Glen	09071100[1]	Colorado River near Glenwood Springs, Colorado
Cameo	09095500	Colorado River near Cameo, Colorado
Gunn	09152500	Gunnison River near Grand Junction, Colorado
Dolor	09180000	Dolores River near Cisco, Utah
Cisco	09180500	Colorado River near Cisco, Utah
Arch	09355500	San Juan River near Archuleta, New Mexico
Bluff	09379500	San Juan River near Bluff, Utah
Lees	09380000	Colorado River at Lees Ferry, Arizona

[1] This is a water quality station. Stream flow was measured at streamflow-gaging station 09072500, Colorado River at Glenwood Springs, Colo., prior to water year 1966. From water year 1966 through water year 2002, streamflow was determined as the difference between values at streamflow-gauing stations 09085000, Roaring Fork River at Glenwood Springs, Colo., and 09085100, Colorado River below Glenwood Springs, Colo. (Mueller and Osen, 1987)

Table 3. Stream gauging stations from USGS national website

Gauge Number	Gauge Title
09211200	Green River below Fontenelle Reservoir, Wyoming
09260000	Little Snake River near Lily, Colorado
09109000	Taylor River below Taylor Park Reservoir, Colorado
09124600[2]	Gunnison River below Blue Mesa Reservoir, Colorado
09127800[3]	Gunnison River at Crystal Reservoir

Consumptive Uses and Losses

The data required to represent historic consumptive uses and losses (CU&L) was derived from the source data used to develop the Consumptive Uses and Losses Reports. These reports were published every five years beginning in 1971. The reports state CU&L for the Colorado River Basin annually by major tributary. A detailed account of how the data was distributed to a monthly temporal scale and HUC spatial scale for computation of natural flow is included in a companion report authored by R. Clayton (2004).

A brief description of each of the eight (8) categories reported in the CU&L reports is provided. Additional information about the data collected for the CU&L reports can be found in the Technical Appendices that accompany each CU&L report publication. These reports and appendices are published by the Water Conservation Group in the Denver office of the Bureau of Reclamation under contract with the Upper Colorado Regional Office of the Bureau of Reclamation.

Irrigated Agriculture

Irrigated agriculture consumptive use is computed by the Bureau of Reclamation with the modified Blaney Criddle method for Upper Basin states except in New Mexico. The state of New Mexico provides values for irrigated agriculture consumptive use using the original Blaney Criddle method. Irrigated agriculture accounts for the largest portion of anthropogenic consumptive use. Crop distribution and acreage data are gathered from three sources; county agriculture statistics, census of agriculture, and GIS coverages.

Reservoir Evaporation

Reservoir evaporation is reported for two categories based on the data available for each reservoir. The first category is termed major reservoirs. These are reservoirs in the Upper

[2] This gauge is no longer maintained by the USGS; therefore, reservoir outflows recorded by Reclamation for Blue Mesa reservoir replaced this gauge data.

[3] This gauge is no longer maintained by the USGS; therefore, reservoir outflows recorded by Reclamation Crystal reservoir replaced this gauge data.

Colorado River basin where monthly evaporation is computed or end of month surface area is provided by the Upper Colorado Regional Office Water Operations group. When surface area is provided, Reclamation's Denver Office computes net evaporation for each reservoir. Table 4 lists the major reservoirs.

Table 4. Major reservoirs

Reservoir Name	Location in HUC	State Reservoir Located	Data provided
Granby Dam	14010001	Colorado	Surface Area
Shadow Mountain	14010001	Colorado	Surface Area
Williams Fork	14010001	Colorado	Surface Area
Willow Creek Dam	14010001	Colorado	Surface Area
Wolford Mountain	14010001	Colorado	Surface Area
Dillon	14010002	Colorado	Surface Area
Green Mountain Dam	14010002	Colorado	Surface Area
Ruedi Dam	14010004	Colorado	Surface Area
Rifle Gap Dam	14010005	Colorado	Surface Area
Vega Dam	14010005	Colorado	Surface Area
Taylor Park Dam	14020001	Colorado	Surface Area
Blue Mesa	14020002	Colorado	Evaporation
Crawford Dam	14020002	Colorado	Surface Area
Crystal Dam	14020002	Colorado	Surface Area
Morrow Point	14020002	Colorado	Evaporation
Ridgway Dam	14020006	Colorado	Surface Area
Silver Jack Dam	14020002	Colorado	Surface Area
Paonia Dam	14020004	Colorado	Surface Area
Fruitgrowers Dam	14020005	Colorado	Surface Area
McPhee Dam	14030002	Colorado	Evaporation
Fontenelle	14040103	Wyoming	Evaporation
Big Sandy	14040104	Wyoming	Surface Area
Eden	14040104	Wyoming	Surface Area
Meeks Cabin	14040107	Wyoming	Surface Area
Flaming Gorge	14040106	Utah	Evaporation
Stateline	14040107	Utah	Surface Area
Redfleet	14060002	Utah	Surface Area
Steinaker	14060002	Utah	Surface Area
Bottle Hollow	14060003	Utah	Surface Area
Moon Lake	14060003	Utah	Surface Area
Currant Creek	14060004	Utah	Surface Area
Starvation	14060004	Utah	Surface Area
Strawberry	14060004	Utah	Surface Area
Enl. Strawberry (Soldier Creek)	14060004	Utah	Evaporation
Scofield	14060007	Utah	Surface Area
Huntington North	14060009	Utah	Surface Area
Joe's Valley	14060009	Utah	Surface Area
Lake Powell	14070006	Arizona	Evaporation
Navajo Dam	14080101	NewMexico	Evaporation
Vallecito Dam	14080101	Colorado	Evaporation
Lemon Dam	14080104	Colorado	Evaporation
Jackson Gulch Dam	14080107	Colorado	Evaporation

The second category includes reservoirs that do not report monthly data and are termed minor reservoirs. For these reservoirs a "fullness factor" was estimated on the basis of reservoir use and historical hydrologic conditions. These "fullness factors" are used to obtain estimates of average annual water surface area for the unreported reservoirs. Annual free water surface (FWS) evaporation rates were used in conjunction with surface area to determine reservoir evaporation.

The FWS evaporation value was taken from NOAA Technical Report NWS 33, “Evaporation Atlas for the Contiguous 48 United States”, June 1982, Map 3 of 4 : Annual FWS Evaporation based on the reservoir location information. An account was taken of precipitation and runoff salvage to determine net evaporation rates. The net evaporation rates were applied to the estimates of average annual water-surface area to yield the values of annual reservoir evaporation.

Stockponds

Stockpond surface areas were estimated from the May 1975 Soil Conservation Service (SCS) publication, "Livestock Water Use." The subbasin stockpond areas were subdivided by State and basin using the livestock population distribution. The same procedure used to calculate the unmeasured reservoir evaporation was used to estimate the stockpond evaporation

Livestock

Livestock population data was taken from annual State Agriculture Statistics and the 1992 and 1997 Census of Agriculture. Livestock population data included cattle, sheep, horses, and hogs. Consumption rates for the various livestock were derived from various reports, including the SCS publication, "Livestock Water Use," May 1975.

Thermal Power

The net use of water for the production of thermal electric energy from the tributaries of the Colorado River Basin was estimated from records obtained from the various power companies in the Basin.

Minerals

The Upper Basin uses water in the production of numerous minerals in addition to energy-related materials such as oil and natural gas. Estimates of the water consumptively used were based largely on phone surveys conducted by the U.S. Geological Survey in certain years that quantified water use in the basin. Intermediate years were interpolated between available data. In some cases where, for privacy reasons, companies were unwilling to supply information, information was obtained from the U.S. Bureau of Mines.

Municipal and Industrial

The basis for estimating municipal and industrial uses was the urban and rural population within the reporting areas. Preparation of annual population estimates was guided by the census, various State and county statistical reviews, and reports that included population estimates for local areas. Water supply withdrawal for urban, rural, commercial, industrial, and public uses were taken from data collected by the USGS and summarized in reports published every five years titled "Estimated Use of Water in the United States". Typically, this information is reported by hydrologic unit and state.

Exports/Imports

Nearly all the transbasin diversions both out of and into the Colorado River System were measured and reported by the Geological Survey, or local water commissioners and users. The remainders were estimated on the basis of past records and capacity of facilities.

Reservoir Regulation

Reservoir regulation accounts for the water reservoirs store or release each year during operation. This category does not account for losses due to reservoir evaporation. Reservoir evaporation was covered in the consumptive uses and losses categories.

Mainstem Reservoirs

Two different levels of reservoir regulation detail are included in the model. The greatest detail is included in the reservoirs termed mainstem reservoirs. These reservoirs include Fontenelle, Flaming Gorge, Taylor Park, Blue Mesa, Morrow Point, Crystal, Navajo, and Lake Powell. These reservoirs explicitly model the historic operations with reservoir objects in RiverWare.

These objects are all loaded with historic pool elevation data retrieved from the Hydrologic Data Base (HDB) at the Upper Colorado regional office. Blue Mesa and Crystal Reservoir are also loaded with historic outflow from HDB because data from a USGS streamflow gauge is not available directly downstream of the reservoir.

Two mainstem reservoirs model bank storage. Bank Storage is modeled in Flaming Gorge as the change in storage times the bank storage coefficient (3 percent). In Powell, historic bank storage is directly input rather than allowing the RiverWare model to compute the bank storage. The Upper Colorado regional office provides the historic bank storage, which is computed by the water operations group with a mass balance algorithm.

Nonmainstem Reservoirs

The second level is termed nonmainstem reservoirs. These reservoirs were accounted for in the computation of natural flow from 1906-1974 in addition to the reservoirs discussed above. To remain consistent with the previous methods used to compute natural flow these were included in the recent computation of natural flow. Table 5 lists the nonmainstem reservoirs. For these reservoirs we only collect the historic monthly change in storage that occurred for each reservoir. These reservoirs are not explicitly modeled as reservoir objects in the model but rather the monthly change in storage is entered in a data object and rules are used to remove or add water at the appropriate point in the river system.

Table 5. Nonmainstem reservoirs

Reservoir Name	HUC	State
Shadow Mountain	14010001	Colorado
Granby	14010001	Colorado
Willow Creek	14010001	Colorado
Williams Fork	14010001	Colorado
Dillon	14010002	Colorado
Green Mountain	14010002	Colorado
Homestake	14010003	Colorado
Reudi	14010004	Colorado
Paonia	14020004	Colorado
Vega	14010005	Colorado
Scofield	14060007	Utah
Starvation	14060004	Utah
Joes Valley	14060009	Utah
Vallecito	14080101	Colorado
Lemon	14080104	Colorado
Jacksons Gulch	14080107	Colorado
Strawberry[4]	14060004	Utah
Solider Creek[5]	14060004	Utah

Salt Methods

As discussed earlier natural salt is more involved than natural flow. Similar to natural flow, natural salt is first back-computed in RiverWare as described in the introduction but the result from the back computation can not be used to directly model natural salt. The data used to back-compute natural salt has greater uncertainty than the data used to compute natural flow. The uncertainty is present in our estimate of salt contributed from agriculture. In order to model the uncertainty, a statistical model of the relationship between natural flow and salt is developed for each reach in the Upper Colorado Basin. In this section, we first describe the data used to directly back compute natural salt, then describe the statistical model that produced the final values of natural salt used for planning models.

Back Compute Natural Salt

Natural salt is first computed using basic accounting. Natural salt mass is computed as

$$naturalSaltMass = historicSaltMass - agriculturalreturnSaltPickup + exportedSaltMass - importedSaltMass$$

[4] This became Solider Creek in the 1980's.
[5] Starts in September 1983. This was Strawberry before the expansion.

A description of the data and source of the data is provided in the following sections.

Salt Concentration Gauge Data

Salt concentration data is available from the output of the SLOAD program. Table 2, explained in the section titled Stream Gauge Data, lists the stream gauges that monitor salt concentration. At these gauges daily electrical conductance (EC) values are collected along with grab samples of total dissolved solids (TDS) taken are various intervals. The SLOAD program accepts monthly EC, TDS, and streamflow as inputs and computes monthly TDS.

Agricultural Salt Pickup

Limited source data is available to quantify agricultural salt pickup (loading). Presently, the agricultural salt loading data is available as a single annual value at each gauge location. These values were derived from an input file used in previous versions of the CRSS policy model. The file these values were taken from was generated at an earlier date using the Demand Input Data generation program SMDID. The file provides a return flow and return flow salinity pickup concentration. The agricultural salt pickup mass was computed as

$$agriculturalSaltMassPickup(tons) = \frac{returnFlow(ac-ft) \times returnFlowSalinityPickup(mg/L)}{735.474((tons/ac-ft)/(mg/L))}$$

Data to compute agricultural salt loading was only available as an annual 1970 value at all agriculture locations. These values were held constant and applied for all years. This assumption will force the variability in agricultural salt loading to be back computed into the natural salt mass. Therefore, it is important to recognize that the natural salt mass, as well as the natural flow, is NOT only what would naturally have occurred throughout the basin without anthropogenic effects. It also incorporates the error in any assumptions or in the accuracy of our estimates of the anthropogenic effects that we removed from the historic gauge records. Figure 3 graphically depicts the agricultural salt loading attributed throughout the Colorado River Basin.

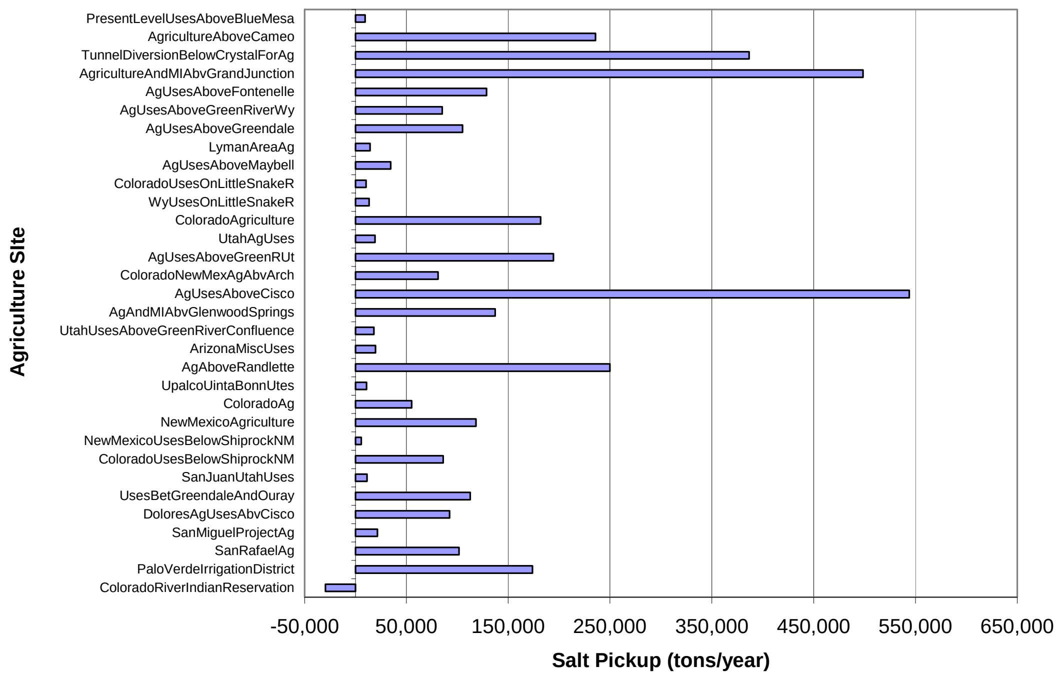

Figure 3. Agricultural salt pickup mass by site

Next, the annual agriculture salinity pickup was disaggregated to a monthly time step to facilitate recomputing natural salt at a monthly time step. As a reminder, the monthly time step is presently required for CRSS rules to function in future simulations.

Export and Import Salt Concentration

As exports(imports) remove(add) water to the Colorado River basin they also remove(add) salt. The amount of salt removed(added) is modeled as a constant salt concentration assigned to each export(import). Since concentration is constant the tons vary as the export(import) flows vary. The concentrations used for each export are listed in Table 6. These concentrations were taken from the previous CRSS policy model. It was assumed that these are representative of the concentrations seen in tributaries high in the Colorado River basin.

Table 6. Export and import salt concentrations in the Upper Basin

Export(Import) Title	Constant Concentration (mg/L)
PriceRiverExport	100
ExportsAbv09217000	100
ExportsAbv09234500	100
ExportsAbv092510000	100
ExportsAbv09315000	Not Used
ExportsAbv09355500	75

Export(Import) Title	Constant Concentration (mg/L)
ExportsAbvBlueMesa	100
ExportsAbvGlenwoodSprings	100
ExportsFromRoaringForkRiver	100
ImportsAbvGlenwoodSprings	100
ImportUsesAbv09152500	100
ImportUsesDoloresProject	130
ExportUsesDoloresProject	130
SanRafaelExports	100
DuchesneRiverExports	150
LitlleSnakeRiverExports	100
IntrabasinExport	100

Nonparametric Natural Salt Model

The nonparametric natural salt model replaces the previous salt model developed by the USGS (Mueller and Osen, 1987). Research studies completed by Reclamation examining the determination of natural salt above the Colorado River near Glenwood Springs, Colorado gauge, led to the conclusion that the relationship between natural flow and salt mass had changed since the completion of the previous salt model (Prairie, 2004). The research found the changes in the relationship had contributed to an over-estimation of natural salt.

Efforts to correct the USGS salt model were unsuccessful because the original data used to develop the USGS salt model could not be recovered. We took advantage of the opportunity to reexamine the salt model and incorporate improvements from recent research. A new nonparametric salt model was developed that 1) removed the overestimation observed with the USGS salt model and 2) incorporated uncertainty in the computation of natural salt mass.

The nonparametric salt model was initially developed in Prairie (2002) and further described in Prairie et al. (2002). Initially, the nonparametric salt model was developed on a single gauge (Colorado River near Glenwood Spring, Colorado) to develop and test the new model. The tests showed that the nonparametric model removed the overestimation documented when using the current USGS salt model results. Recent efforts extended the nonparametric salt model to the remaining 14 gauges throughout the Upper Basin that monitor salt concentration.

Monthly Regressions

With both total natural flow and total natural salt computed at each Upper Basin gauge, the data required for the nonparametric salt model is available. These two inputs are utilized to develop local regressions for each month at the 15 gauges (5 of the 20 gauges that record flows do not monitor salinity). Therefore, 15 by 12 regressions are generated. For example, Figure 4 shows the 12 regressions developed for the Colorado River at Lees Ferry, Arizona gauge. The remaining regression relationships can be found in Appendix C. In the figure it is evident that the local regressions are typically nonlinear and that the scatter(uncertainty) around the regression is more pronounced during low and transition flow months. Increased scatter indicates more variability in the relationship between natural flow and associated natural salt mass.

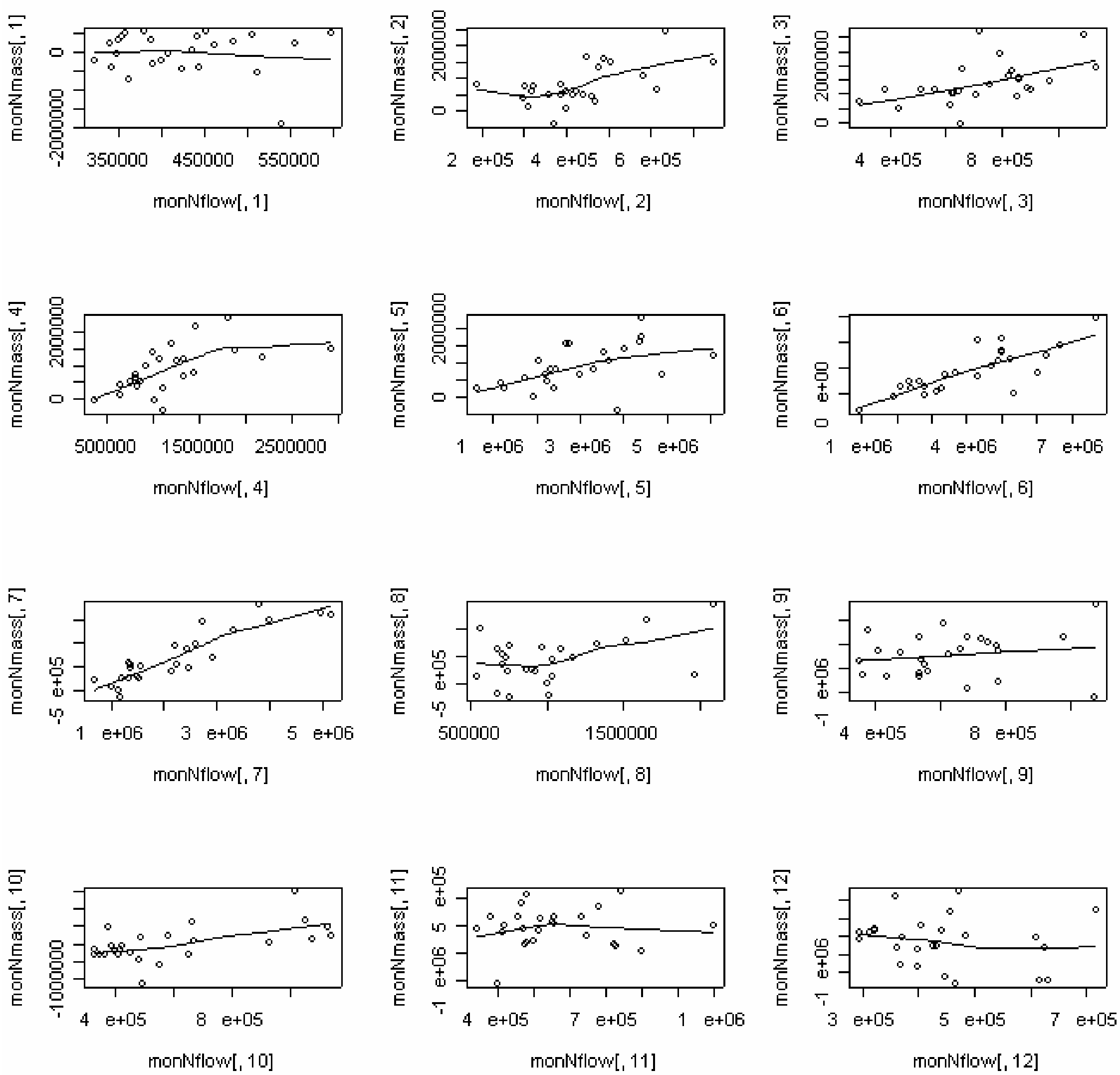

Figure 4. Monthly regression relationships for Colorado River at Lees Ferry, Arizona

Incorporating Uncertainty

The nonparametric salt model incorporates uncertainty in generated natural salt by utilizing residual resampling (Prairie et al., 2002). Residual resampling incorporates the scatter around the regression shown in Figure 4 by generating natural salt through the following steps.

1. A natural salt y_1 is first determined given a natural flow x_1.
2. A k- nearest neighbor algorithm then identifies the k nearest residuals, e to x_1, y_1 on the regression line.

3. These neighbors are weighted so the nearest neighbor has the greatest weight and the farthest the least.
4. One of the residuals e^* is then randomly chosen and added to y_1 arriving at our natural salt y_1^* as $y_1^* = y_1 + e^*$.
5. Steps 1-4 are repeated for each natural flow generating an associated natural salt.

When these steps are repeated with an ensemble of natural flow time series a corresponding ensemble of natural salt time series is generated that incorporate the uncertainty of the local regression shown by the scatter around each regression. Figure 5 graphically shows the results from running the recomputed natural flow sequence through the nonparametric salt model 100 times thus generating 100 sequences of natural salt associated with the natural flow. Figure 5 displays the region of 1 percent to 99 percent confidence of the 100 natural salt sequences. The new salt model line shows the recomputed natural salt back-computed as described earlier. Additionally, the back-computed natural salt is the salt computed from the Natural Flow and Salt Calculation Model. The without uncertainty line shows the natural salt that would be computed from the nonparametric salt model without residual resampling.

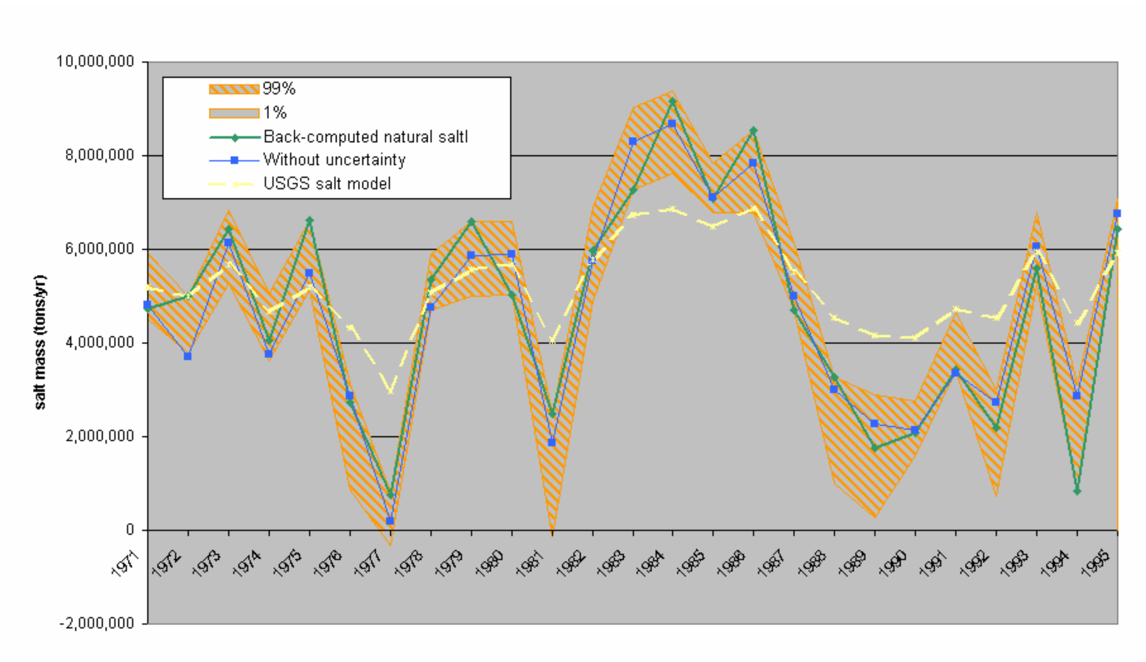

Figure 5. Natural salt mass with uncertainty at Colorado River at Lees Ferry, Arizona.

The USGS salt model line shows results of running the recomputed natural flow through the USGS salt model. The USGS salt model is not able to capture the annual variations in natural salt that the nonparametric salt model captures. The 1% to 99% region from the nonparametric salt model does not include results from the USGS model for many years. Only during the periods of average flows do the USGS salt model results lie within this region. Typically, the USGS salt model generates average salinity values and cannot capture extreme events such as high or low flow periods.

The confidence interval does not always capture the back-computed natural salt mass accurately during high flows. This results from the fact that we are simulating natural salt monthly with twelve regressions then summing the salt from these regressions to view annual results. Because the salinity standards are annually based but the CRSS model requires monthly data to simulate future operations we presently need salinity at a monthly time step to use the CRSS simulation model. Aggregating the results from 100 simulations using the nonparametric salt model aggregates the scatter (residuals) from the 12 monthly regressions generating increased uncertainty in annual results. Future work will explore development of annual regressions for each gauge, replacing the monthly regressions. Statistical methods need to be developed to distribute the annual data to monthly. Presently, time constraints have not allowed further exploration of this option.

Lower Basin

This section explains the steps taken to compute natural flow and natural salt in the Lower Colorado River Basin (Lower Basin) from 1971-1995. For this report, the Lower Basin was defined as the portion of the lower Colorado River from Lees Ferry Gauging Station[6] to Imperial Dam. The Lower Basin was split into five reaches, each reach terminating at the gauge listed in Table 7.

Table 7. Lower Basin reaches used to calculate natural flow

Reach Number	Gauge Number	Gauge Name
1	09402500	Colorado River Near Grand Canyon, AZ
2	09421500	Colorado River Below Hoover Dam, AZ-NV
3	09423000	Colorado River Below Davis Dam, AZ-NV
4	09427520	Colorado River Below Parker Dam, AZ-CA
5	09429490	Colorado River Above Imperial Dam, AZ-CA

The five Lower Basin reaches identified in Table 8 were abbreviated as follows:

1. Lees Ferry to Grand Canyon
2. Grand Canyon to Hoover Dam
3. Hoover Dam to Davis Dam
4. Davis Dam to Parker Dam
5. Parker Dam to Imperial Dam

Flow Methods

This section explains the calculation of natural local intervening streamflow (natural flow) in the Lower Basin. These calculations account for the historic streamflow (in acre-feet) gained or lost by reach, and the error associated with the modeling assumptions and data collection or analysis techniques used (e.g. averaging). The term “natural” in this context refers to the absence of human development (e.g. reservoirs).

Natural flow was computed in the Lower Basin using a new RiverWare[7] model developed for this project from CRSS. This new model, named the *Lower Basin Natural Flow Calculation*

[6] *Lees Ferry* is a USGS gauging station located on the Colorado River mainstem, upstream of the confluence with the Paria River, approximately 17 river miles below Glen Canyon Dam. In contrast, *Lee Ferry*, commonly referred to as “compact point,” is located on the Colorado River mainstem approximately one river mile downstream of the Paria River confluence. Lee Ferry is the division point between the Upper Basin and Lower Basin of the Colorado River as established by the Colorado River Compact of 1922.

[7] RiverWare is a generalized river basin modeling tool used by Reclamation to develop computer models for short, medium, and long-term operations and planning on the Colorado River.

Model, was designed to easily load historical monthly data. These data requirements include consumptive uses for each authorized Lower Basin diverter, gauged streamflow, and reservoir regulation. RiverWare was used to ensure algorithms associated with the computation of natural flow are consistent with the algorithms used for future simulation in CRSS.

Methodology

Natural flow is back-computed (derived) in the Lower Basin using the following mass balance algorithm:

$$naturalFlow = historicFlow + totalDepeltion \pm resevoirregulation$$

An overview of how each component of the natural flow algorithm is applied to a typical reach in the Lower Basin is provided in the upcoming sections; the application of each component to specific Lower Basin reaches is detailed in the flow schematics presented in Appendix A[8].

Streamflow Gauge Data

Historic streamflow gauge data in the Lower Basin was taken from two sources. The first source was output from the SLOAD[9] program. SLOAD data was used whenever possible because natural salt relationships – another phase of this project not described in this report – were developed by the USGS from SLOAD flows.

SLOAD produced output for six of the ten streamflow gauges in the Lower Basin. The streamflow gauges included in SLOAD are listed in Table 8. Where SLOAD data was unavailable, streamflow gauge data was taken from USGS records provided on their national website (http://water.usgs.gov), as listed in Table 9.

Table 8. Lower Basin SLOAD streamflow gauging stations provided by USGS Grand Junction Office

SLOAD filename	Gauge Number	Gauge Title
Lees	09380000	Colorado River At Lees Ferry, AZ
Grcan	09402500	Colorado River Near Grand Canyon, AZ
Virgin	09415000	Virgin R At Littlefield, AZ
Hoover	09421500	Colorado River Below Hoover Dam, AZ-NV
Parker	09427520	Colorado River Below Parker Dam, AZ-CA

[8] The flow schematics identify the gauges or dams used at the beginning and end of each reach, along with tributary inflows, depletions, gains, and reservoir regulation within each reach.

[9] SLOAD is a program run by the United States Geological Survey (USGS) that computes salinity concentration from flow data and electrical conductivity (EC) measurements collected by the USGS. The output from SLOAD provides flow in acre-feet/month, salt mass in tons/month, and salt concentration in mg/L.

Imper	09429490	Colorado River Above Imperial Dam, AZ-CA

Table 9. Lower Basin streamflow gauging stations from USGS national website

Gauge Number	Gauge Title
09382000	Paria River At Lees Ferry, AZ
09402000	Little Colorado River Near Cameron, AZ
09423000	Colorado River Below Davis Dam, AZ-NV
09426000	Bill Williams River Below Alamo Dam, AZ

Consumptive Uses and Losses

Decree Accounting

Water use records compiled in accordance with Article V of the Decree of the Supreme Court of the United States in Arizona v. California, dated March 9, 1964 (Decree Accounting) were used to determine consumptive use in the Lower Basin. Decree Accounting records were gathered from the Lower Colorado Hydrologic Data Base (LCHDB) and loaded into the model using an automated data management interface. Two data types from LCHDB were required model inputs for each decree user:

1) total diversion[10]
2) total consumptive use[11]

Decree diversions were placed in the model with attention given to spatial accuracy. Every Lower Basin decree diversion upstream of Imperial Dam identified in LCHDB was incorporated into the model. A complete list of the decree diversions in the model, the name associated with that diversion in LCHDB, and its corresponding Site_Datatype_ID is provided in Appendix C. There are fifty-two (52) Lower Basin decree users currently in the model from Lees Ferry to Imperial Dam.

Evaporation

Evaporation is calculated with a user-specified method in RiverWare called ***MonthlyEvaporationCalc***. The method multiplies the end of month (EOM) surface area by the corresponding monthly evaporation coefficient.

$$Evaporation = EOMreservoirSurfaceArea \times MonthlyEvaporationCoefficient$$

Three (3) mainstem reservoirs are modeled in the Lower Basin:

- Lake Mead
- Lake Mohave
- Lake Havasu.

Each reservoir has a distinct set of 12 evaporation coefficients, a different coefficient for each month of the calendar year. Evaporation coefficients are user-specified inputs to the model located in a data slot for each reservoir object.

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[10] Total diversion records from LCHDB match the diversions recorded in the official Decree Accounting reports produced by the Lower Colorado Regional Office.

[11] Total consumptive use numbers from LCHDB include unmeasured returns; for this reason they do not exactly match the consumptive use values published in the official Decree Accounting reports. Unmeasured returns have the effect of reducing total depletions from the system and are computed by multiplying total diversion by an “F” factor developed by the Boulder Canyon Operations Office. Each diverter has an “F” factor associated with its diversion, which may zero in some cases (e.g. exports).

Phreatophytes

Phreatophytes are native vegetation along the Colorado River corridor that depletes water from the system through evapotranspiration[12]. ET_{pht} estimates in the Lower Basin have been provided annually since 1995 by the Lower Colorado River Accounting System (LCRAS) report produced by Reclamation. Prior to 1991, ET_{pht} estimates were calculated from historical acreage and climatological data using the Blaney-Criddle formula as described in Appendix 1 of the March 1992 hydrologic flow and salt database report for the Lower Colorado Region (March 1992 report).

ET_{pht} estimates in the Lower Basin do not exist from 1991 to 1994; for this report, ET_{pht} was estimated from January 1991 to December 1994 by taking monthly averages of the LCRAS record from 1995 to 2002. The monthly average ET_{pht} values by reach are listed in Table 10.

Table 10. Monthly estimates of ET_{pht} based on LCRAS averages from 1995 to 2002

Month	Estimated ET_{pht} Davis To Parker (acre-ft)	Estimated ET_{pht} Parker To Imperial (acre-ft)
January	3,788	6,445
February	4,762	8,011
March	8,888	16,006
April	15,635	29,950
May	25,910	50,090
June	30,042	59,945
July	27,778	58,338
August	24,929	53,161
September	18,648	39,370
October	11,542	24,354
November	5,452	10,180
December	3,488	6,006

Reservoir Regulation

Reservoir regulation accounts for the water reservoirs store or release each year during operation. This category does not include losses due to reservoir evaporation. Reservoir evaporation was covered under consumptive uses and losses.

The components of reservoir regulation modeled in the Lower Basin are change in reservoir storage, and change in bank storage. Historic operations at each of the three (3) Lower Basin reservoirs are explicitly modeled using reservoir objects in RiverWare. These objects are loaded with historic pool elevation data retrieved from LCHDB.

[12] Phreatophyte consumptive use through evapotranspiration is abbreviated as ET_{pht}.

Change in Reservoir Storage

Reservoir storage refers to the active storage capacity (in acre-feet) available in the reservoir for release – it does not include dead storage. Reservoir storage is computed based on an elevation volume table specific to each reservoir. RiverWare calculates the change in reservoir storage at the current timestep internally by taking the current EOM reservoir storage less the previous EOM reservoir storage.

$$DeltaStorage(1) = EOMstorage(1) - EOMstorage(-1)$$

Change in Bank Storage

Bank storage refers to the amount of water stored in the porous media surrounding a reservoir. Of the three Lower Basin mainstem reservoirs, bank storage is only modeled at Lake Mead – change in bank storage is zero for Lake Mohave and Lake Havasu. The RiveWare method used in the natural flow model to calculate Lake Mead bank storage is called ***CRSSBankStorageCalc***, which involves multiplying reservoir storage by a bank storage coefficient. For Lake Mead, the bank storage coefficient is equal to 0.065; therefore, current bank storage is estimated as 6.5 percent of current reservoir storage. Change in bank storage is calculated at the current timestep by taking the current EOM bank storage less the previous EOM bank storage.

$$DeltaBankStorage(1) = EOMbankStorage(1) - EOMbankStorage(-1)$$

Salt Methods

The objective of this section is to explain the calculation of local intervening salt mass (natural salt) in the Lower Basin. These calculations represent the historic salt load (in tons) gained or lost by reach, and the error associated with the modeling assumptions or data collection/analysis techniques used (e.g., regressions).

Natural salt was computed in the Lower Basin using the same RiverWare model used to compute natural flow. As with flow, the use of RiverWare ensures consistency between algorithms that compute historic natural salt and those that simulate future salt loading in the system.

Methodology

Natural salt mass (in tons) is back-computed in the Lower Basin using the following mass balance algorithm:

$$naturalSaltMass = historicSaltMass - agriculturalreturnSaltPickup + exportedSaltMass - importedSaltMass$$

An important subtlety to realize when using RiverWare to compute natural salt is that salt concentration (in mg/L), or flow salinity, is used as model input rather than salt mass (in tons). Flow salinity is the required input parameter used by RiverWare for simulation; however, salt mass is the variable typically published when reporting salt gains in the Lower Basin. Salt mass is calculated internally by RiverWare using the following relationship:

$$\underset{\text{(tons)}}{saltMass} = \underset{\text{(acre-feet)}}{streamFlow} \times \underset{\text{(mg/L)}}{flowSalinity} \times \frac{1 \text{ ton/acre-foot}}{735.474 \text{ mg/L}}$$

Each component of the natural salt calculation and the required model inputs of salt concentration are described in the next four sections.

Salt Concentration Gauge Data

Salt concentration data is available from the output of the SLOAD program for Lower Basin stream gauges as listed in Table 8. Daily electrical conductance (EC) values were collected at these gauges, along with grab samples of total dissolved solids (TDS) taken at various intervals to estimate salt concentration.

Agriculture Salt Pickup

There are two points of agricultural salinity pickup modeled in the Lower Basin:

- Palo Verde Irrigation and Drainage District (PVID)
- Colorado River Indian Reservation (CRIT)

Data for agricultural salinity pickup in the Lower Basin was supplied by the Intensive Salinity Surveillance Program (ISSP), a Reclamation program created to monitor flows and salinity between Parker and Imperial Dams. PVID is a “conventional” agricultural salt loading in the fact that salt tonnage is deposited back to the river via irrigation returns flows. CRIT is a “non-conventional” agricultural salt loading because salt is retained. ISSP data found that CRIT returned less salt to the river than it diverted, creating a salt “sink” – effectively removing salt from the system.

As part of the natural salt calculation in the Lower Basin, ISSP data from calendar year 1971 to 1990, as detailed in Appendix 6B of the March 1992 report, was used to determine an average annual salt loading or retention by PVID and CRIT, respectively. The annual average was distributed monthly by dividing by twelve to produce a constant monthly agricultural salt tons pickup (or removal). Figure 3 displays the average annual salt pickup mass of PVID and CRIT. The constant monthly salt pickup mass used as model input for each entity was as follows:

- PVID = 14,488 tons/month
- CRIT = -2,461 tons/month

Export Salt Concentration

In the Lower Basin, salt exports from the system are modeled by removing the water exported at the current concentration of the river; therefore, river concentration and flow rate together determine the tons of salt exported. In contrast, salt exports in the Upper Basin are modeled at a constant concentration – flow varies, concentration does not. Salt exports in the Lower Basin are listed in Table 11.

Table 11. Salinity exports in the Lower Basin

Diversion Name in the Model	Reach	State
LasVegasWashWQIP	Grand Canyon to Hoover Dam	Nevada
AbvLakeMeadNRA:TempleBarAZ	Grand Canyon to Hoover Dam	Arizona
AbvLakeMeadNRA:LakeMeadNV	Grand Canyon to Hoover Dam	Nevada
LCRDDavisDam	Hoover Dam to Davis Dam	Arizona
LakeMeadNRA:LakeMohaveNV	Hoover Dam to Davis Dam	Nevada
LakeMeadNRA:LakeMohaveAZ	Hoover Dam to Davis Dam	Arizona
SouthernCaliforniaEdison	Davis Dam to Parker Dam	Nevada
Phreatophytes	Davis Dam to Parker Dam	n/a
CAP	Davis Dam to Parker Dam	Arizona
MWD	Davis Dam to Parker Dam	California
CityofBlythe	Parker Dam to Imperial Dam	California
EastBlytheCountyWaterDistrict	Parker Dam to Imperial Dam	California
NativeVegetation	Parker Dam to Imperial Dam	n/a

Import Salt Concentration

Salt loading from non-agricultural sources in the Lower Basin are provided by tributary inflows to the system. There are four major tributary inflows modeled in the Lower Basin. These tributaries and the method of estimating their respective salt loading to the system are listed in Table 12.

Table 12. Salinity Imports in the Lower Basin

Tributary Name	Reach	Method to Estimate Salt
Little Colorado River[13]	Lees Ferry to Grand Canyon	Salt to Flow Ratios
Paria River[14]	Lees Ferry to Grand Canyon	Regression Equation
Virgin River	Grand Canyon to Hoover Dam	SLOAD
Bill Williams River[15]	Davis Dam to Parker Dam	Lumped

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[13] Salt loading from the Little Colorado River was modeled using the same methods as the May 1985 hydrologic flow and salt database report for the Lower Colorado Region (May 1985 report).

[14] Salt loading from the Paria River was modeled using the same methods as the May 1985 report with the following modifactions: examination of the data in Appendix 1 of the May 1985 report revealed that for streamflows greater than 263 acre-feet, the full regression equation was used; however, for streamflows less than 263 acre-feet, the intercept was dropped from the regression to prevent negative salinity values. This method was carried over and used in this report to recalculate the entire record from 1971-1995. The regression equation will be reevaluated for future reports as additional data becomes available.

[15] Salt load from the Bill Williams River was not explicitly modeled for lack of adequate available data; therefore, it was lumped into the gains for that reach.

Flow Verification and Salinity Calibration

Flow Verification

A primary goal in our efforts to recompute natural flow throughout the Colorado River Basin was to ensure consistency in the data and methodologies used to compute natural flow and then those used in the CRSS planning model. As a final check to ensure data and methodology consistency, the Natural Flow and Salt Calculation Model was run with the natural flow as inputs and solved for the historic streamflow. If our model is consistent we should be able to exactly simulate the historic gauge flows throughout the entire basin. Figure 6 is a comparison of the simulated outflow from Powell with the Historic outflow used to compute natural flow. It is evident we exactly reproduced historic outflow indicating that our methods and data are consistent. Figure 7 show a similar plot for the gauge above Imperial Dam.

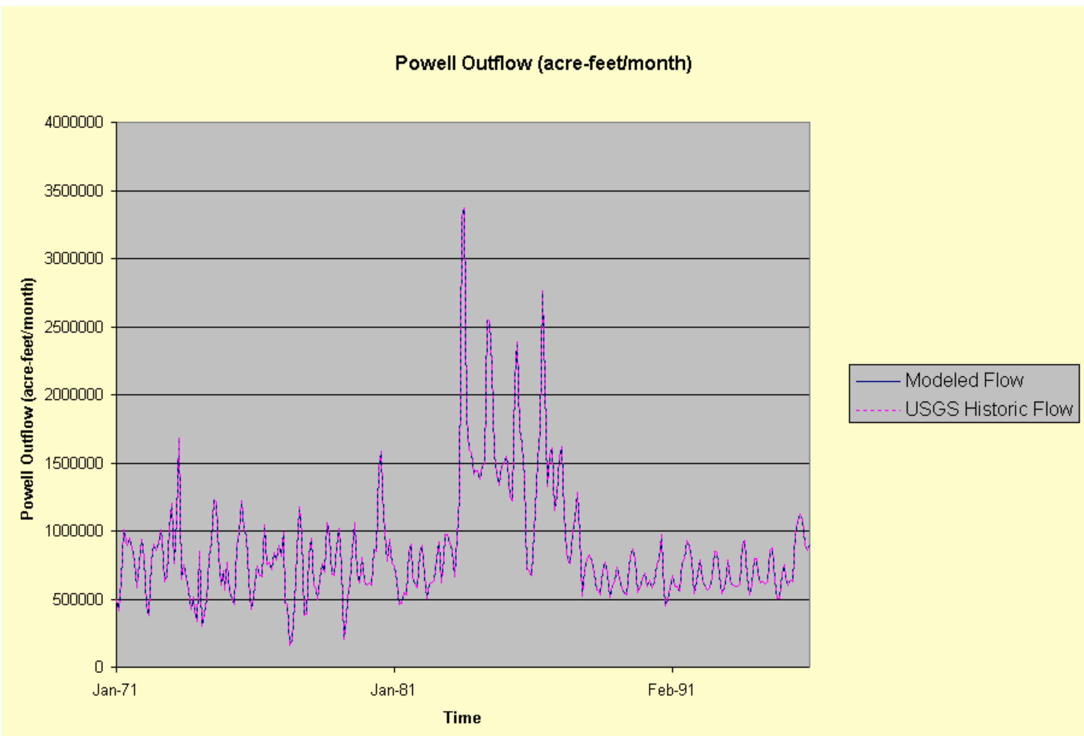

Figure 6. Flow verification at Colorado River at Lees Ferry, Arizona

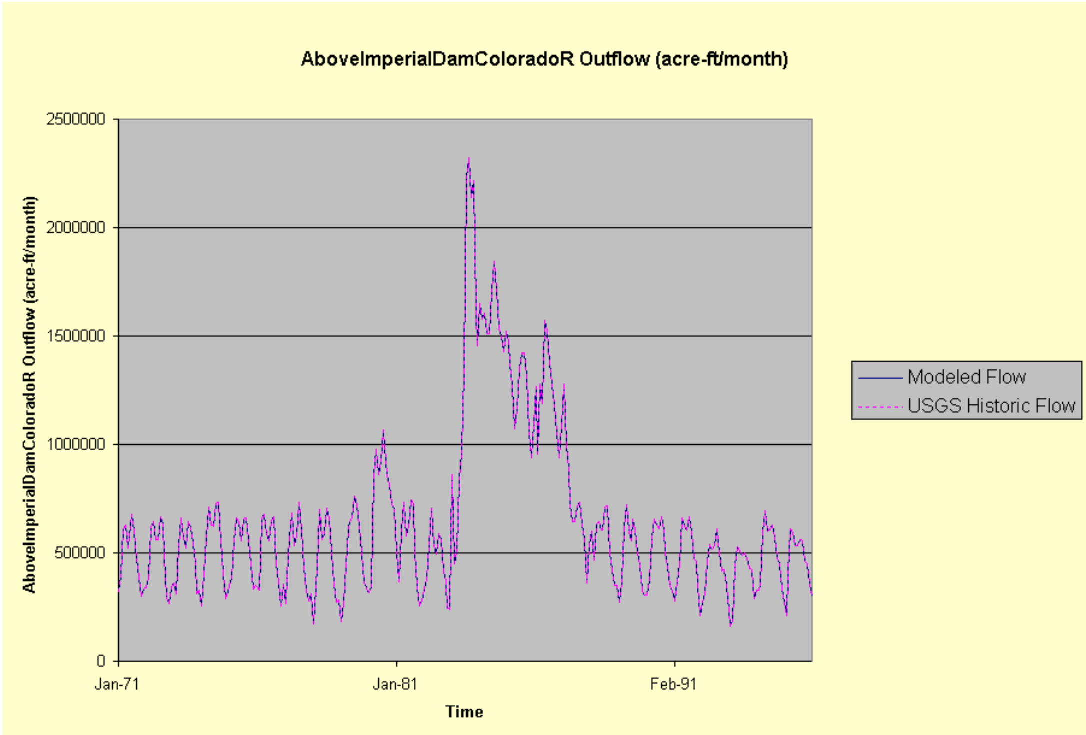

Figure 7. Flow verification at Colorado River above Imperial Dam, Arizona

Salinity Calibration

After the new method to model salinity is incorporated in CRSS, the final step to ensure that the CRSS simulation model is salinity-calibrated involves running the entire CRSS model using 1) the recomputed natural flows throughout the basin and 2) Upper Basin natural salt generated with the monthly nonparametric salt model. When results from this model run simulate salinity at the points of the salinity standards, i.e., Colorado River below Hoover Dam, Colorado River below Parker Dam, and Colorado River at Imperial Dam, capturing the historic salinity concentration at these gauges, the CRSS simulation model will be salinity calibrated, therefore, meeting our final goal. Figures 8 and 9 display the model results for outflow salt concentration below Powell~~,~~ and Above Imperial Dam, respectively. Again, we are able to show that our model accurately reproduces the salt concentration within the bounds of our simulated results.

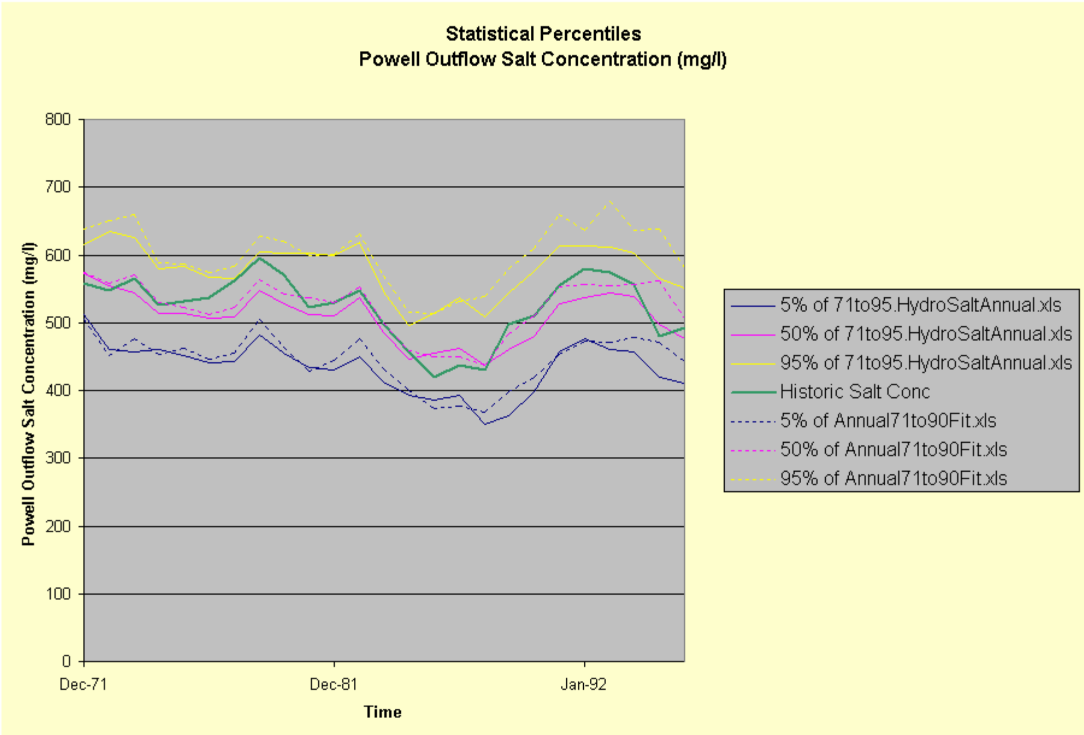

Figure 8. Salinity calibration at Colorado River at Lees Ferry, Arizona

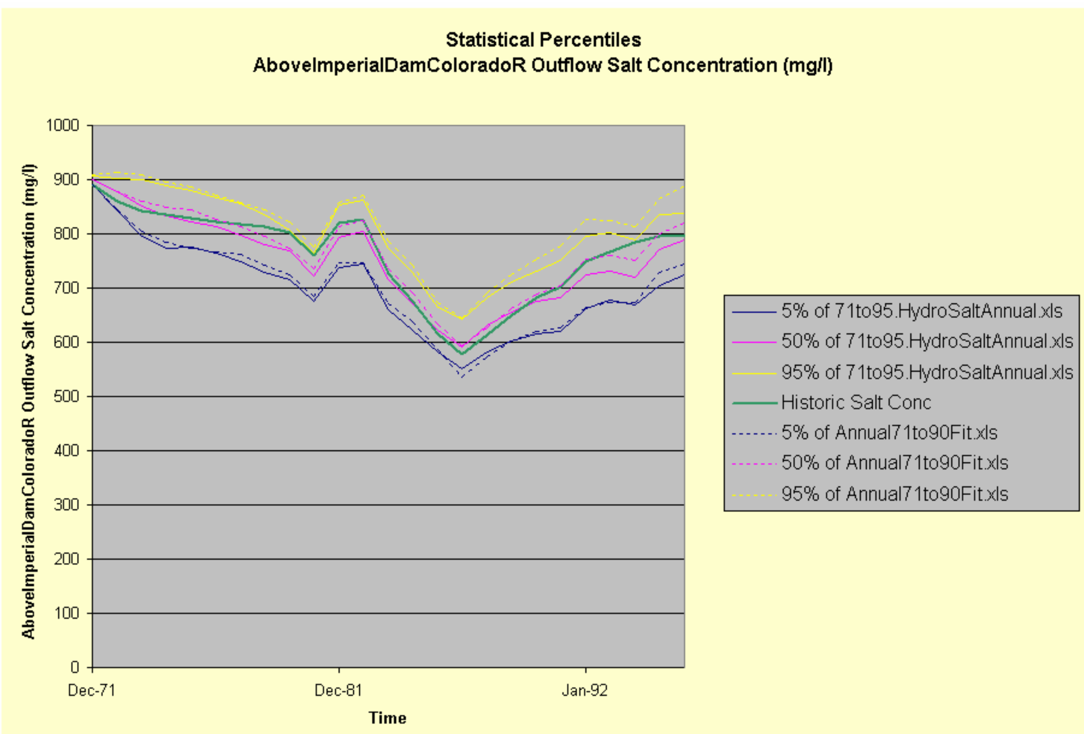

Figure 9. Salinity calibration at Colorado River above Imperial Dam, Arizona

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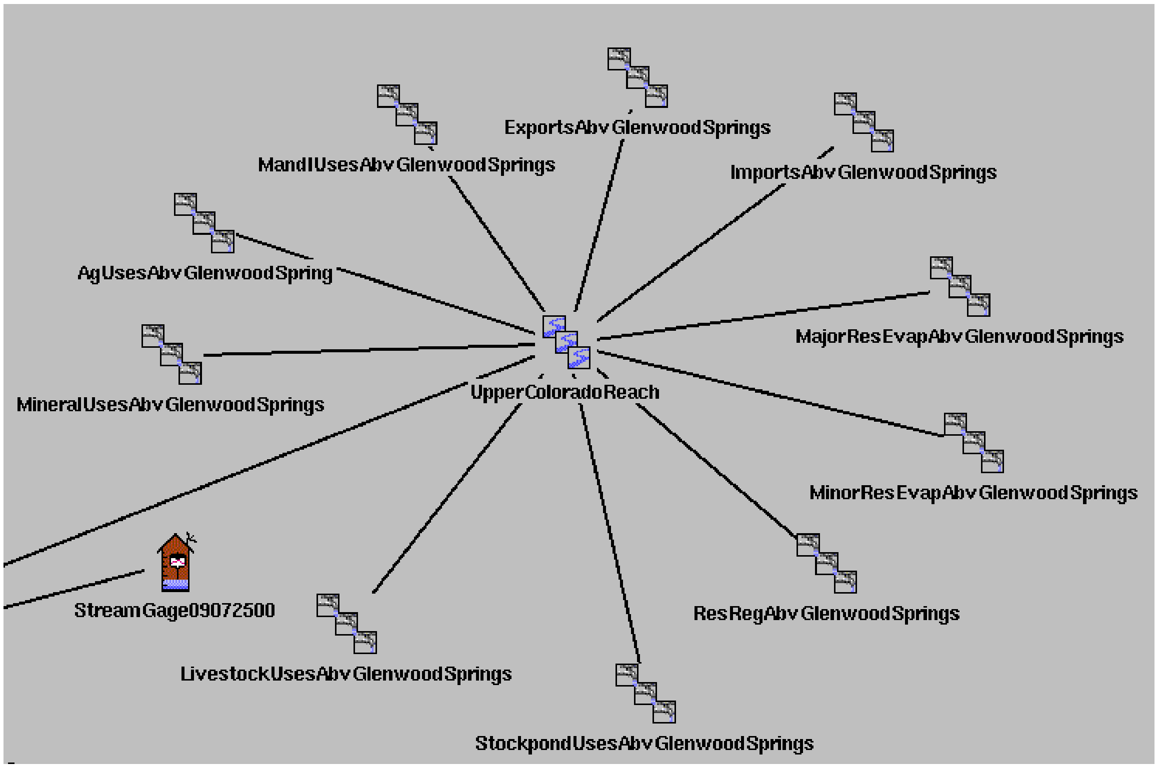
Appendices

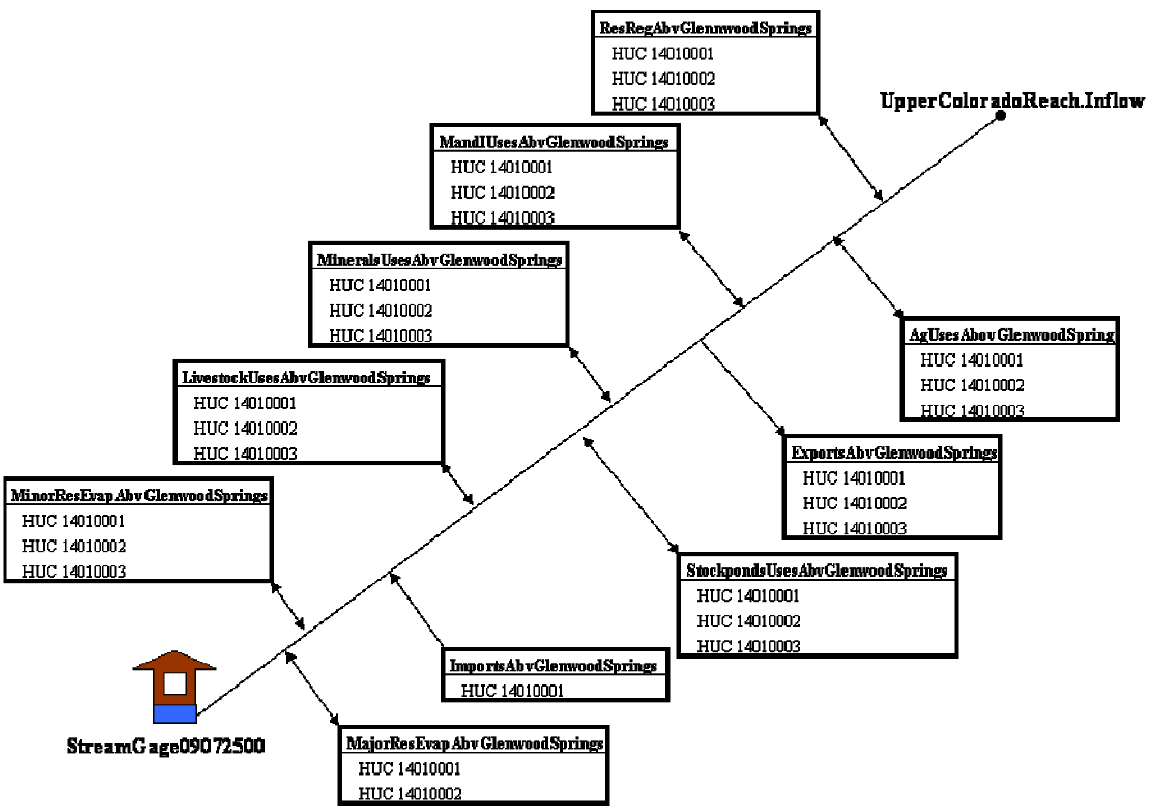
Appendix A: Flow Schematics

Upper Basin

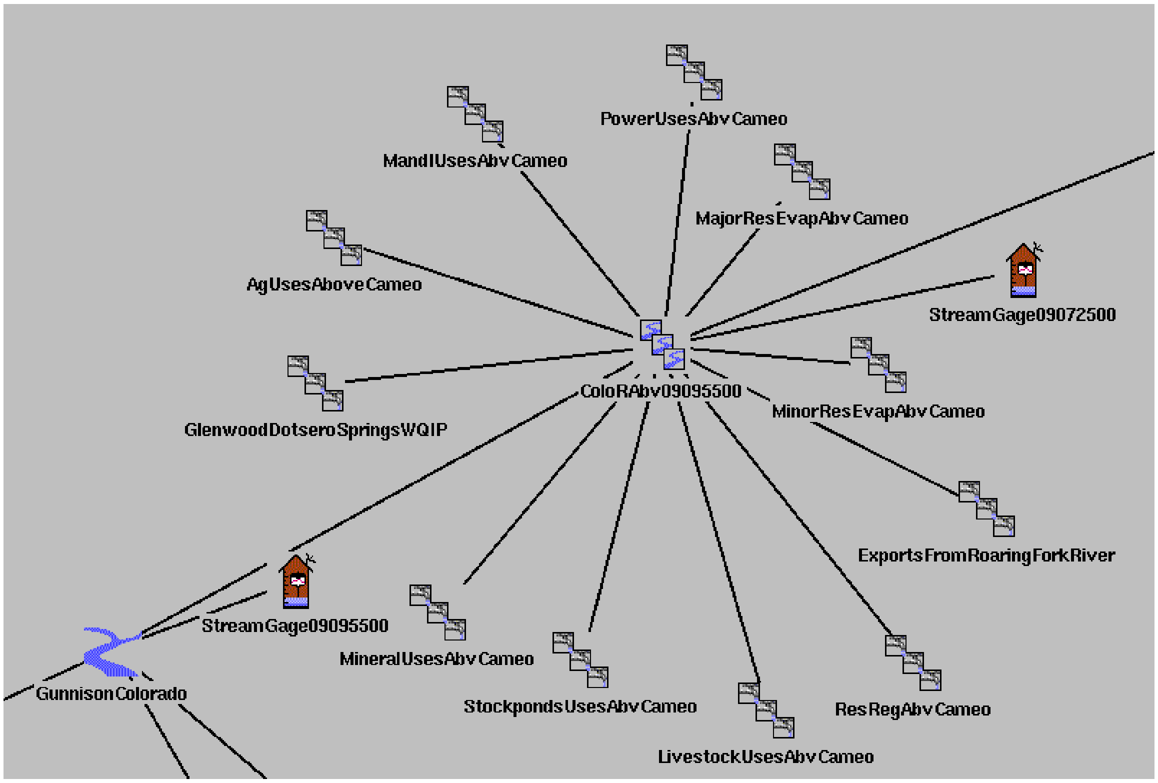
The following pages provide a screenshot of each gauged reach where an intervening natural flow and salt mass are computed. Following the screenshot is a line schematic of the screenshot listing the consumptive uses and losses finest spatial unit and any mainstem reservoir included in each gauged reach.

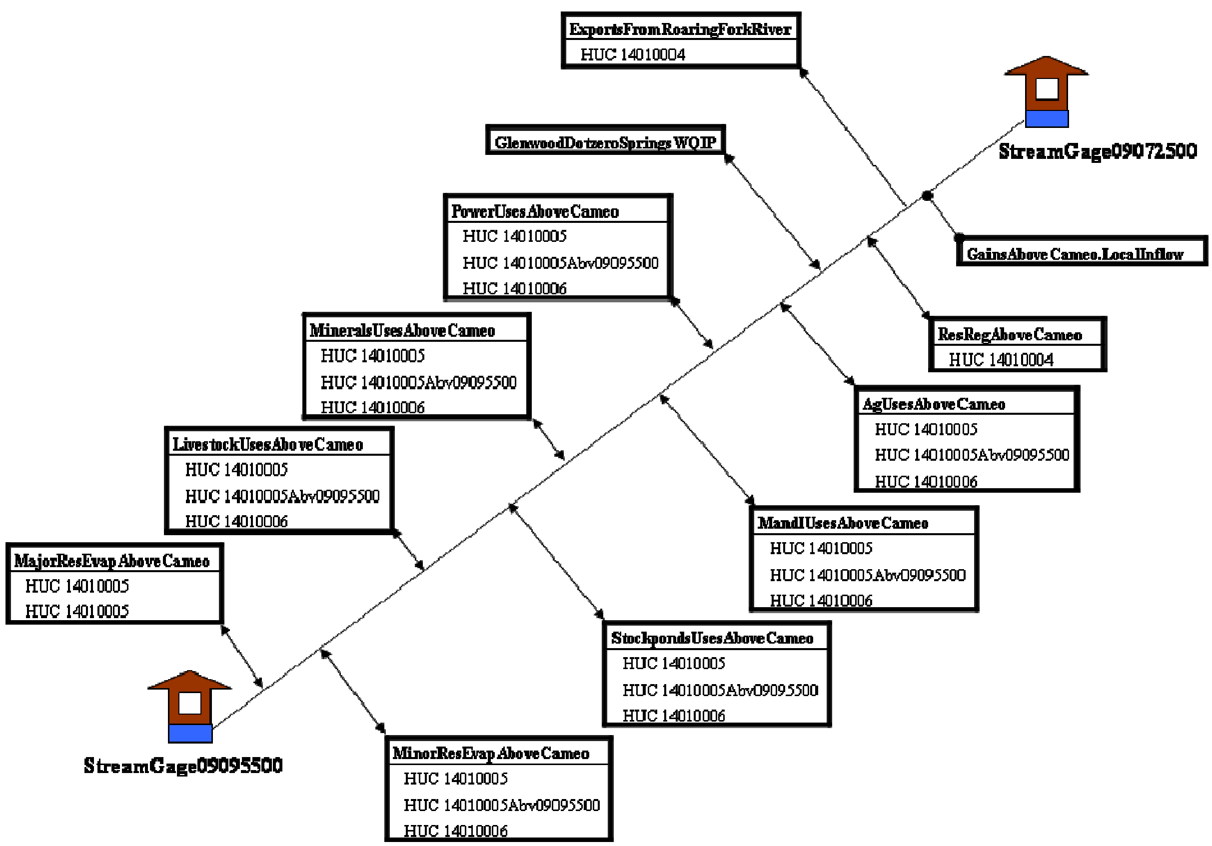
Above Colorado River at Glenwood Springs Reach



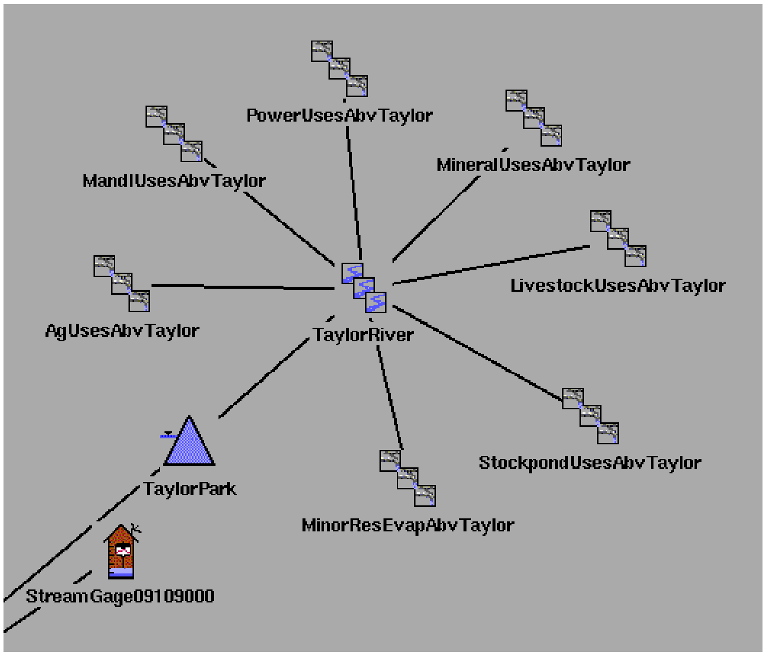


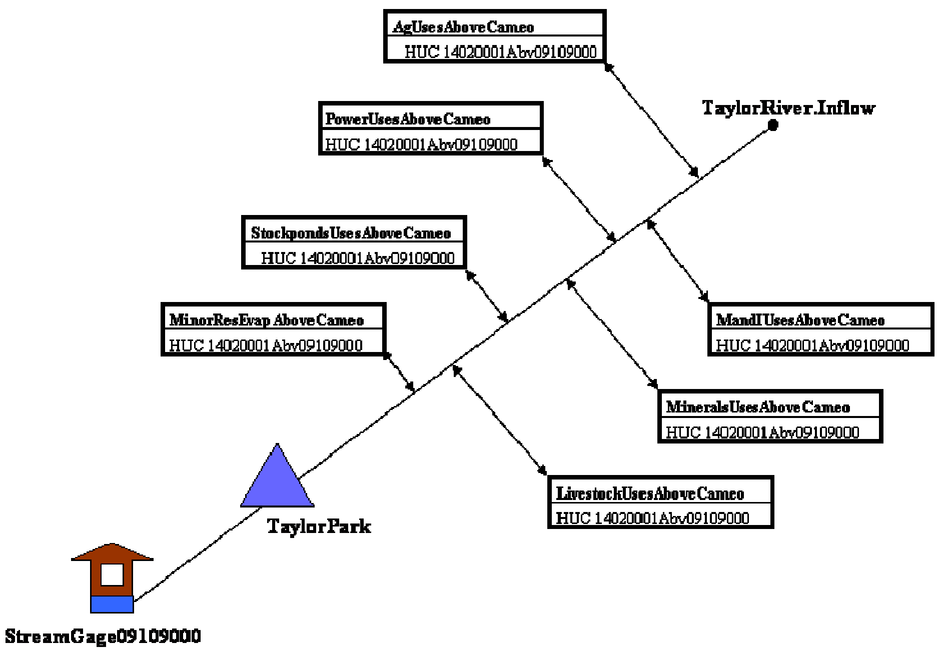
Colorado River at Glenwood Springs to Colorado River near Cameo Reach



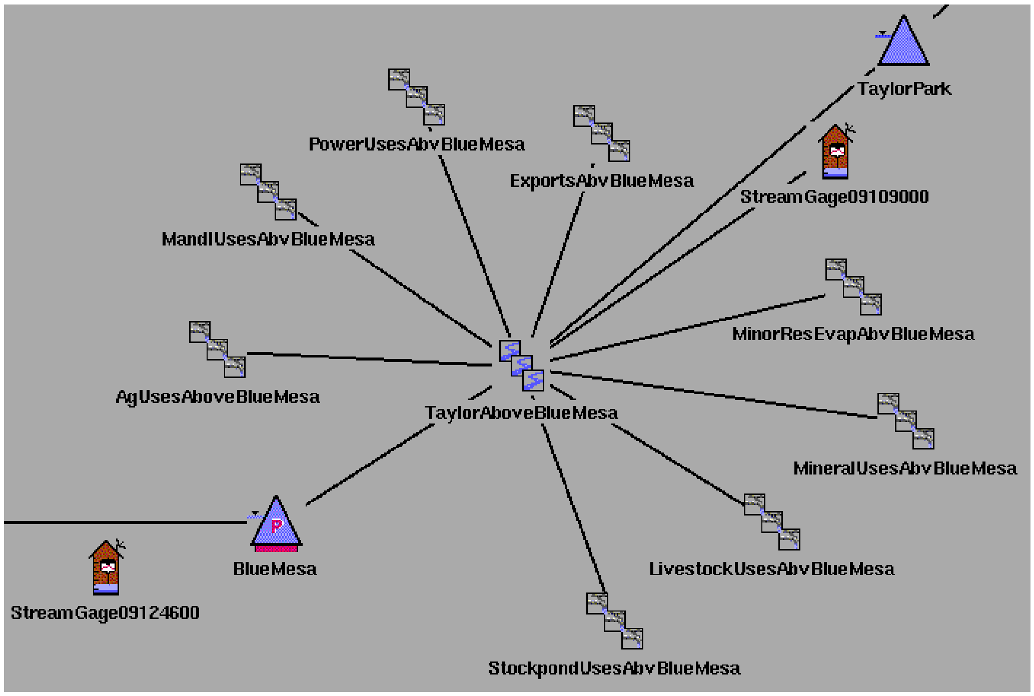


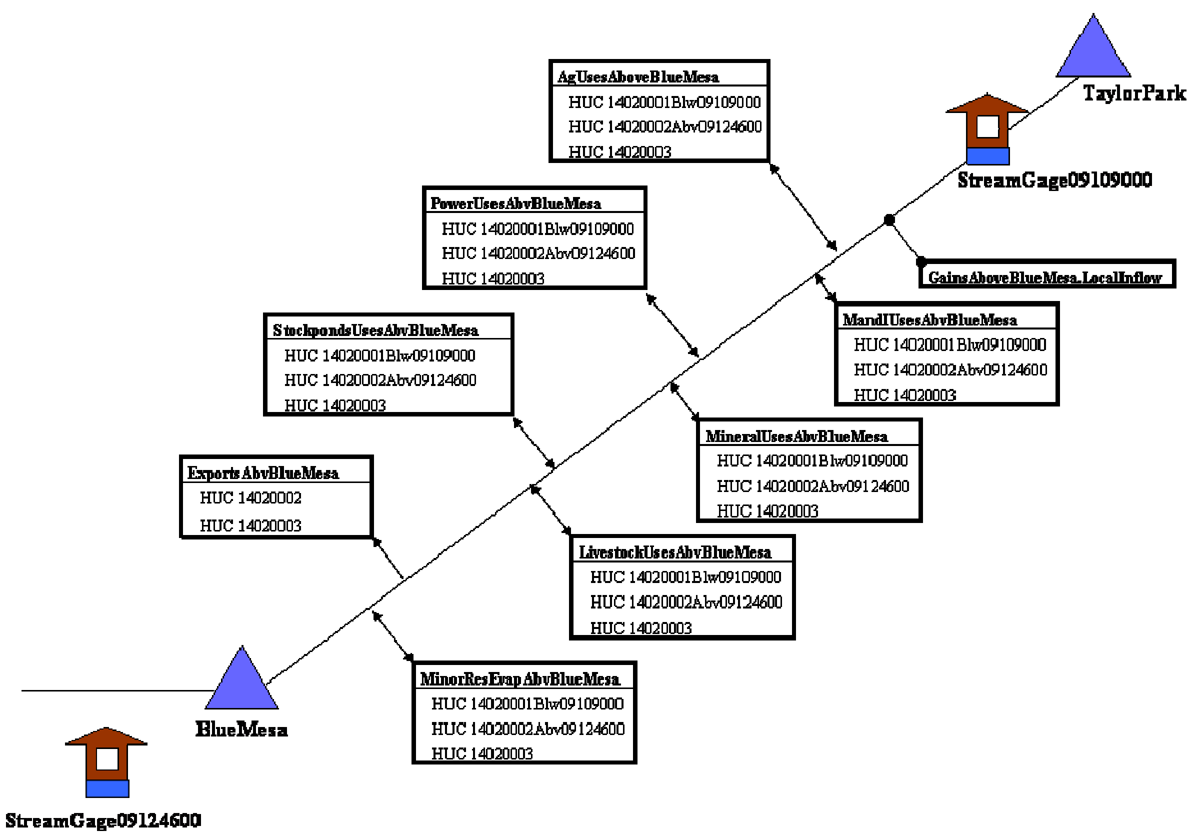
Above Taylor River before Taylor Park Reservoir Reach



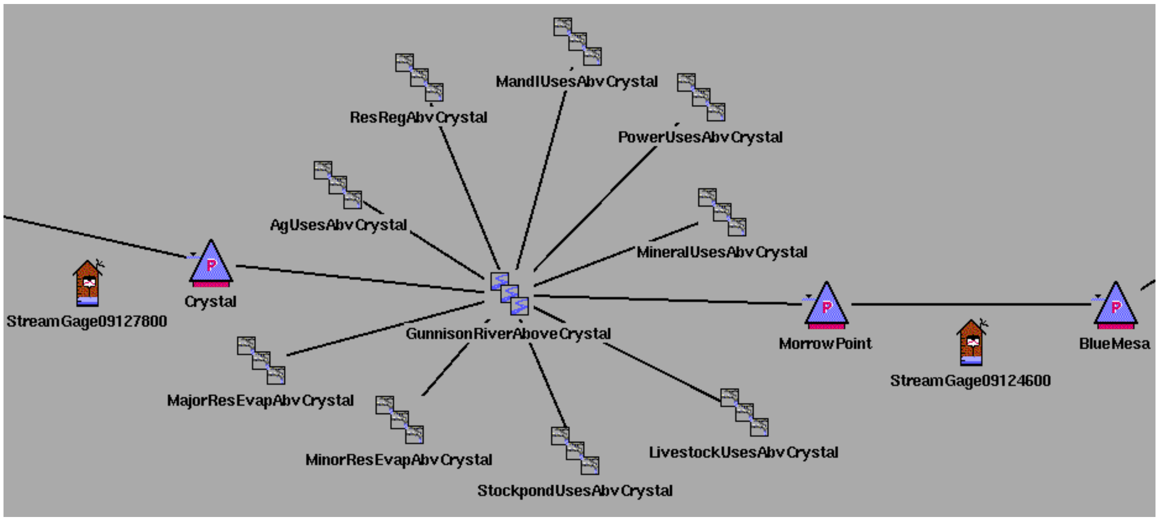


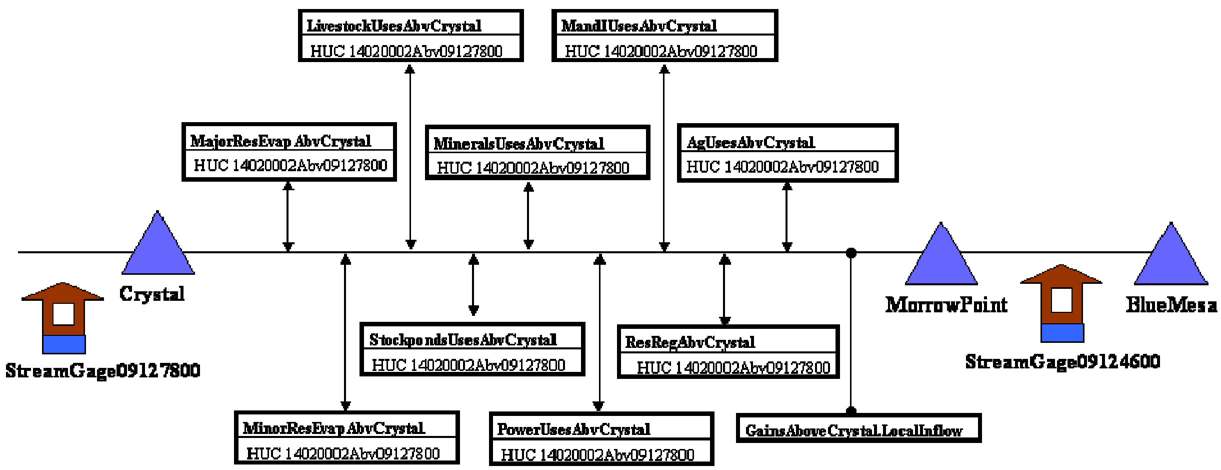
Taylor River before Taylor Park Reservoir to Gunnison River above Blue Mesa Reservoir Reach



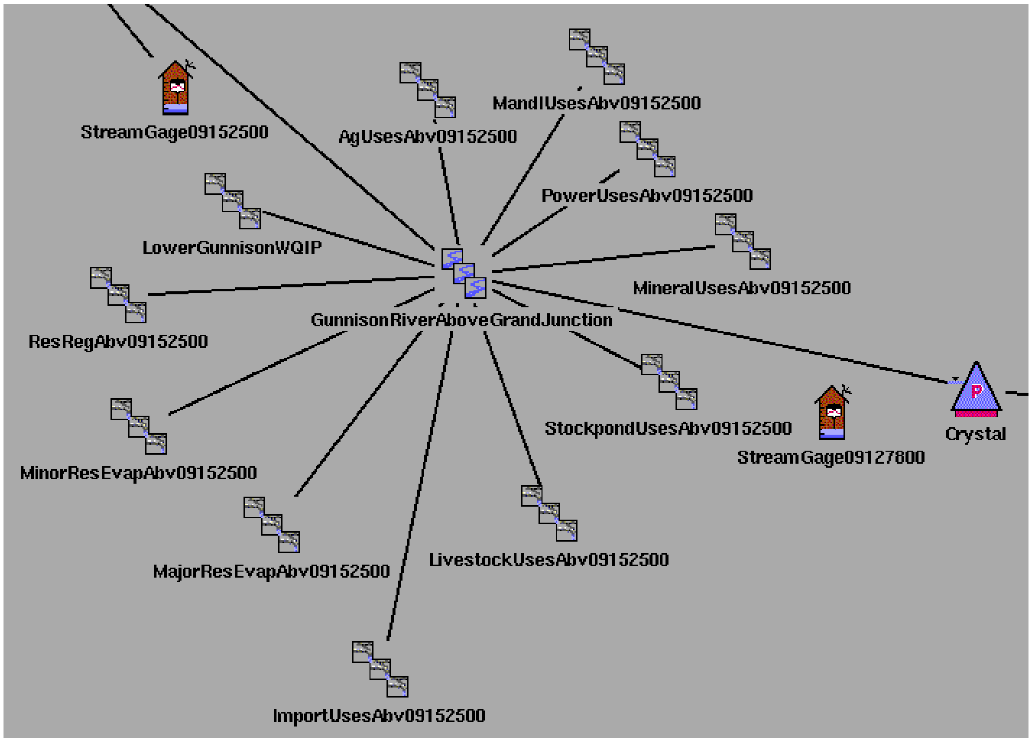


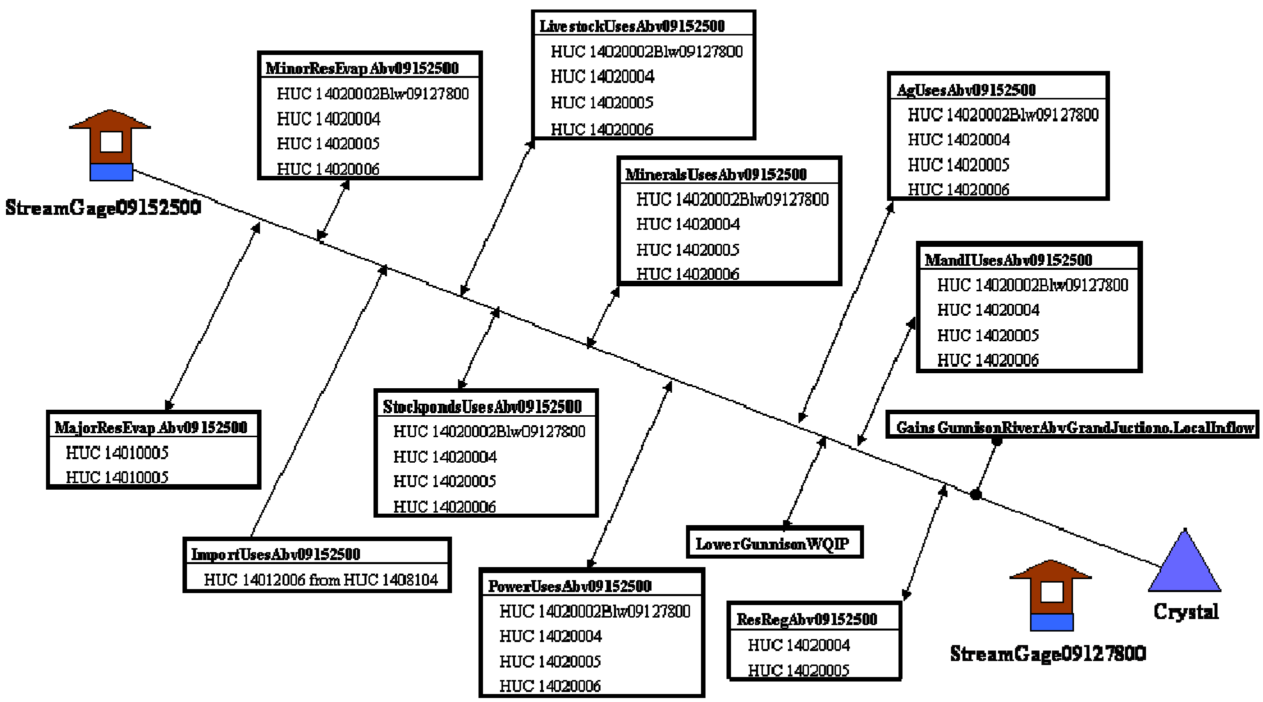
Gunnison River above Blue Mesa Reservoir to Gunnison River at Crystal Reservoir Reach



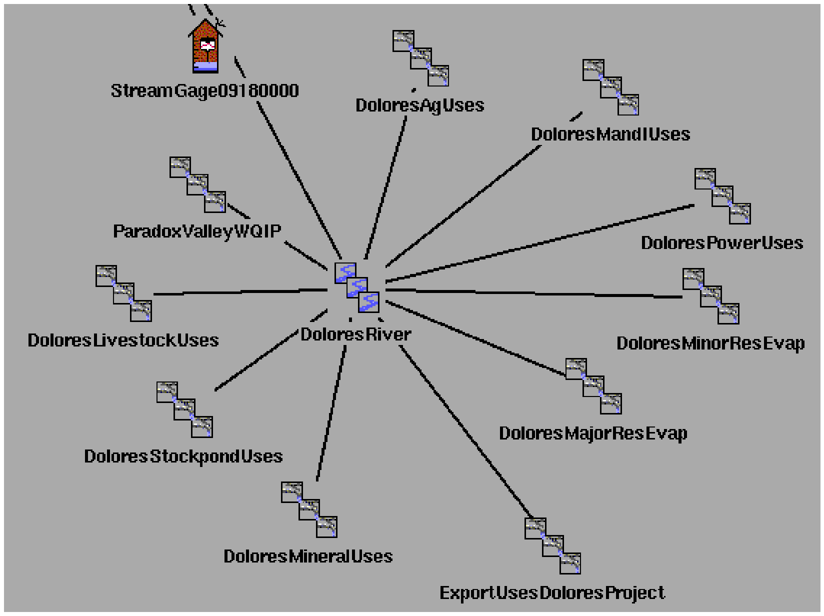


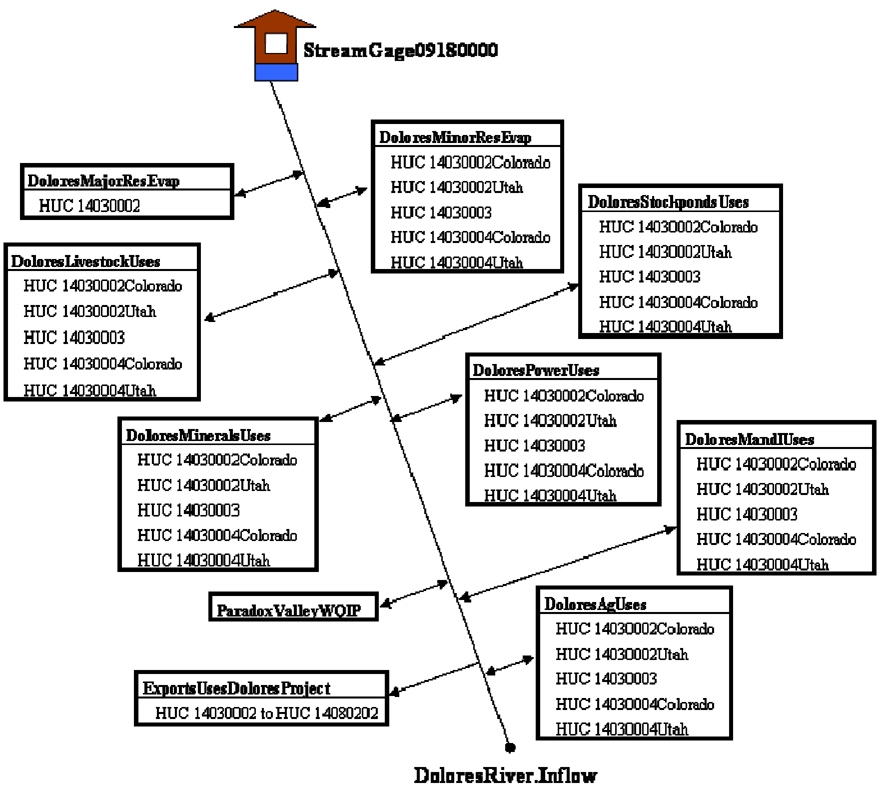
Gunnison River at Crystal Reservoir to Gunnison River near Grand Junction Reach



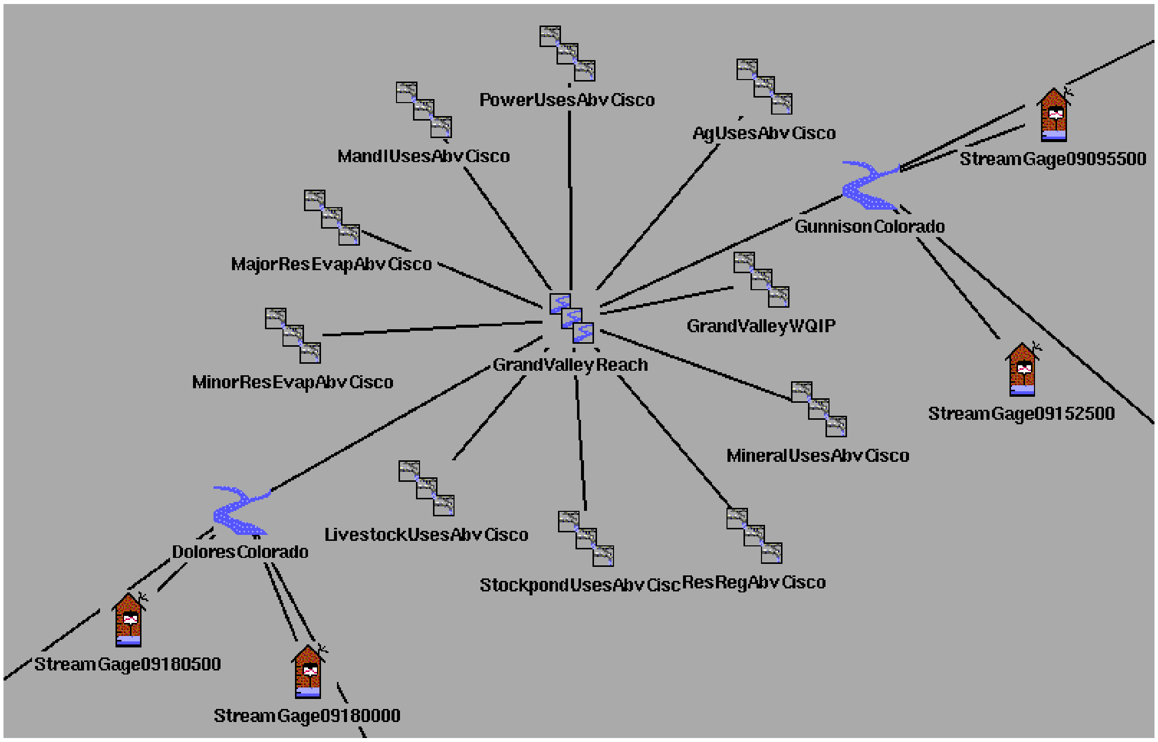


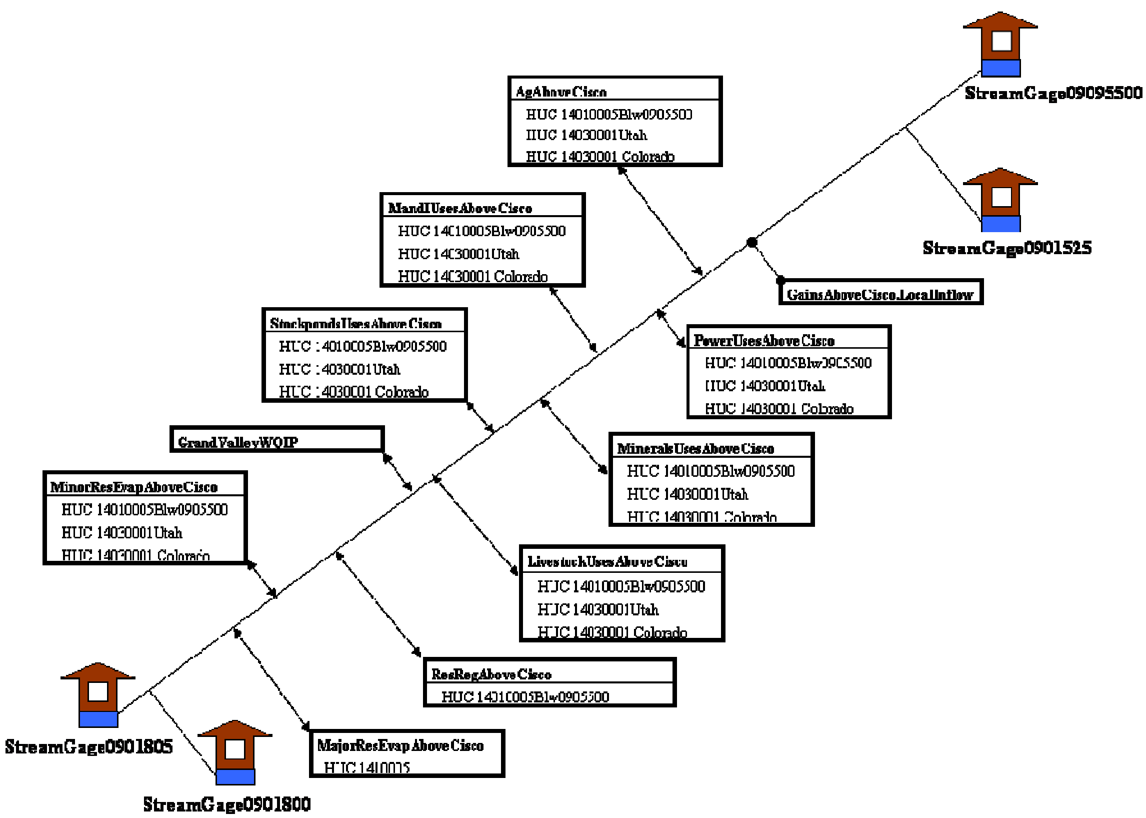
Dolores River near Cisco Reach



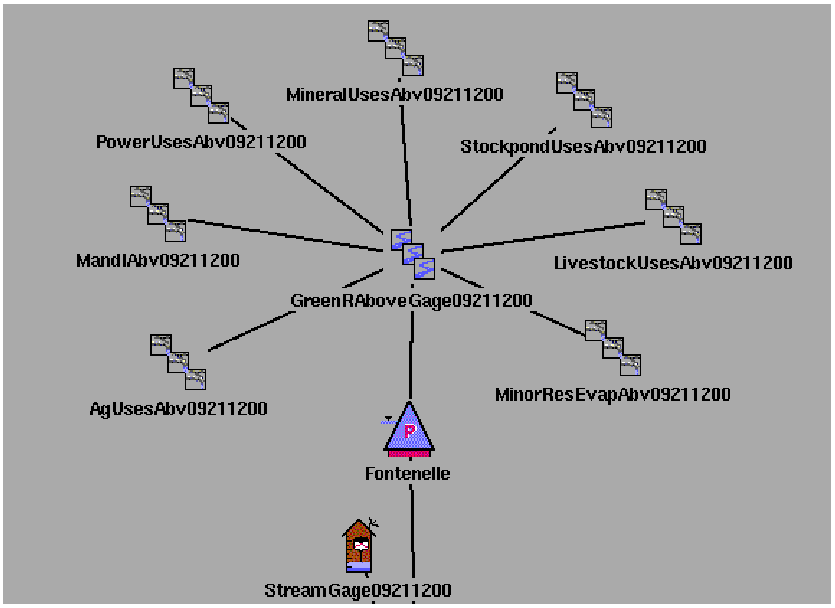


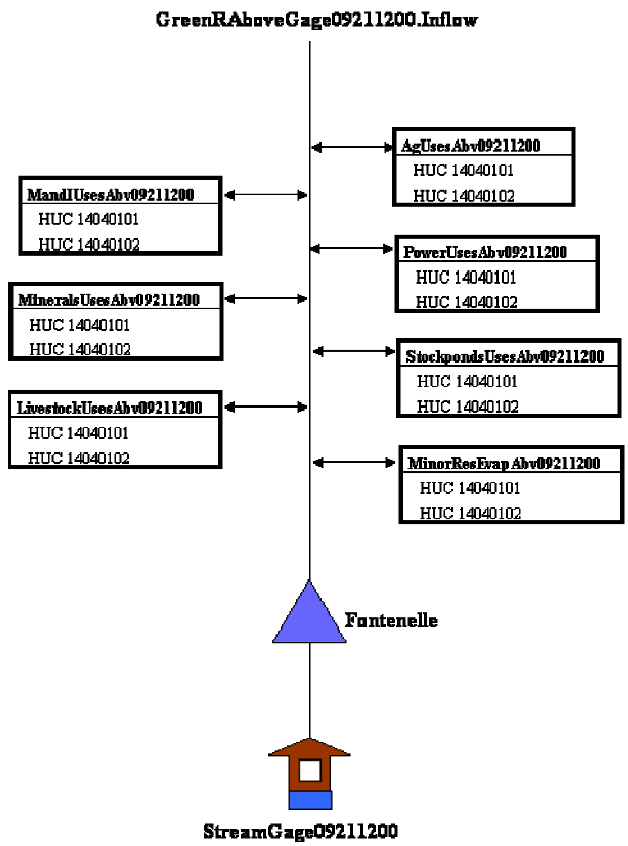
Colorado River near Cameo to Colorado River near Cisco Reach



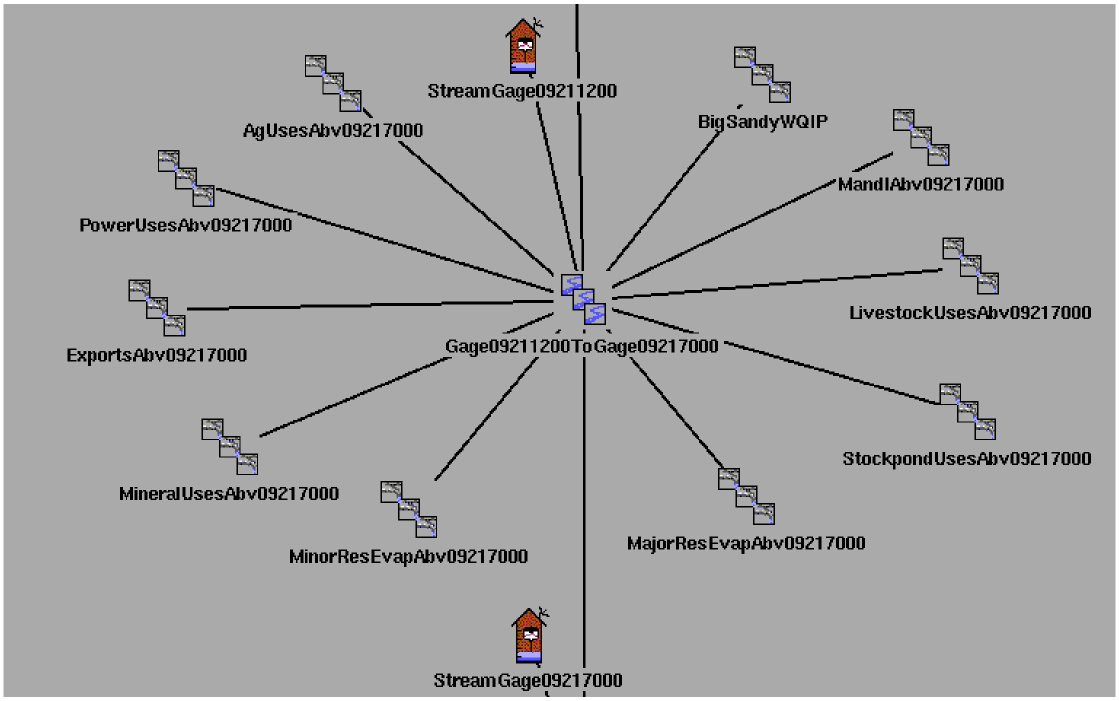


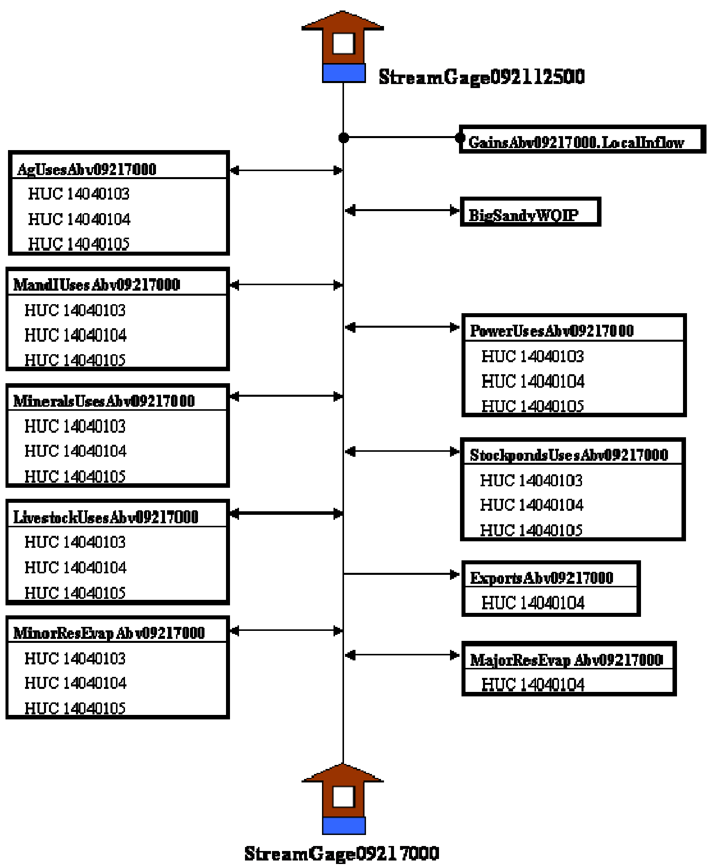
Above Green River below Fontenelle Reservoir Reach



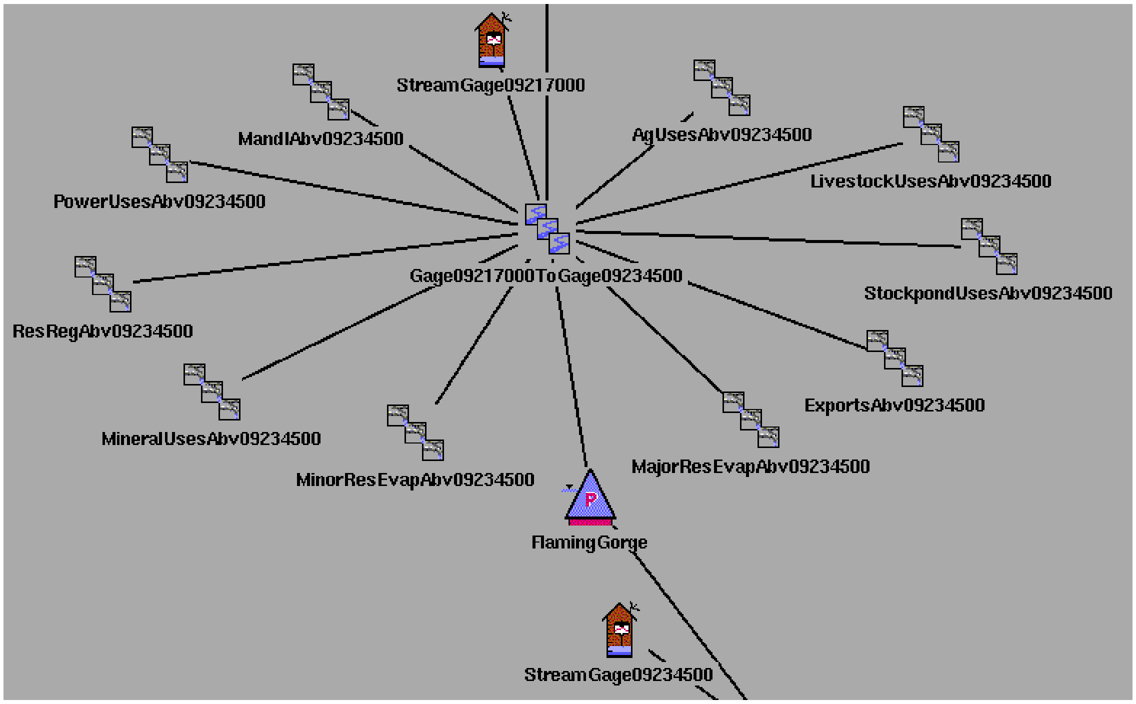


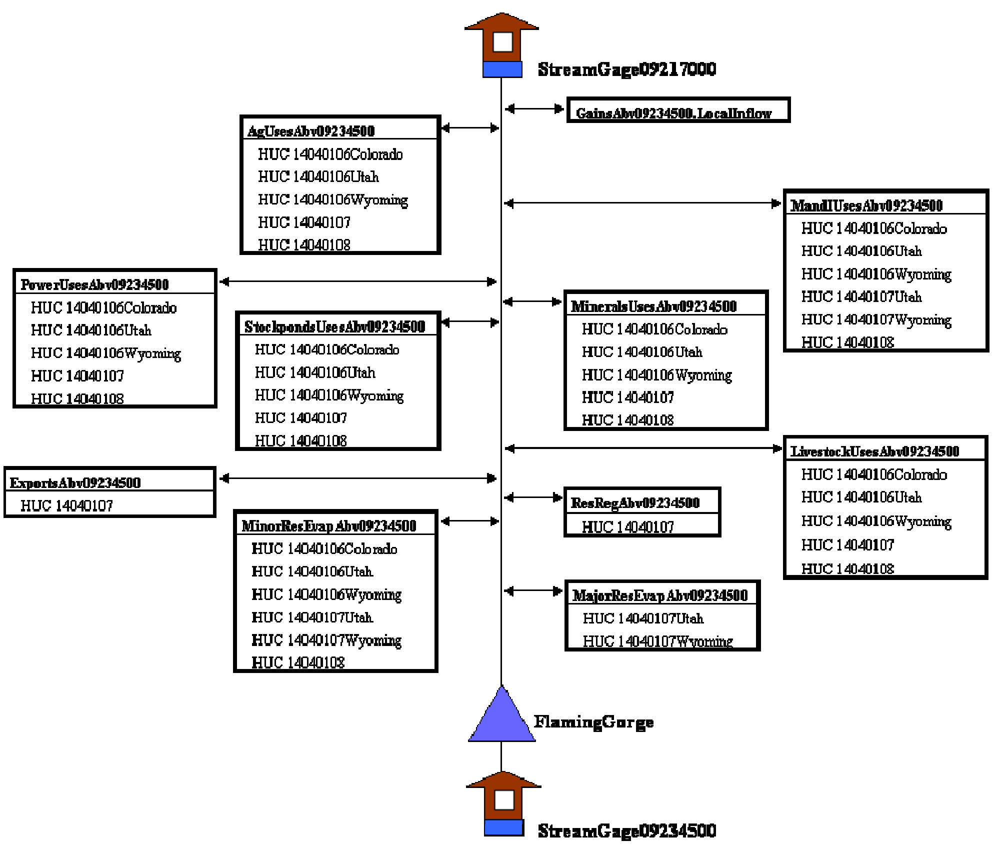
Green River below Fontenelle Reservoir To Green River near Green River, Wyoming Reach



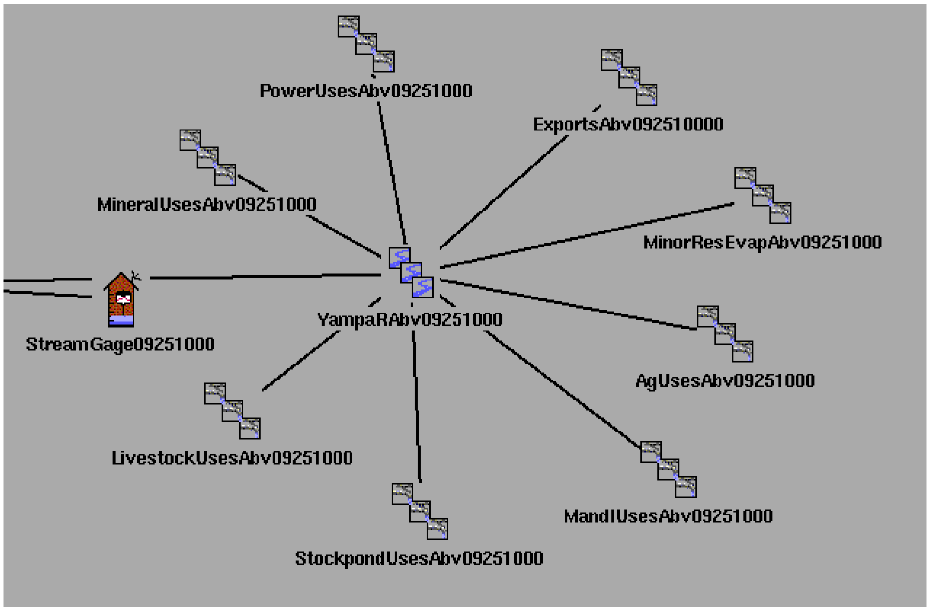


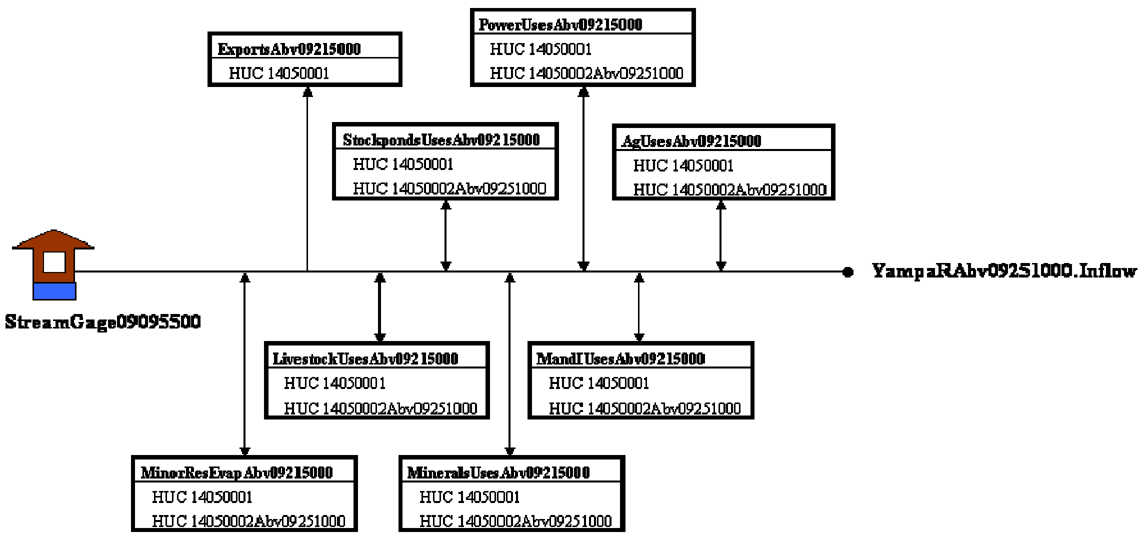
Green River near Green River, Wyoming To Green River near Greendale Reach



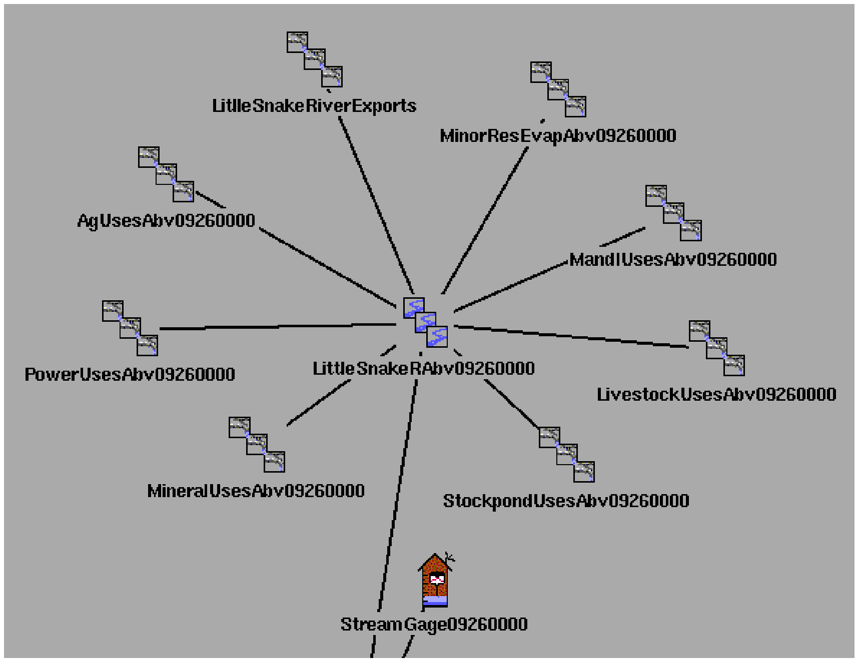


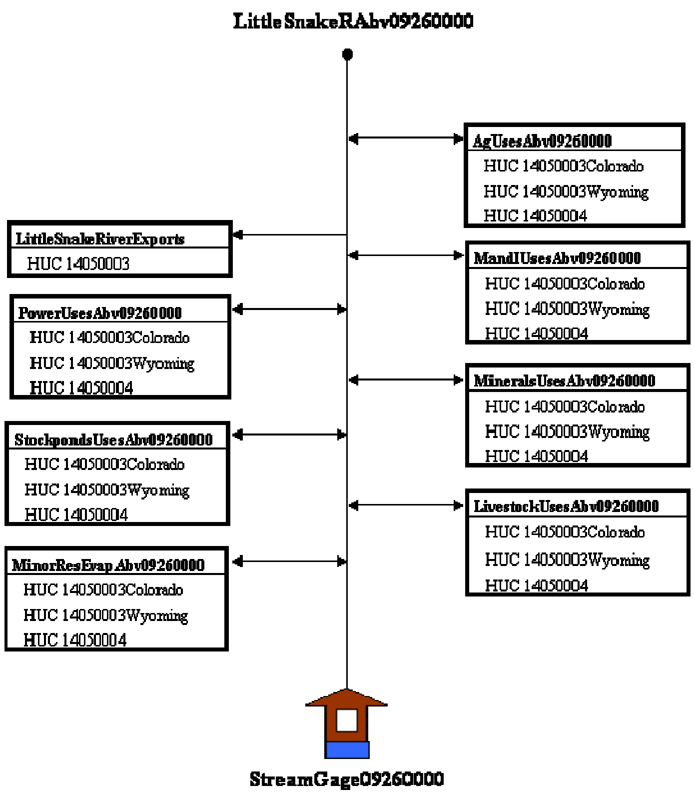
Above Yampa River near Maybell Reach



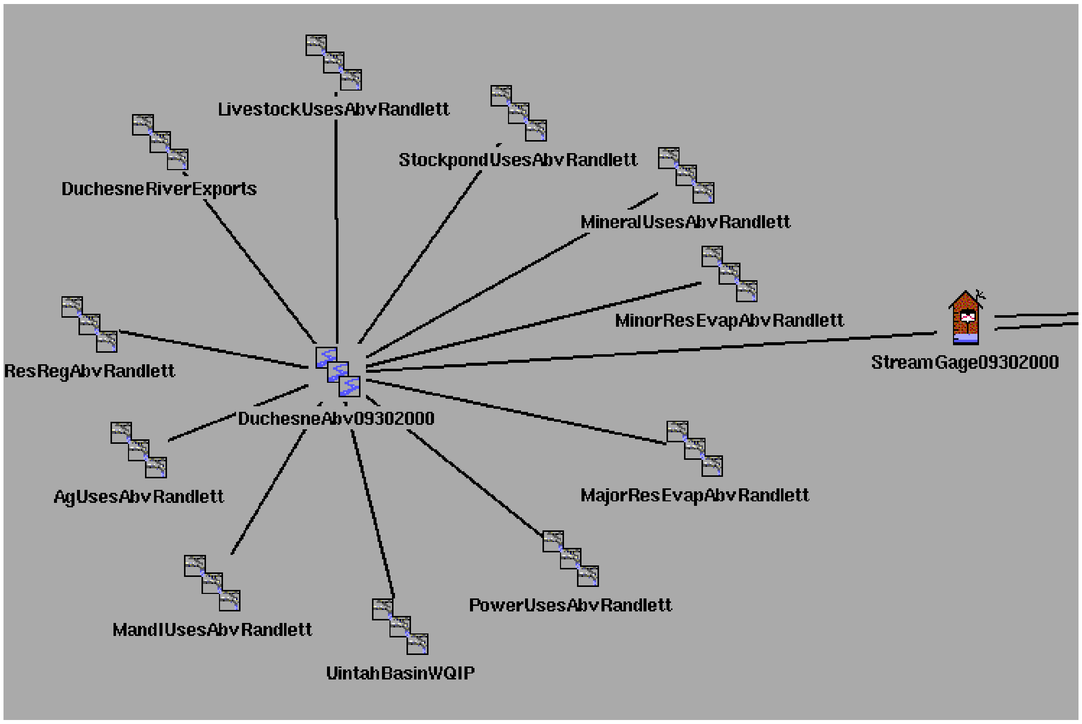


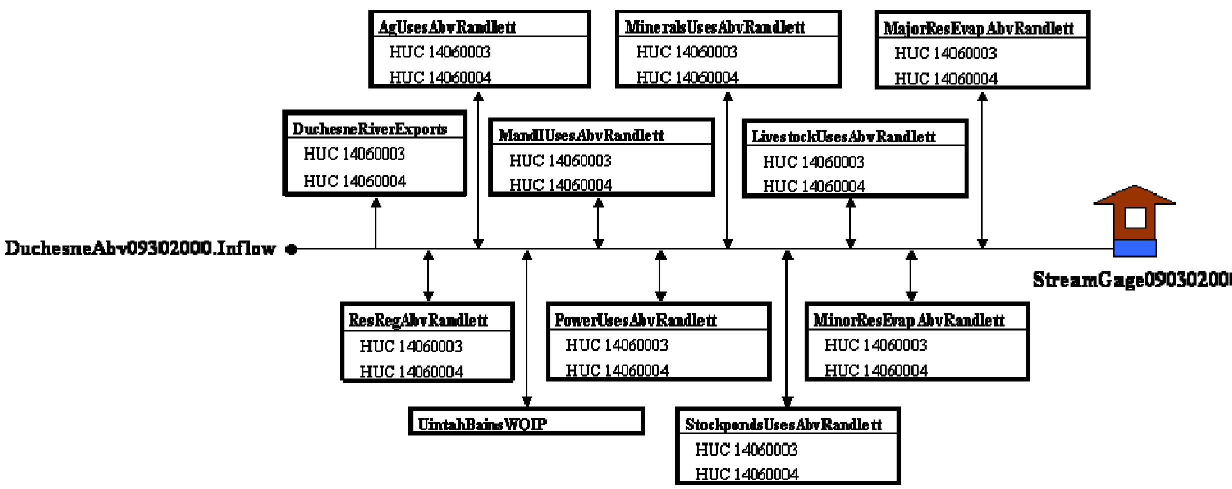
Above Little Snake River near Lily Reach



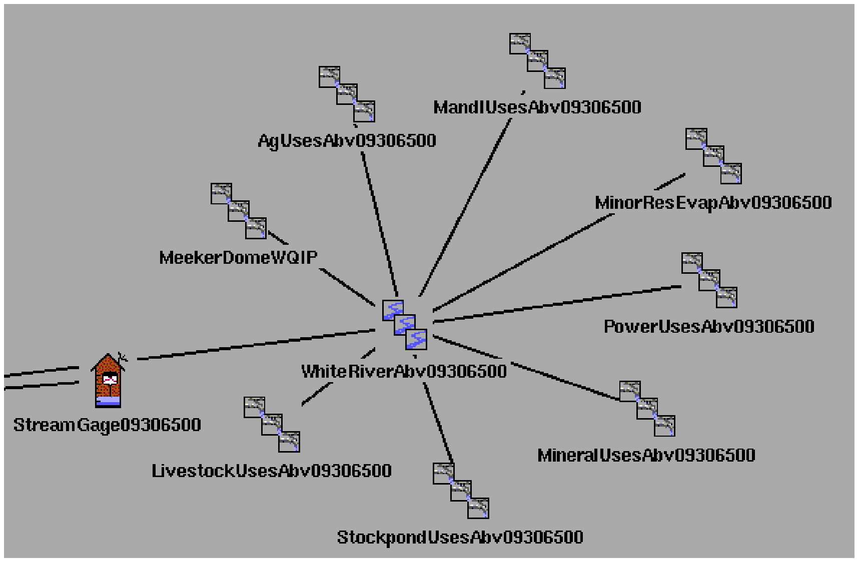


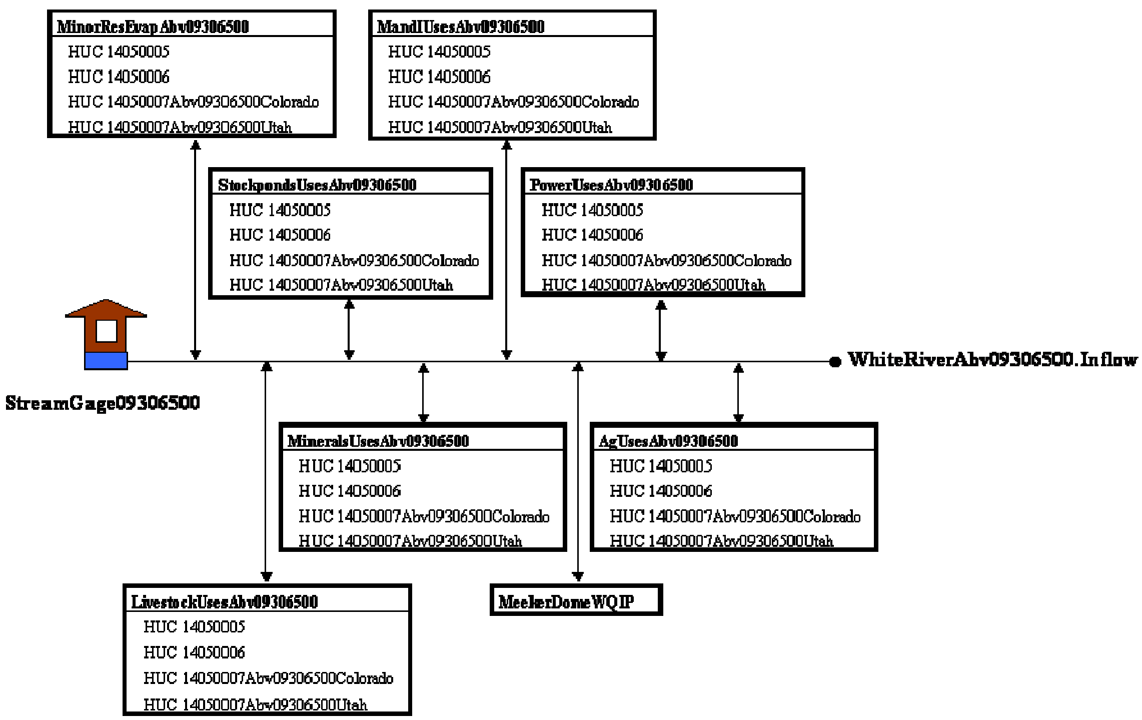
Above Duchesne River near Randlett Reach



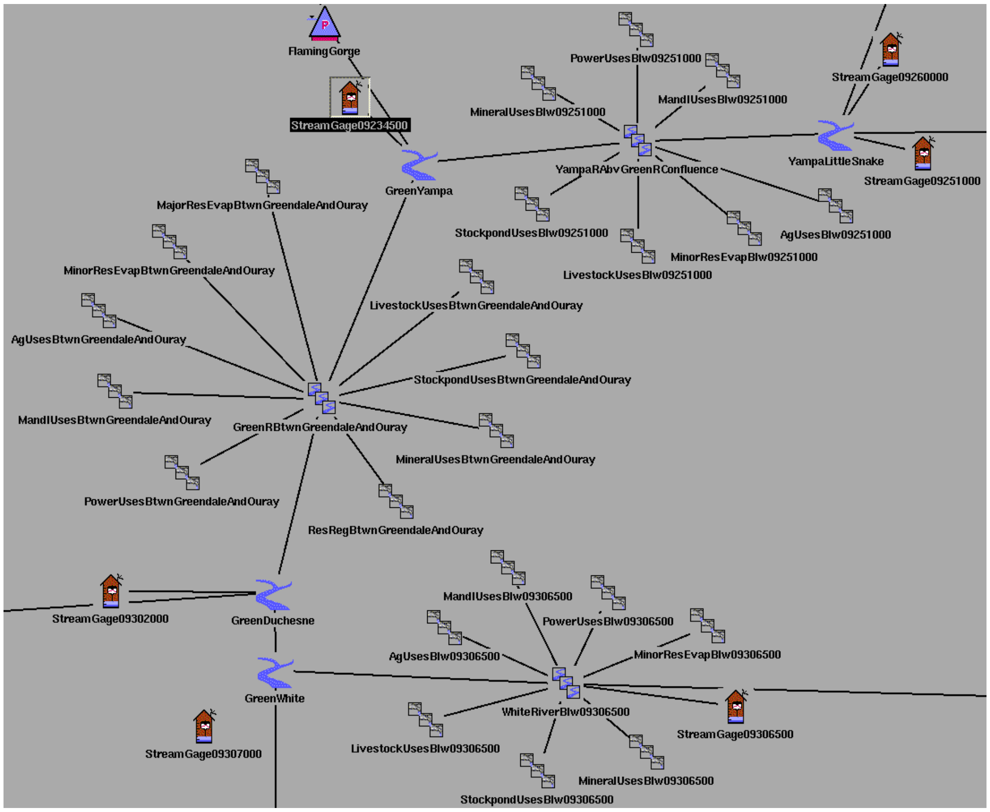


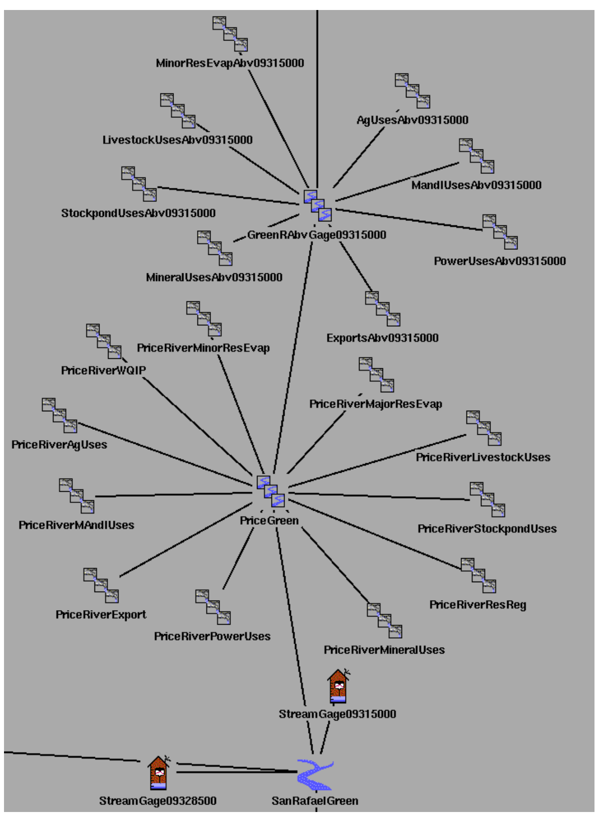
Above White River near Watson Reach

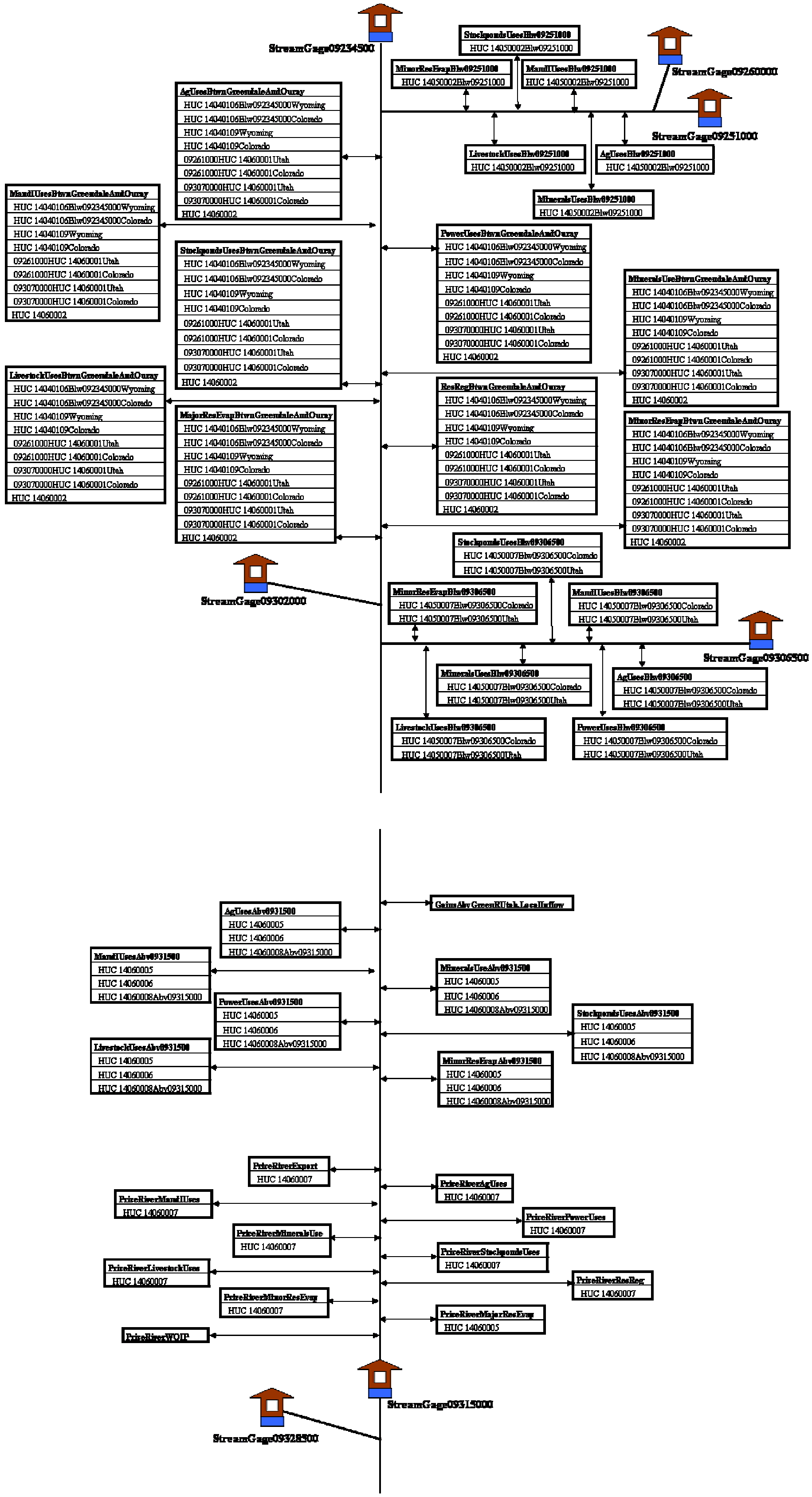




Green River near Greendale to Green River, Utah Reach



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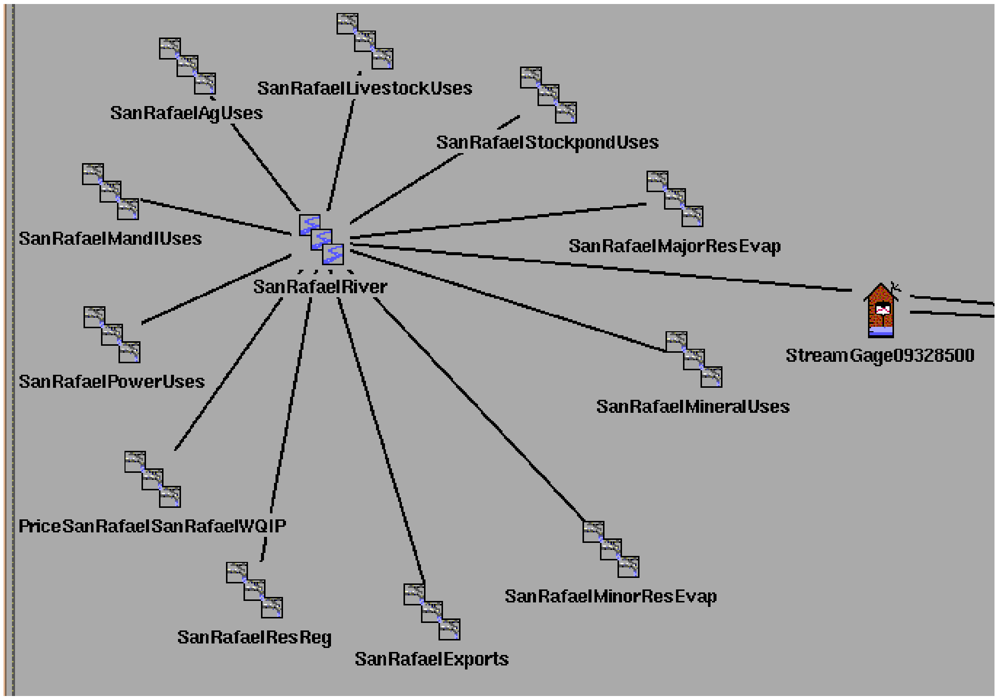
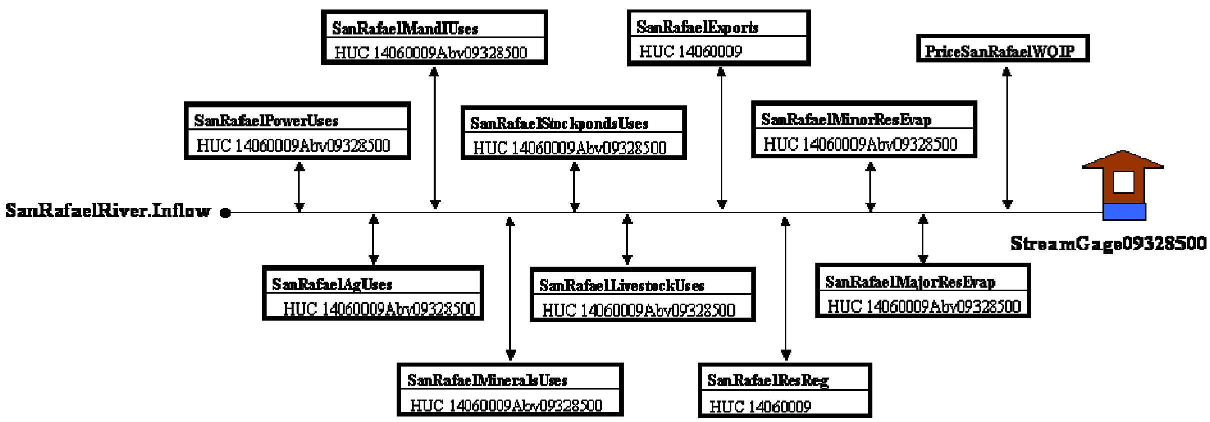
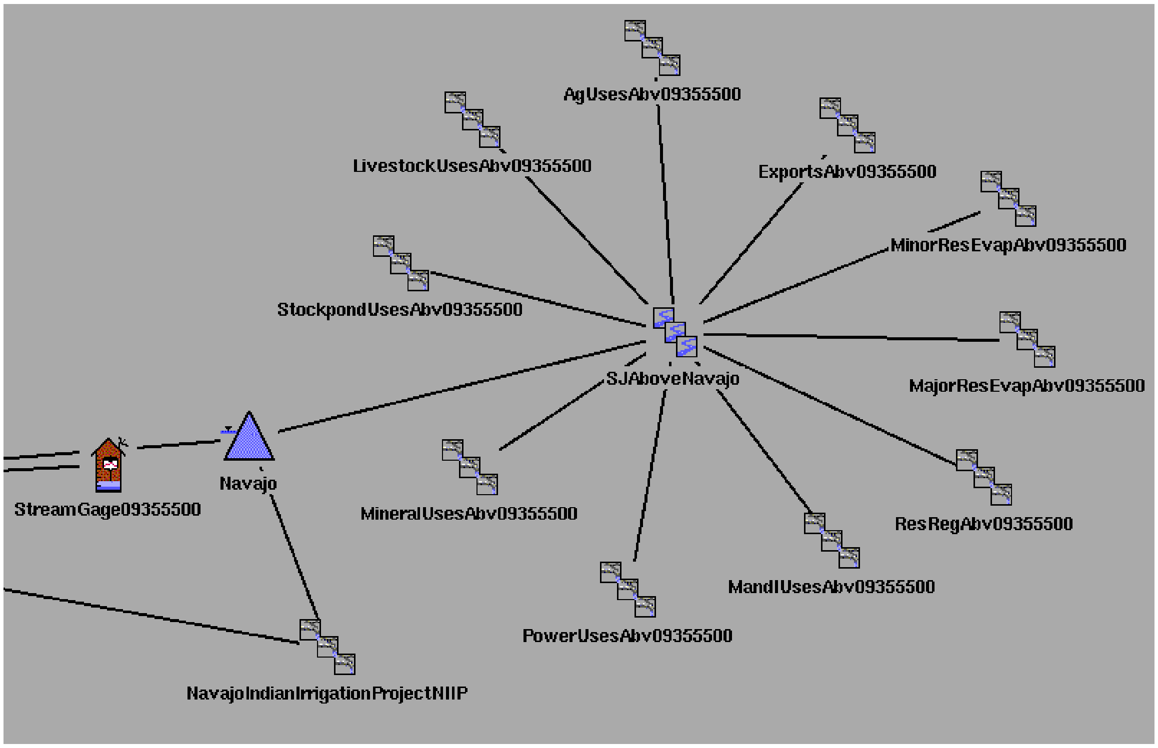
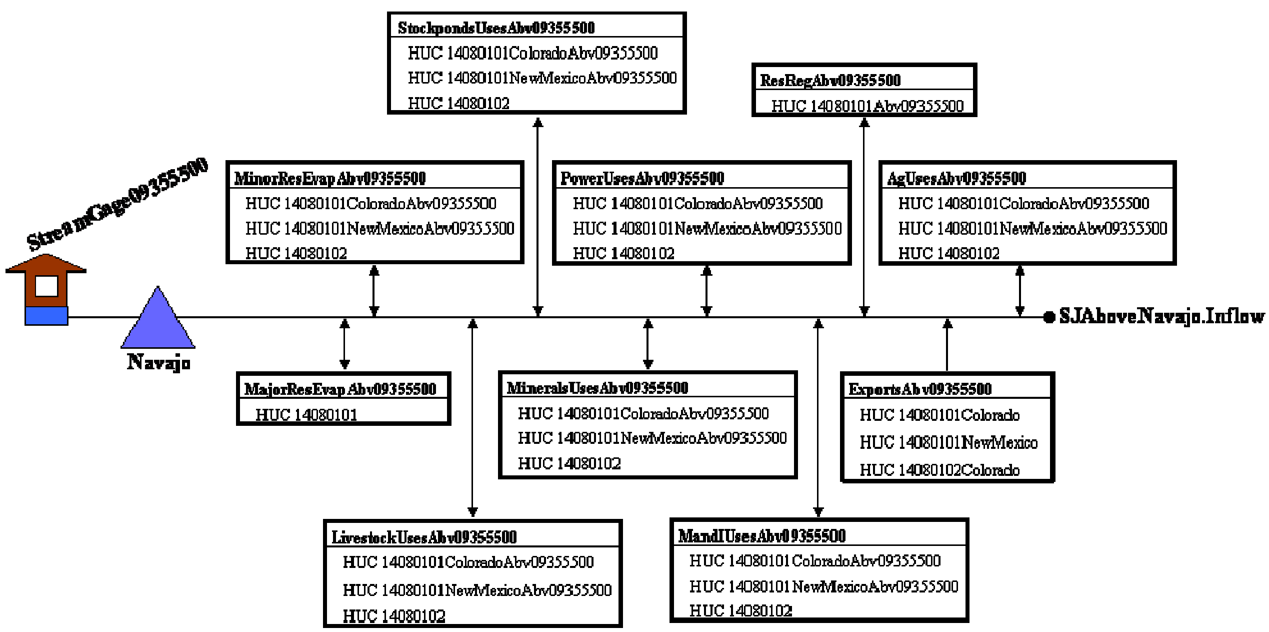
Above San Rafael River near Green River, Utah Reach



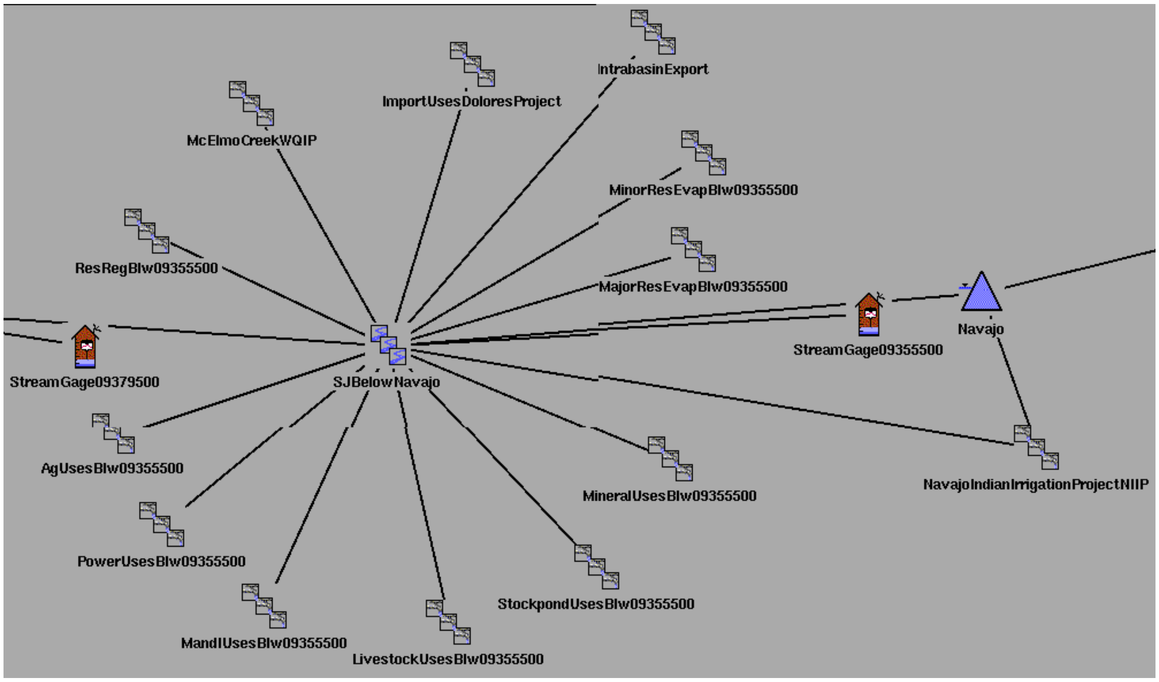


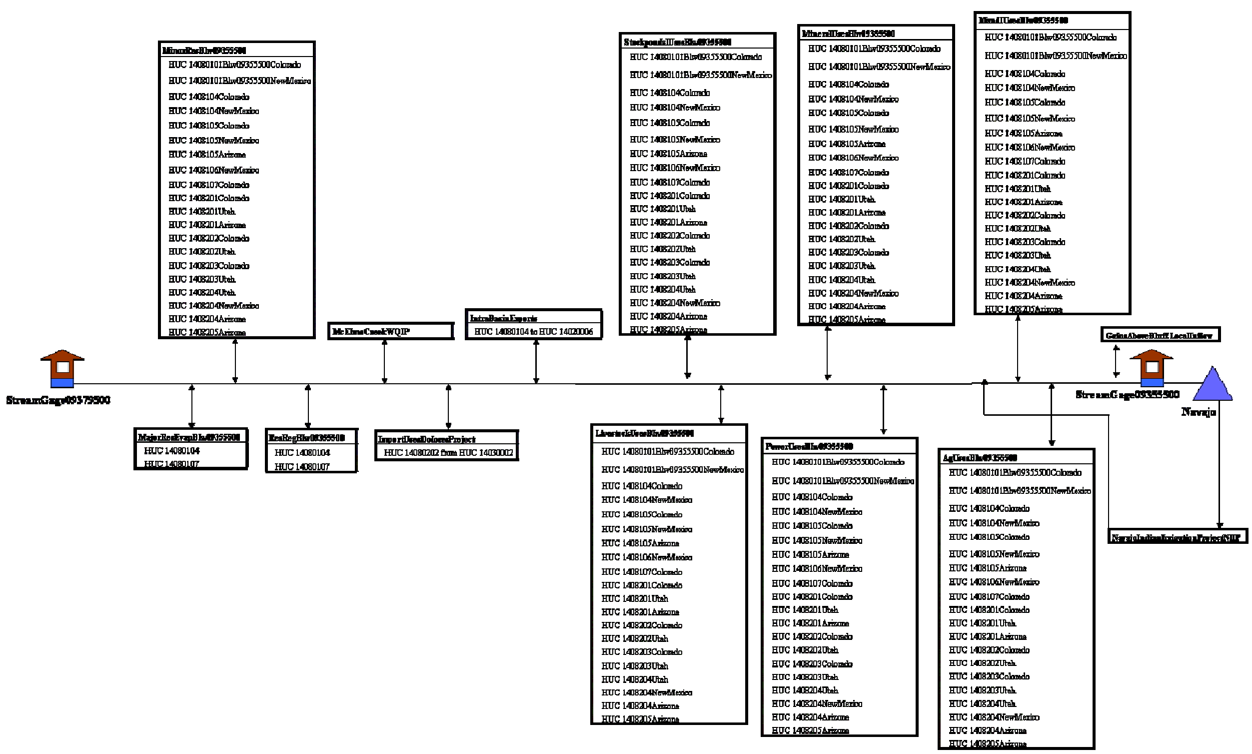
Above San Juan River near Archuletta Reach



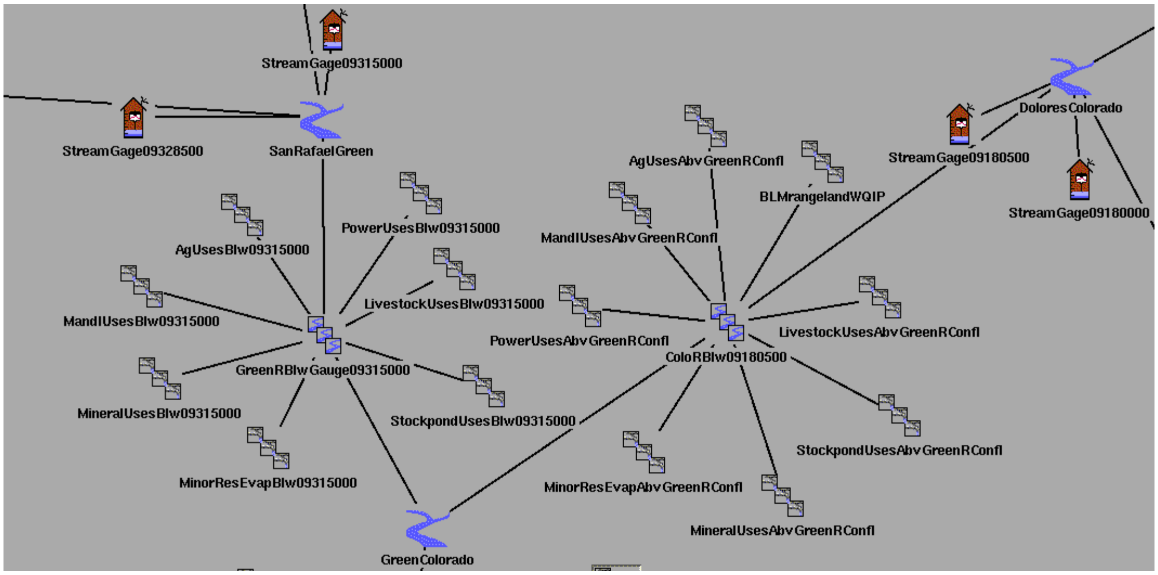


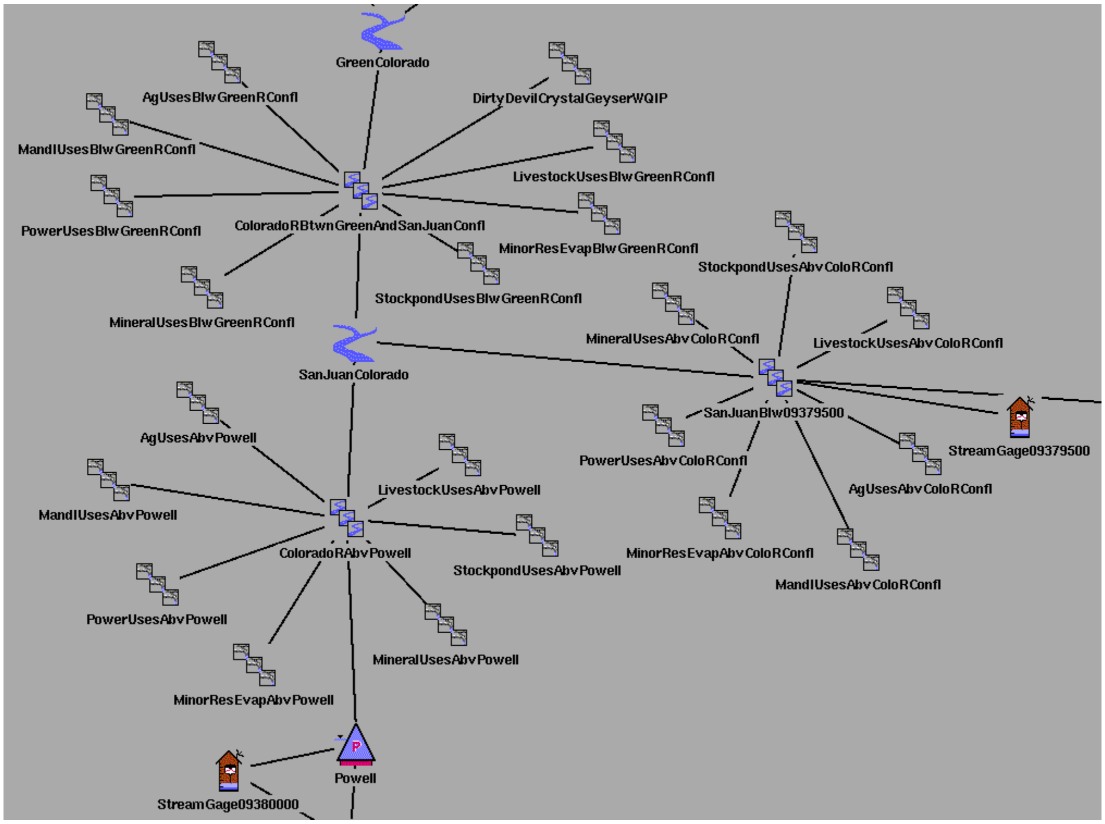
San Juan River near Archuletta to San Juan River near Bluff

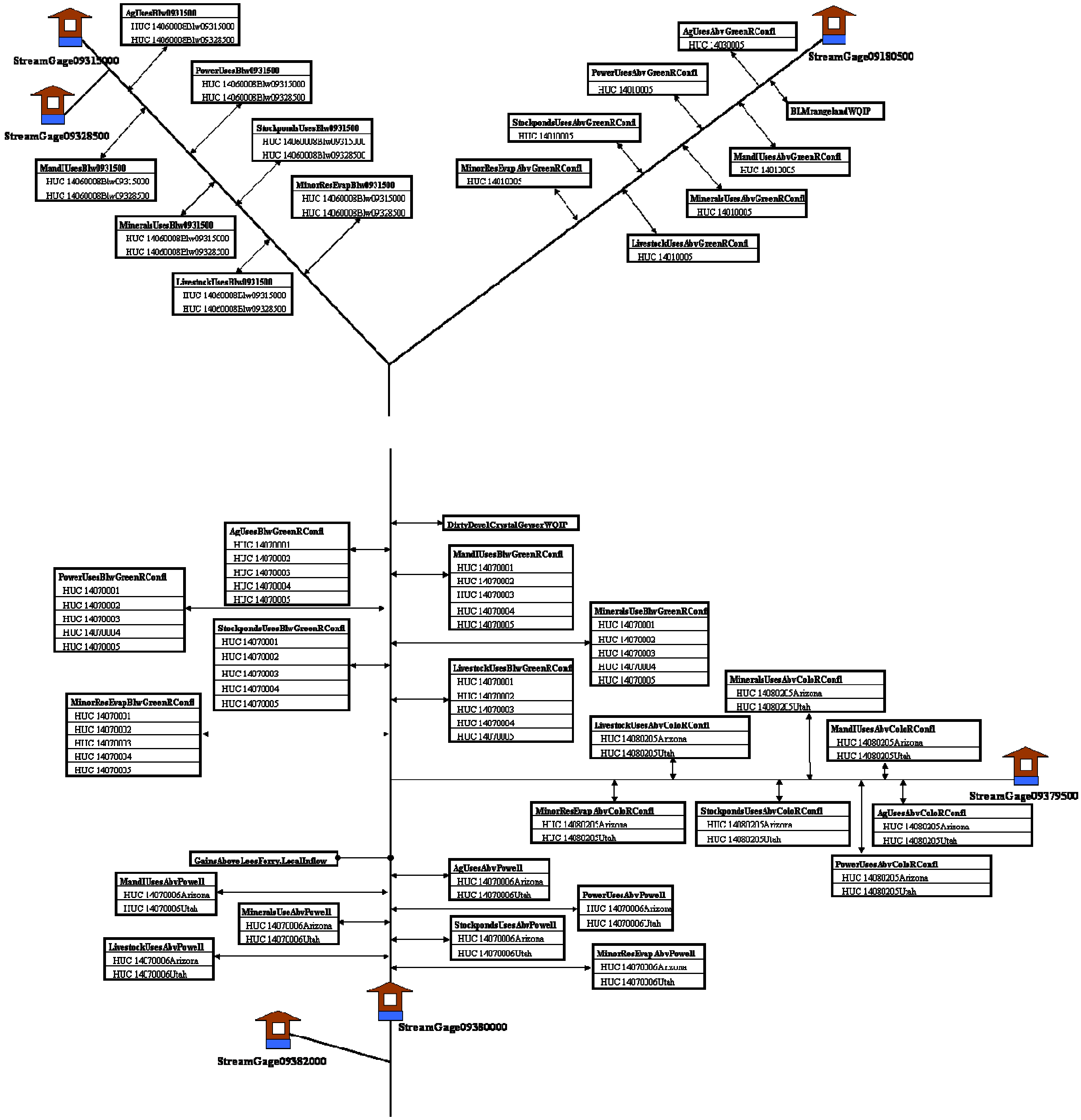




Reach above Colorado River at Lees Ferry



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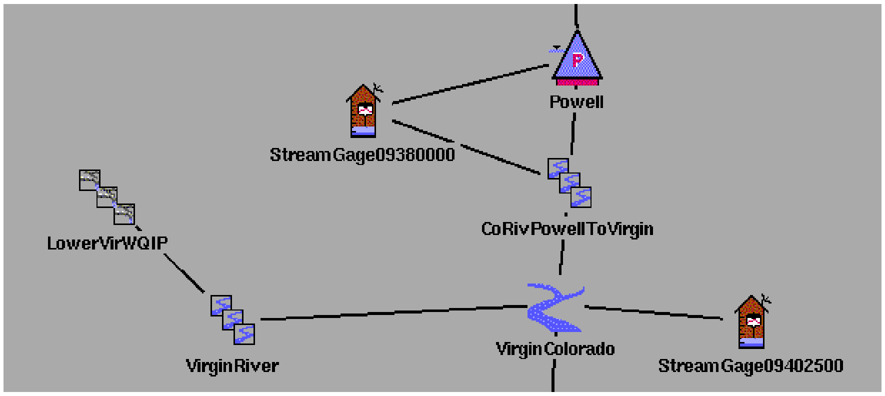
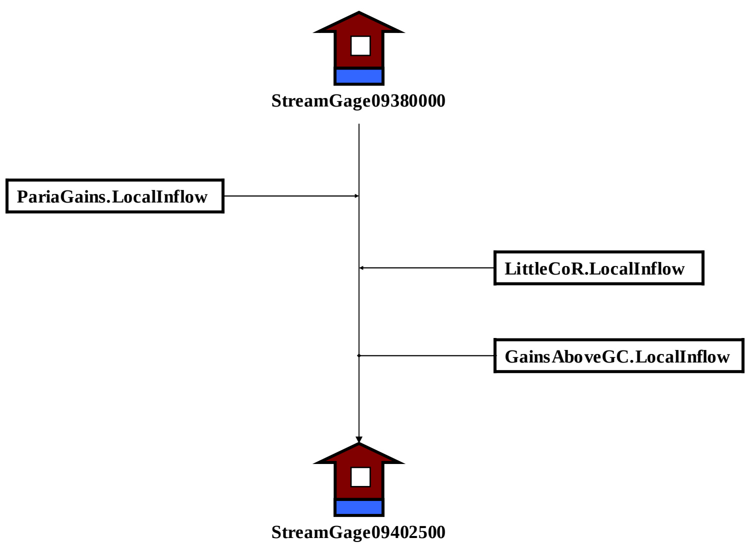
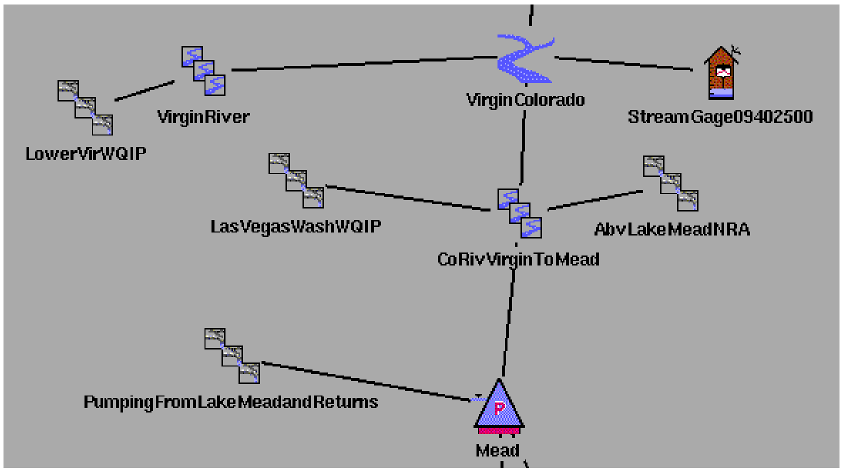
Lower Basin

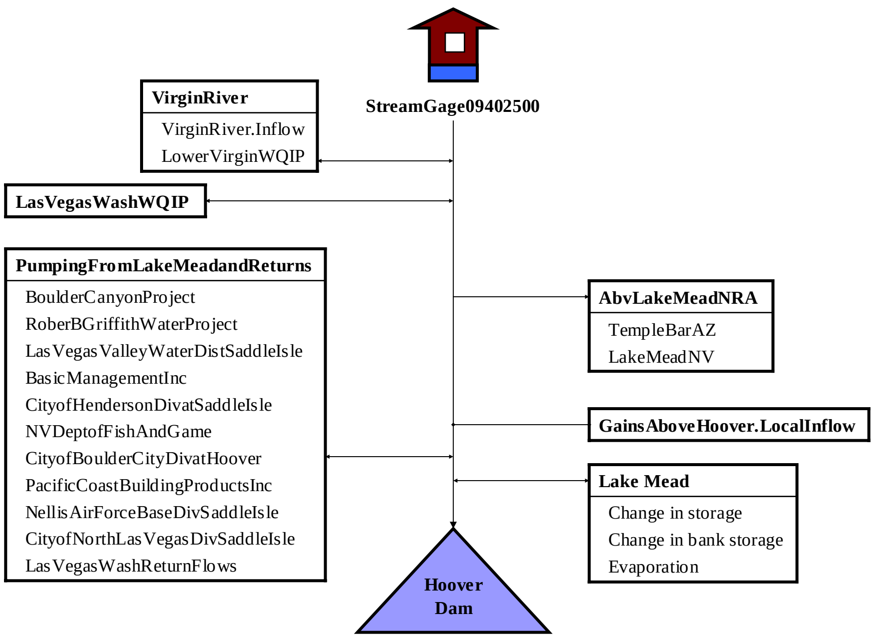
Colorado River at Lees Ferry to Colorado River near Grand Canyon Reach



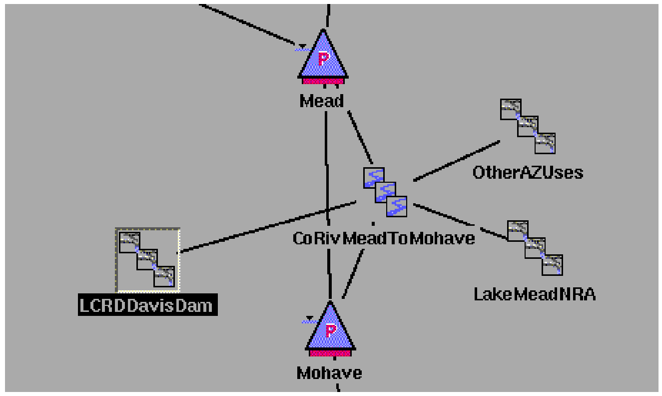


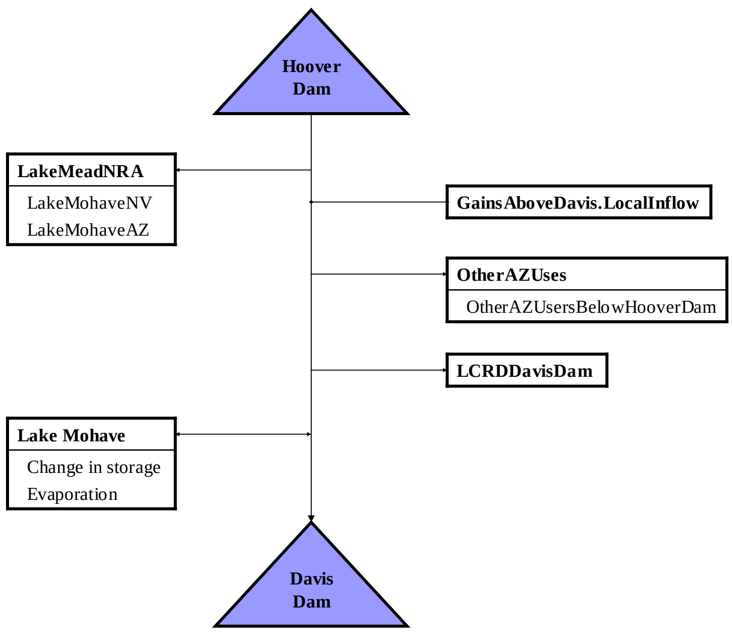
Colorado River near Grand Canyon to Colorado River below Hoover Dam Reach



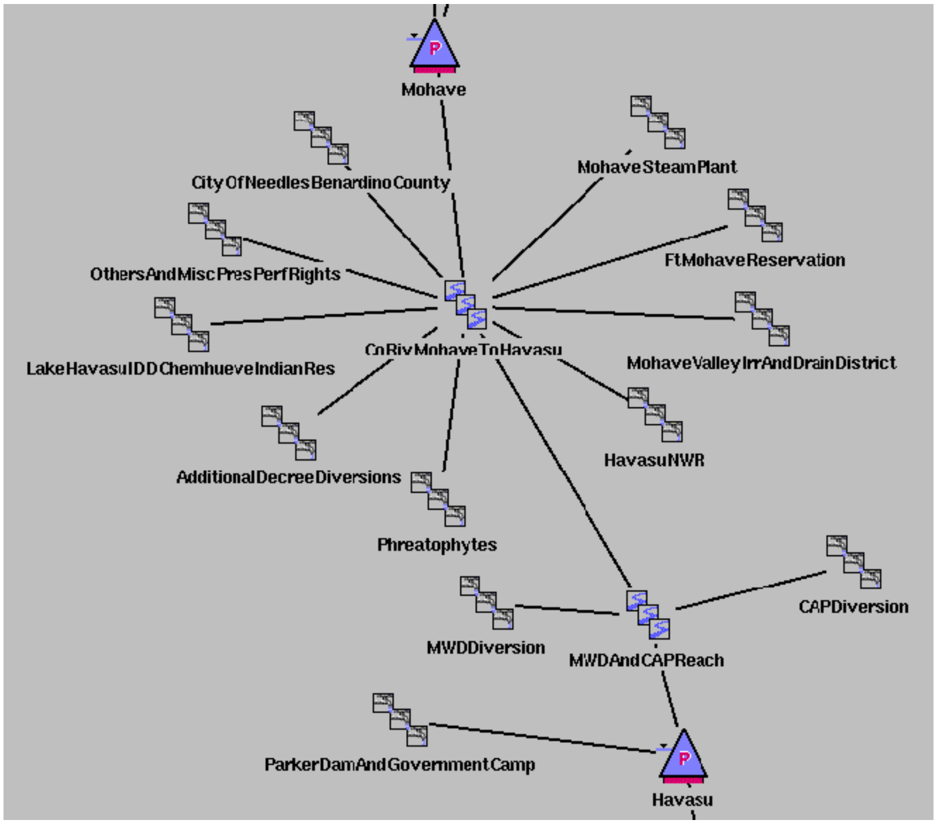


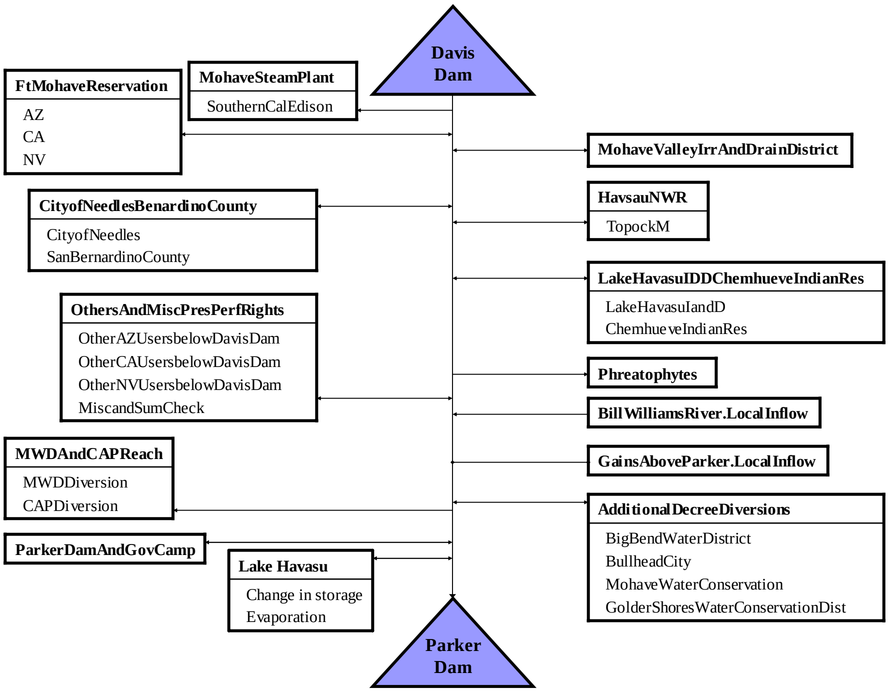
Colorado River below Hoover Dam to Colorado River below Davis Dam Reach



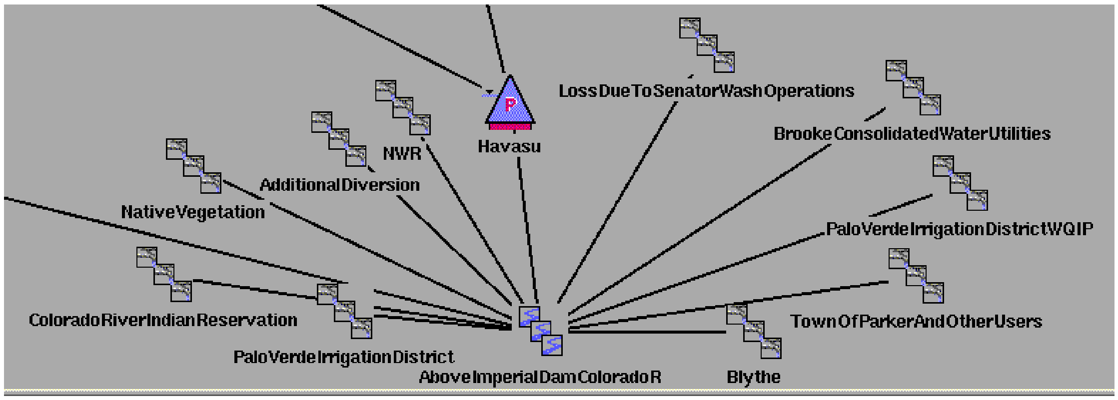


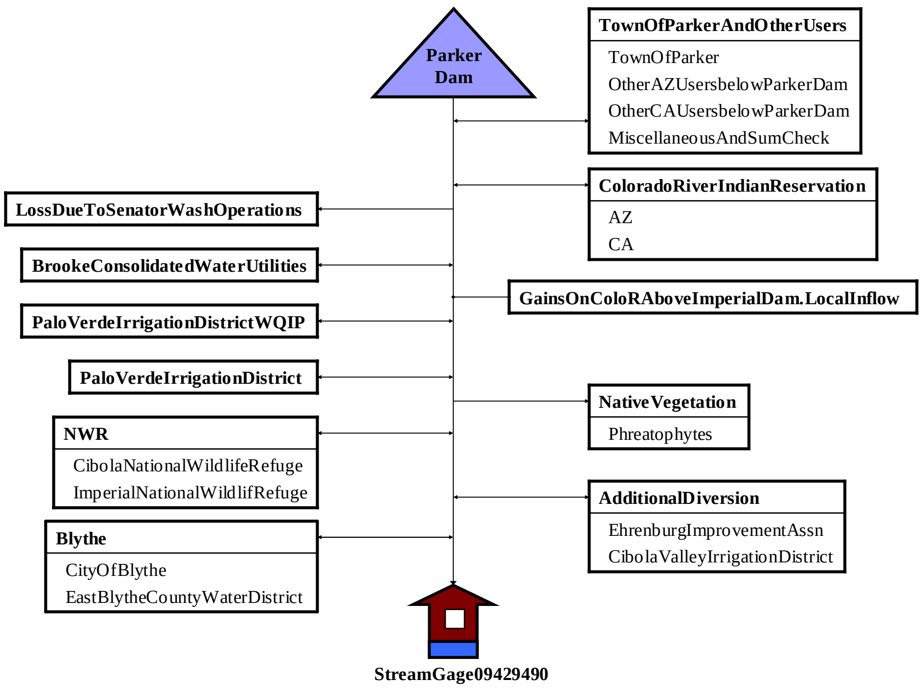
Colorado River below Davis Dam to Colorado River below Parker Reach





Colorado River below Parker Dam to Colorado River above Imperial Reach

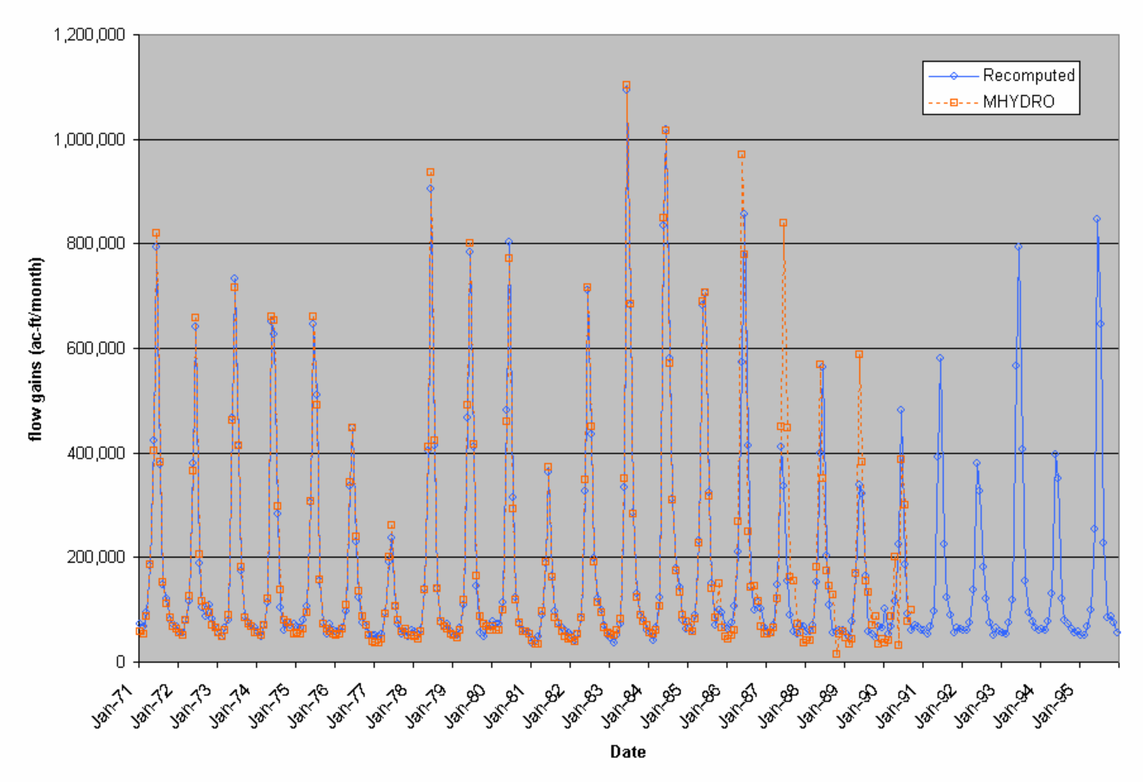


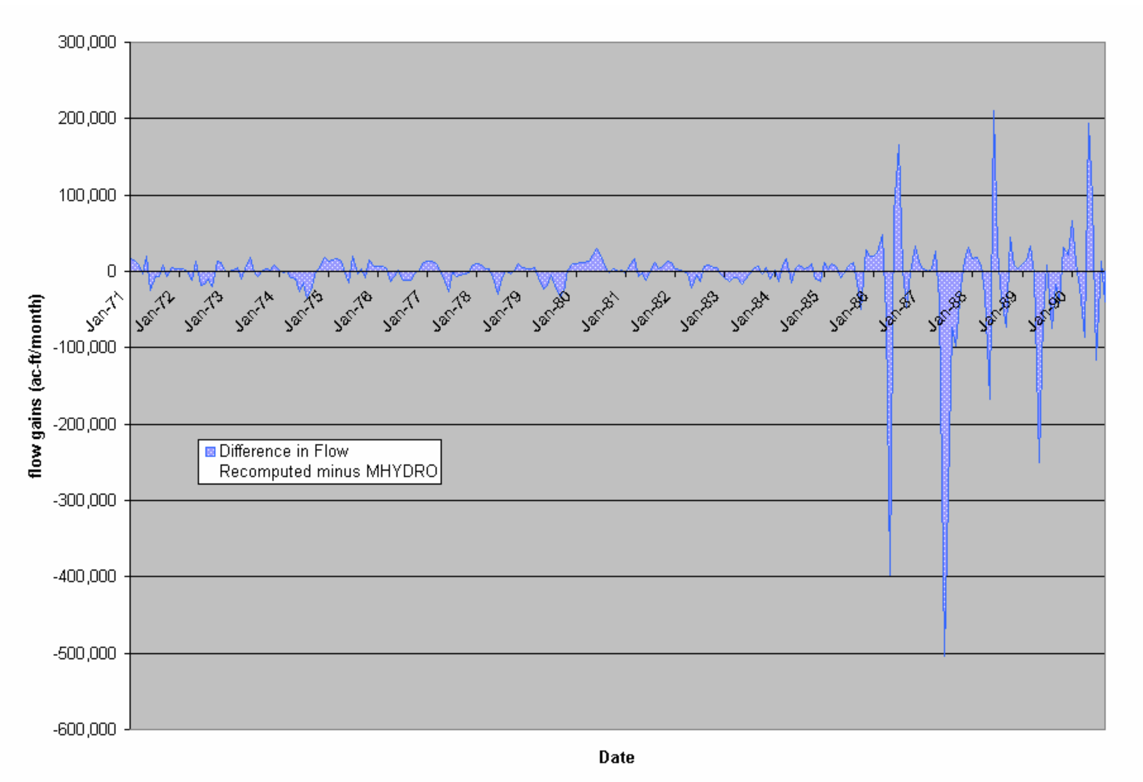


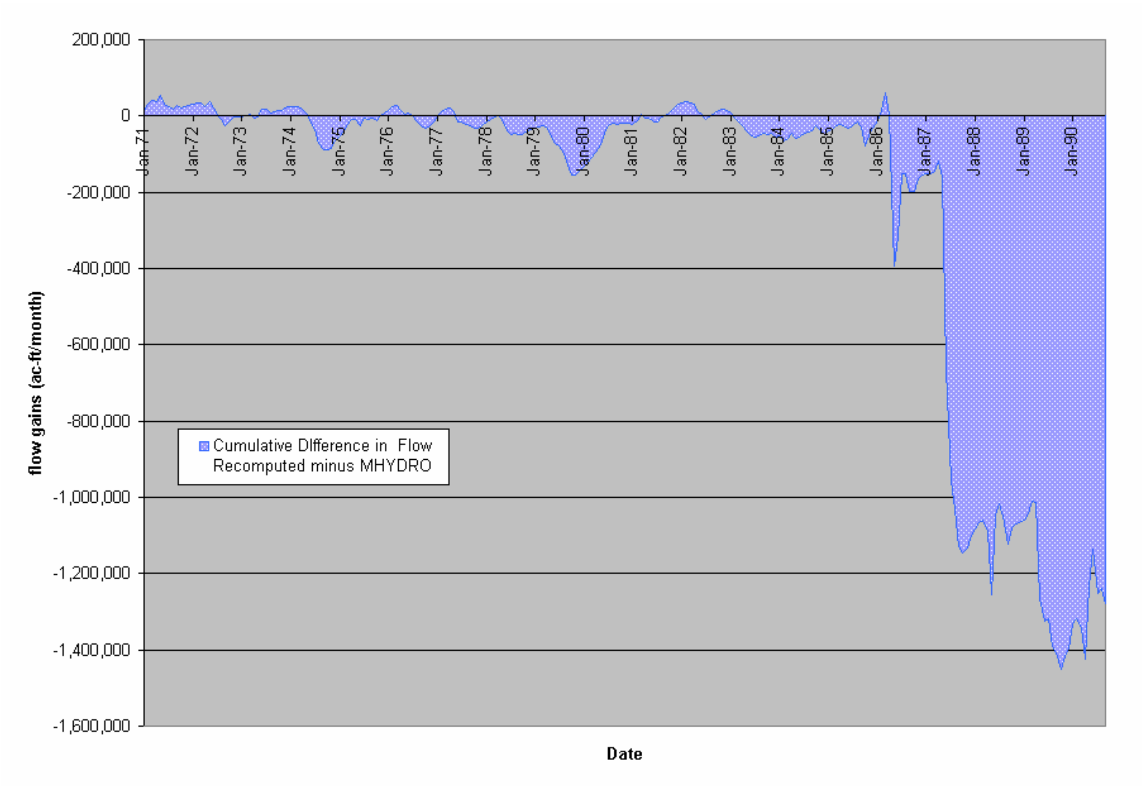
Upper Basin

For each of the nineteen reaches in the Upper Basin three plots are displayed. The first plot shows two timeseries, 1. natural flow from MHYDRO and 2. recomputed natural flow as generated by the Natural Flow and Salt Calculation Model. The second plot shows the difference from recomputed natural flow minus MHYDRO natural flow. The third plots show the cumulative difference from recomputed natural flow minus MHYDRO natural flow. All flows displayed are intervening. Similar graphs depicting total natural flow are also available upon request.

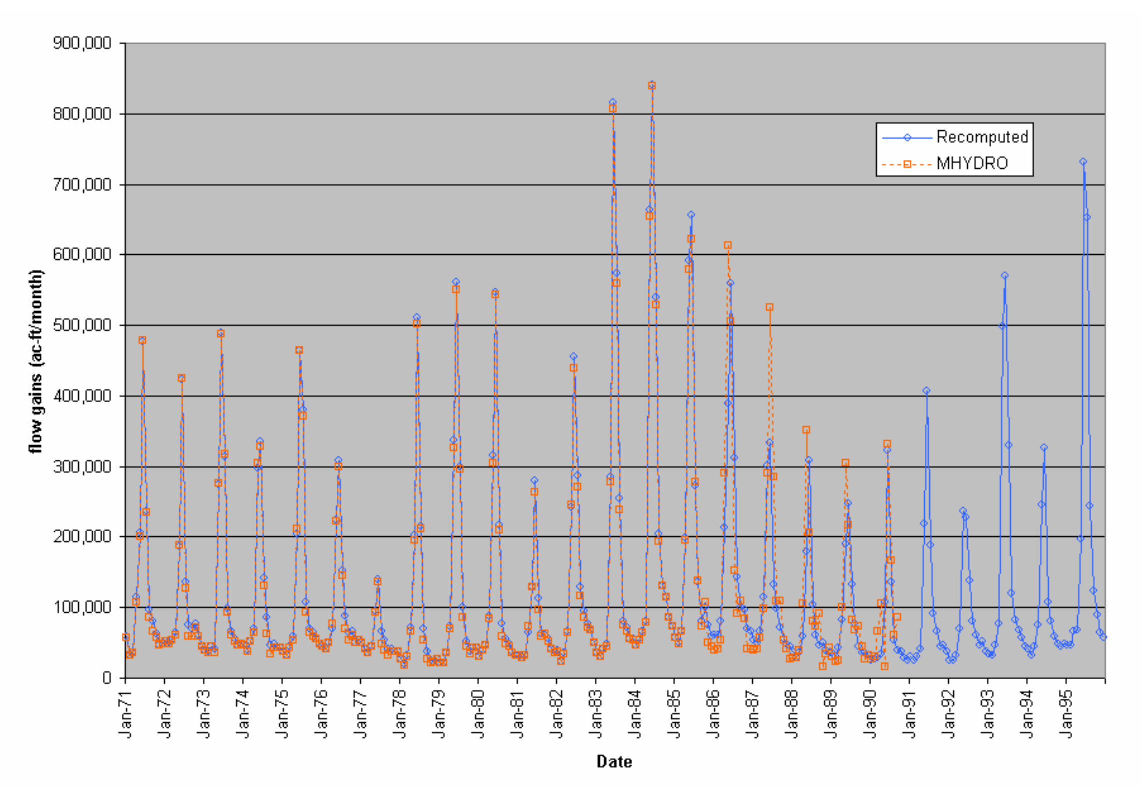
Above Colorado River at Glenwood Springs Reach

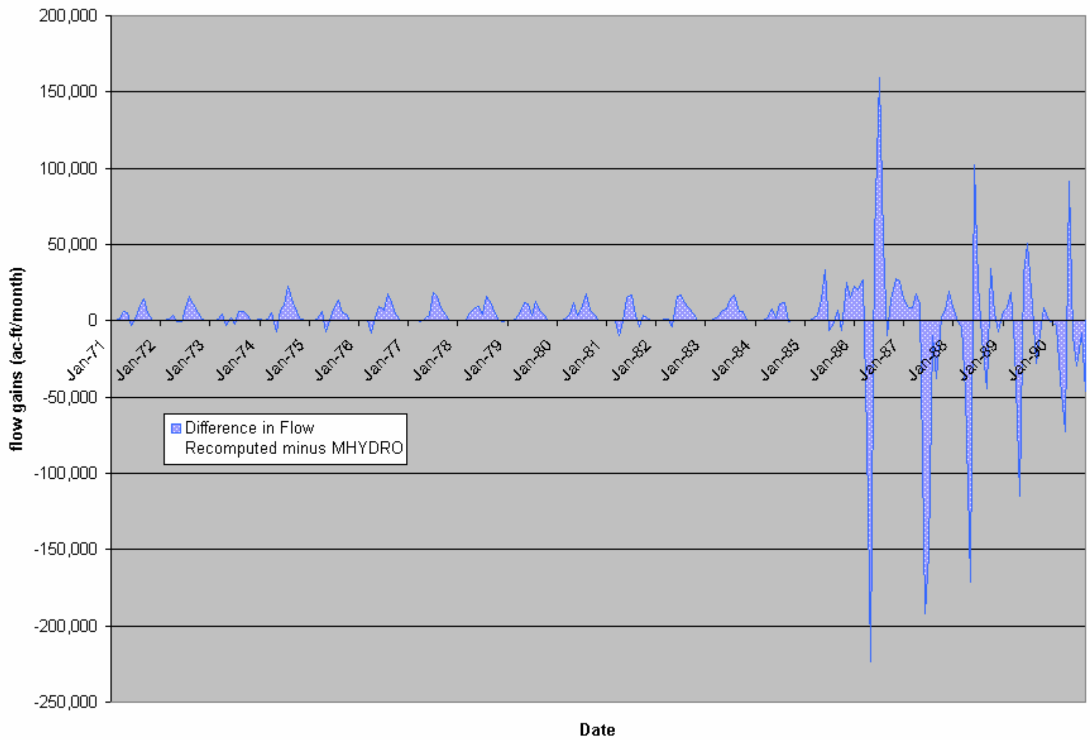




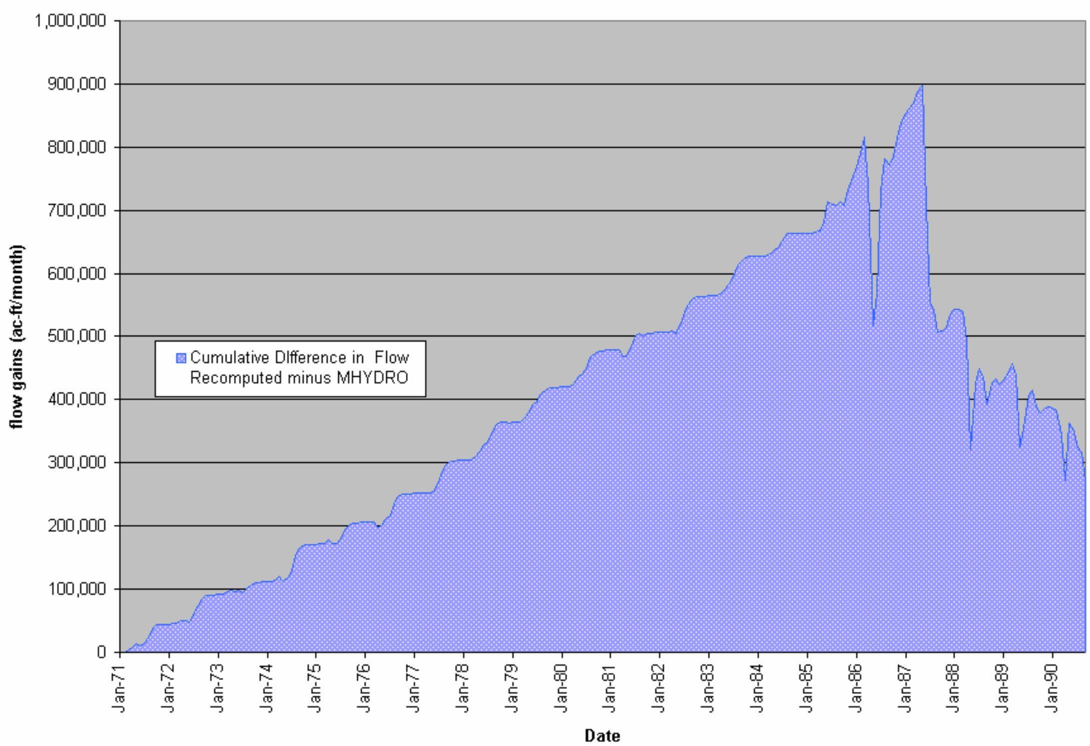


Colorado River at Glenwood Springs to Colorado River near Cameo Reach



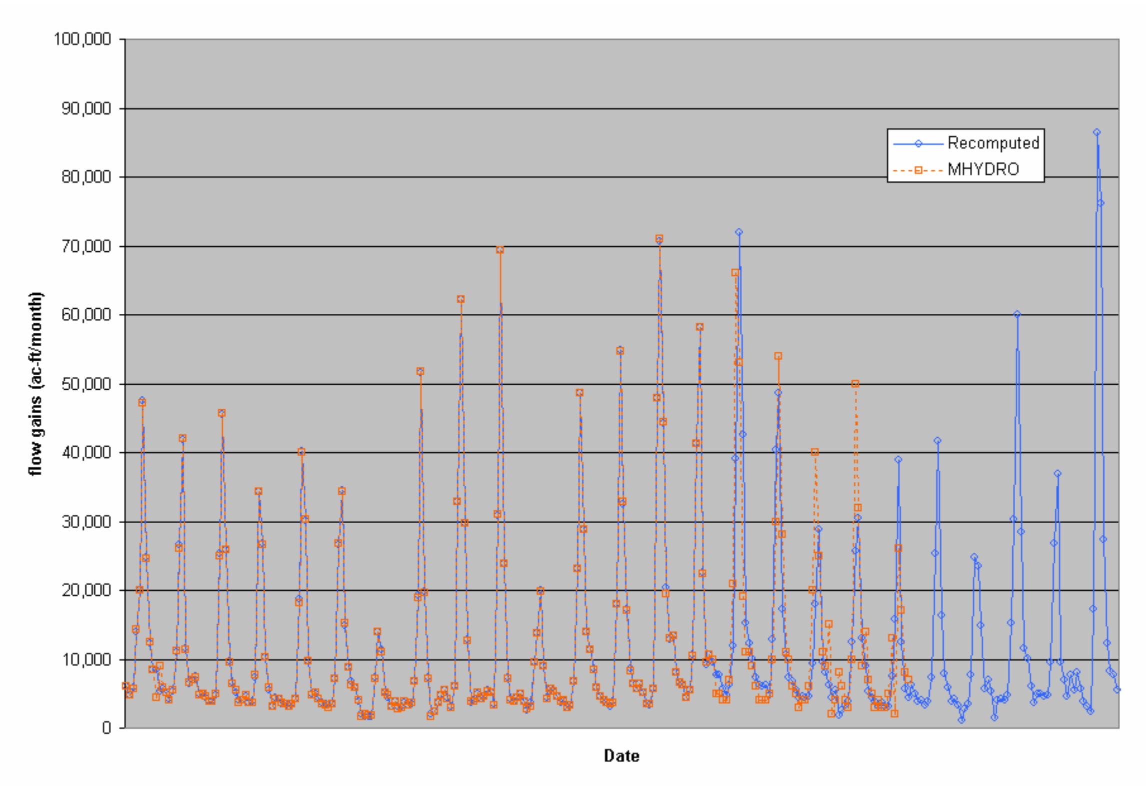


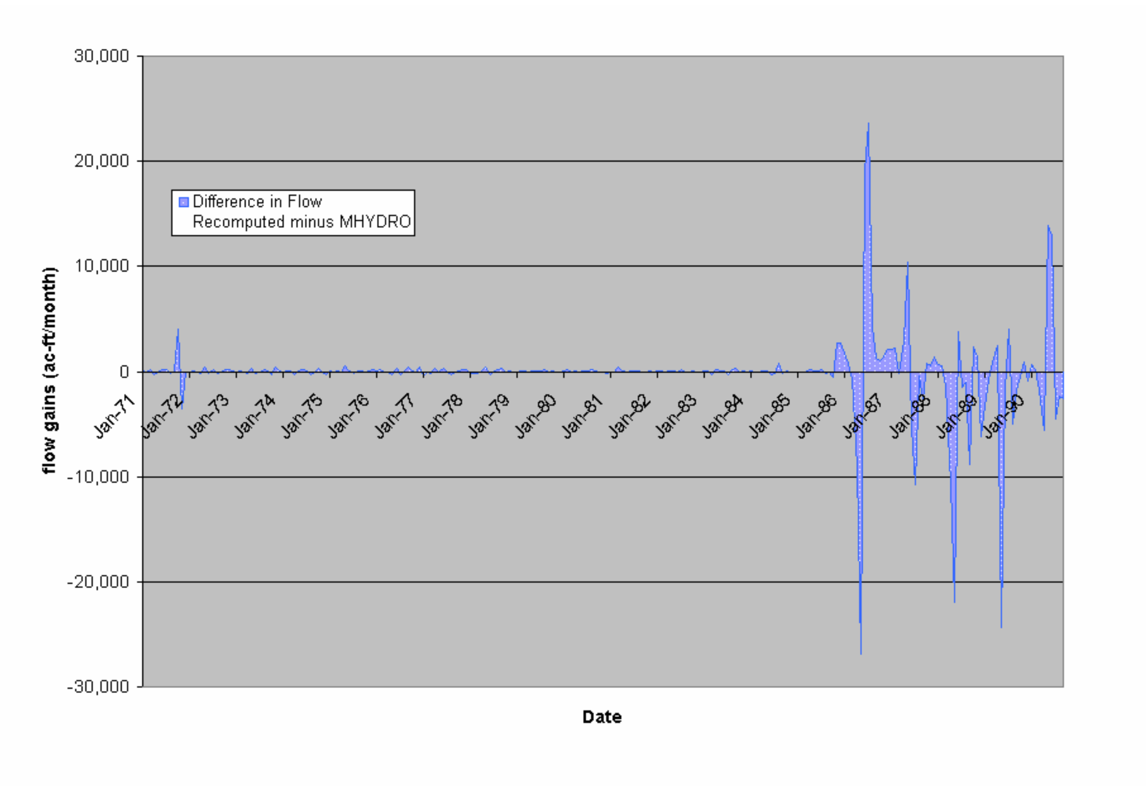
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow
Recomputed minus MHYDRO
Date

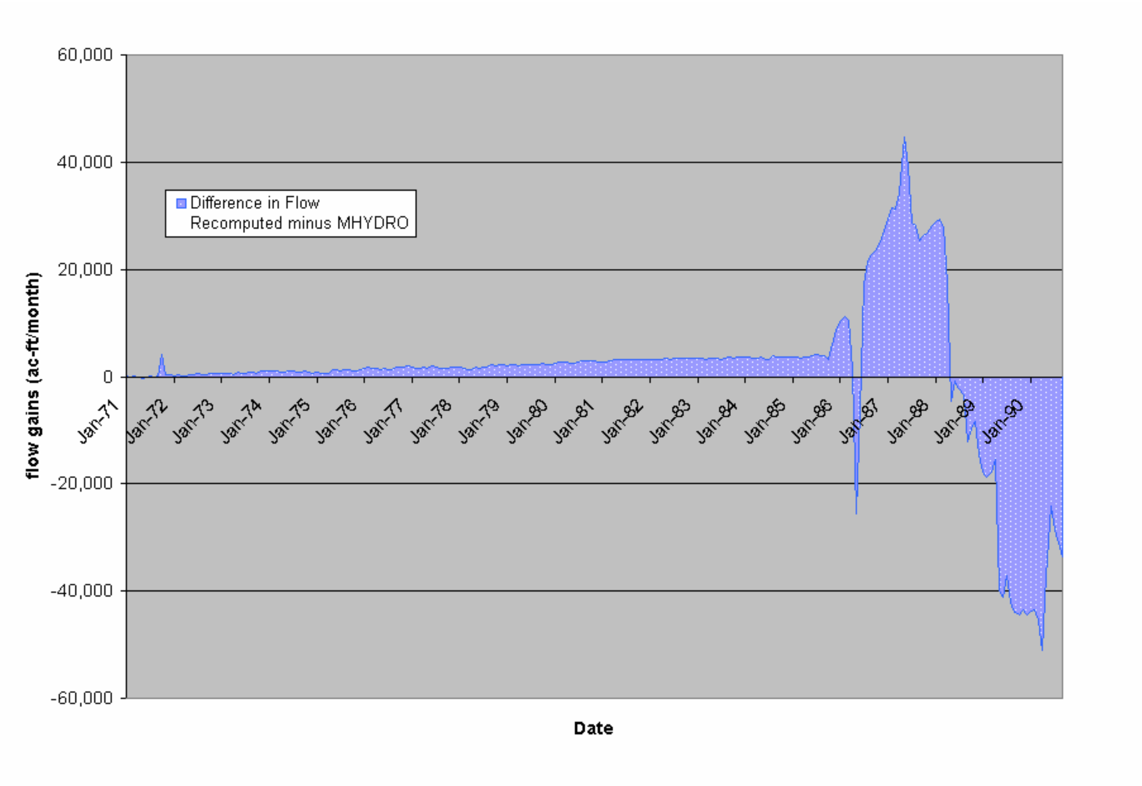


1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
flow gains (ac-ft/month)
Cumulative DIfference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

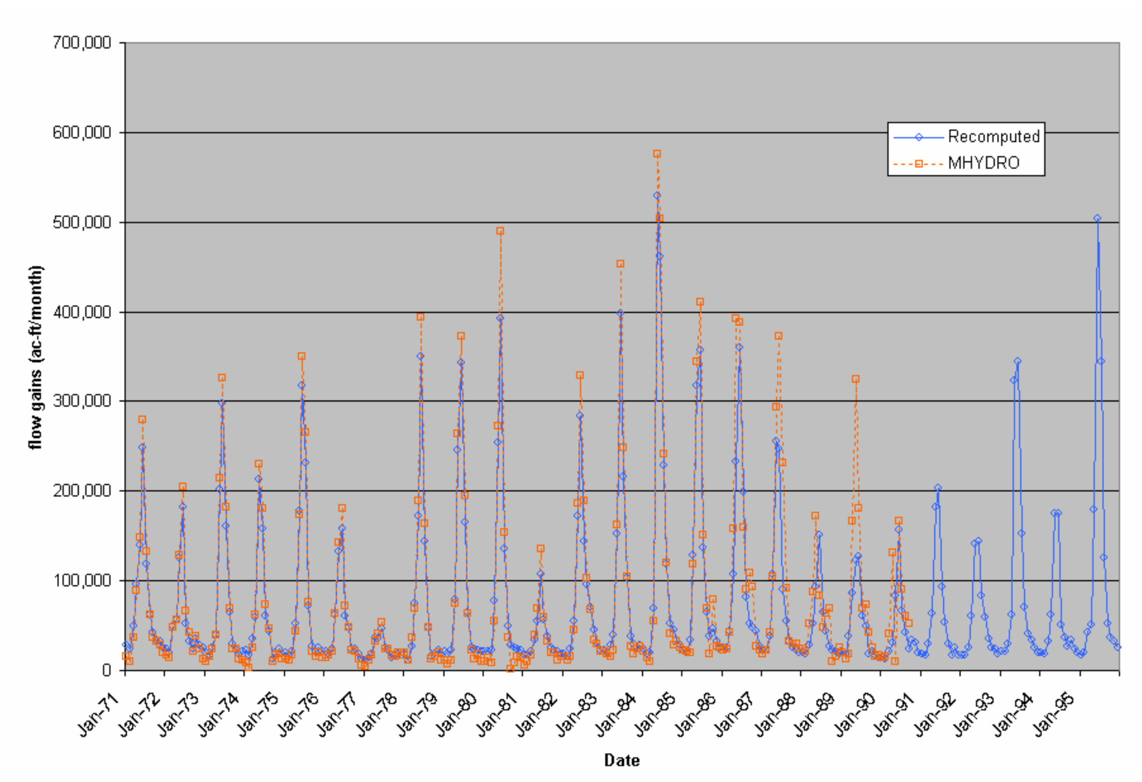
Above Taylor River before Taylor Park Reservoir Reach

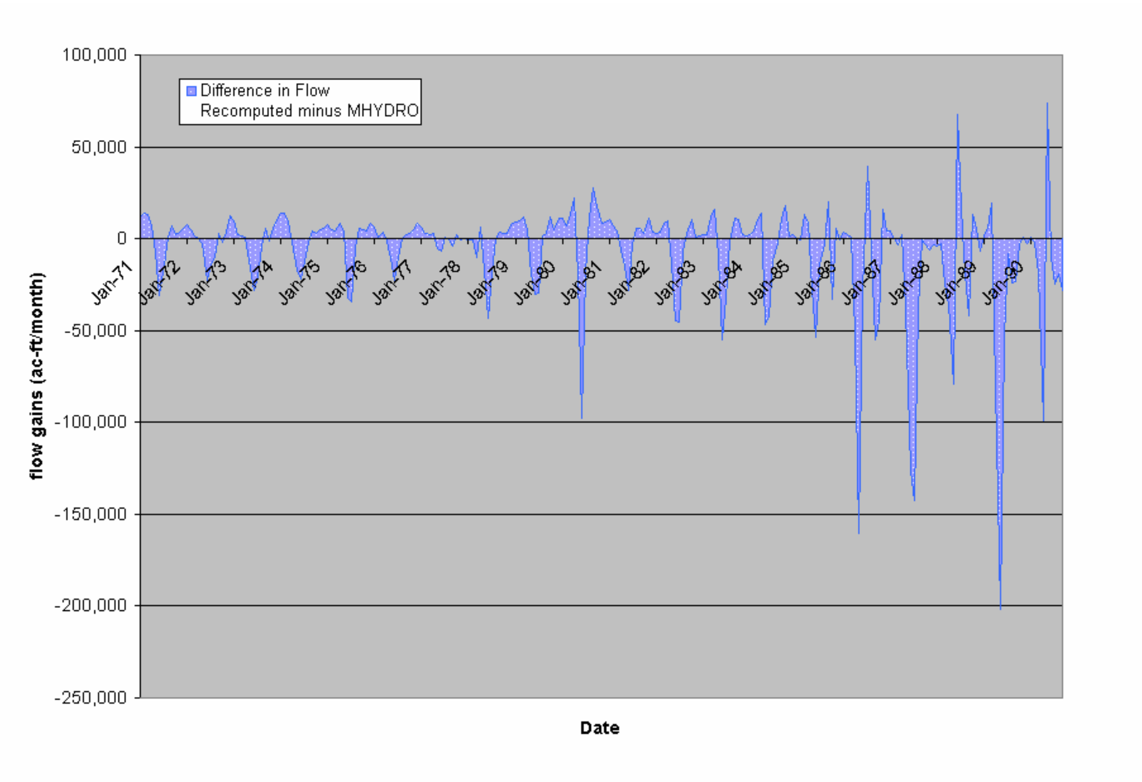






Taylor River before Taylor Park Reservoir to Gunnison River above Blue Mesa Reservoir Reach





100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
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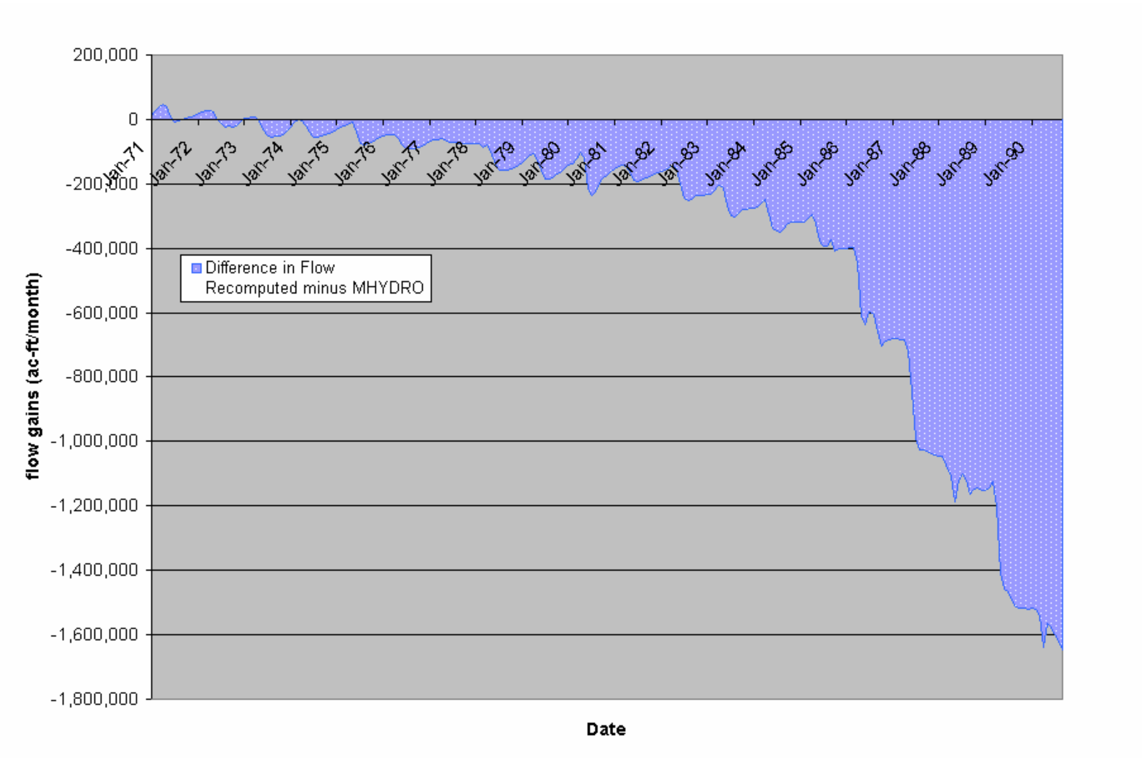
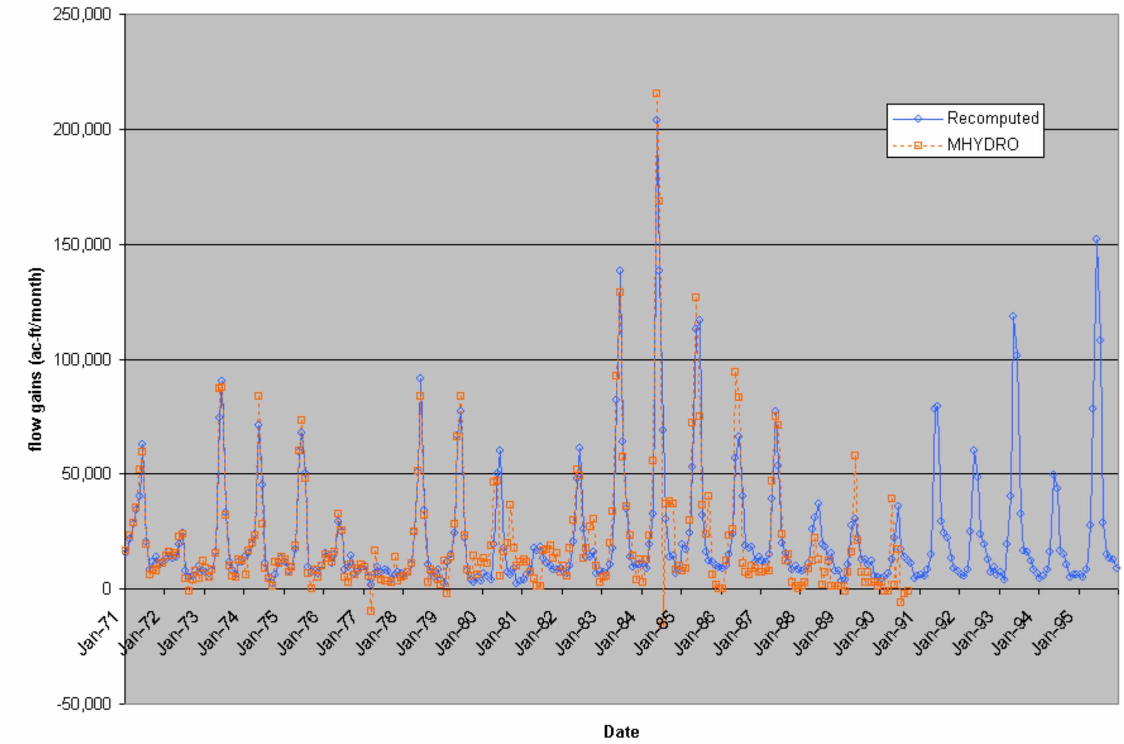
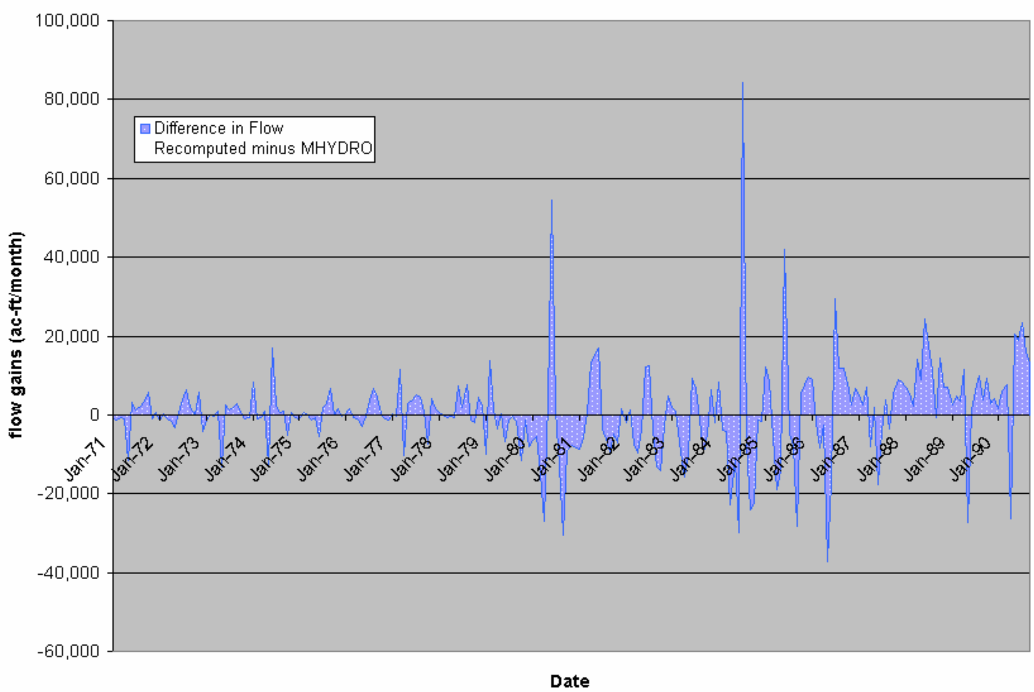
Jan-87
Jan-88
Jan-89
Jan-90
Date

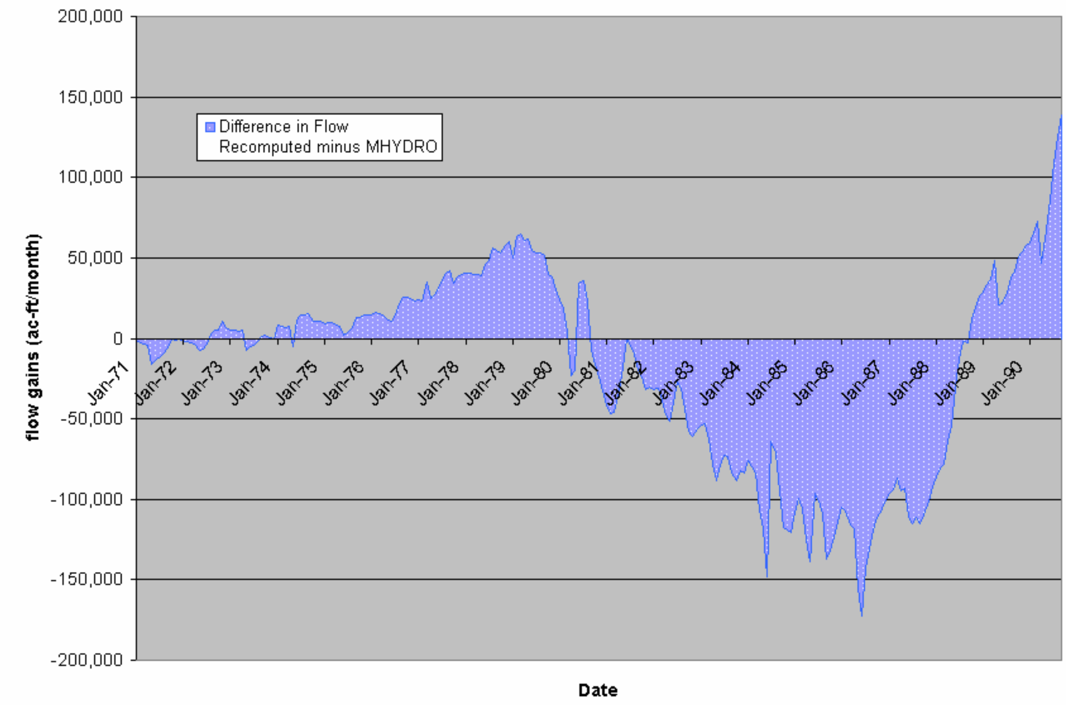


200,000
0
-200,000
-400,000
-600,000
-800,000
-1,000,000
-1,200,000
-1,400,000
-1,600,000
-1,800,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

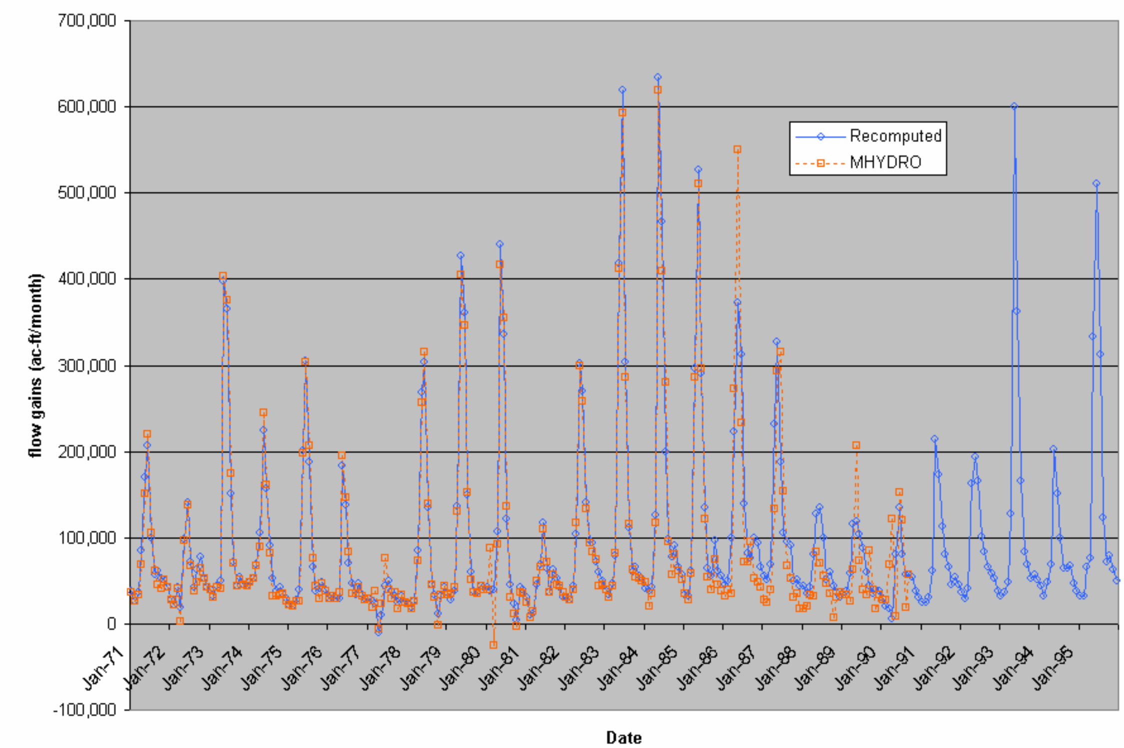
Gunnison River above Blue Mesa Reservoir to Gunnison River at Crystal Reservoir Reach

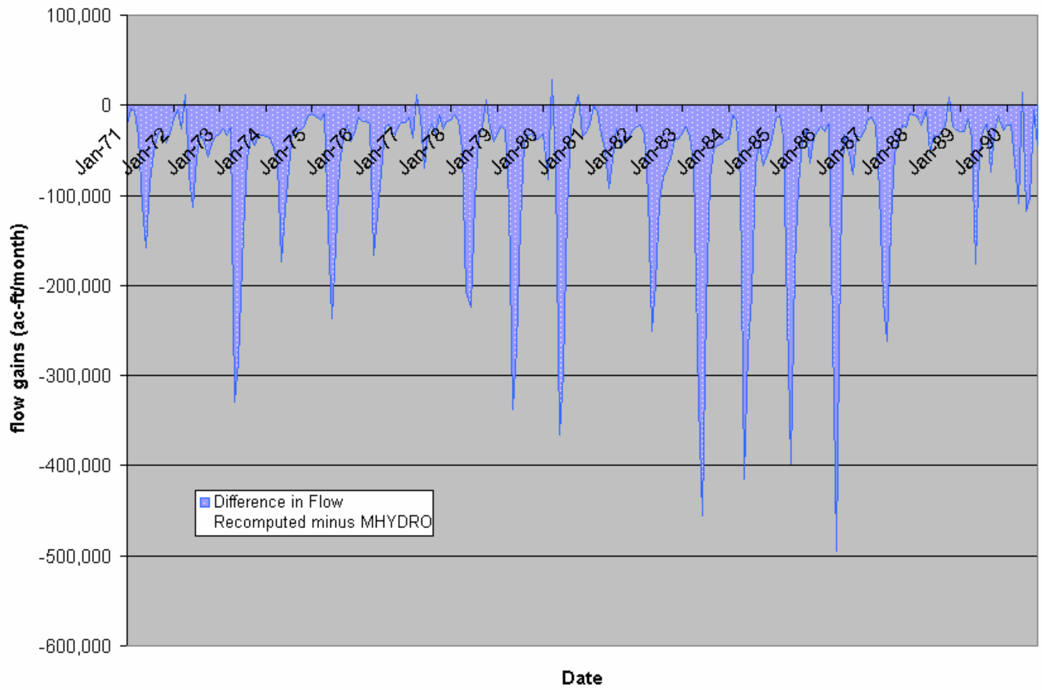


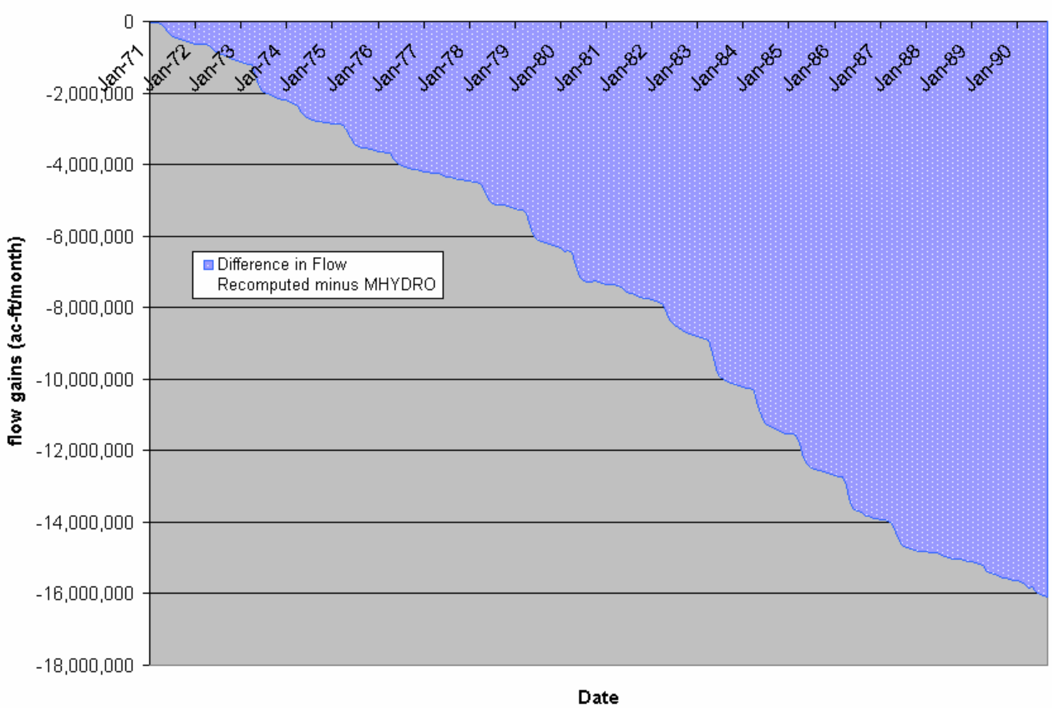




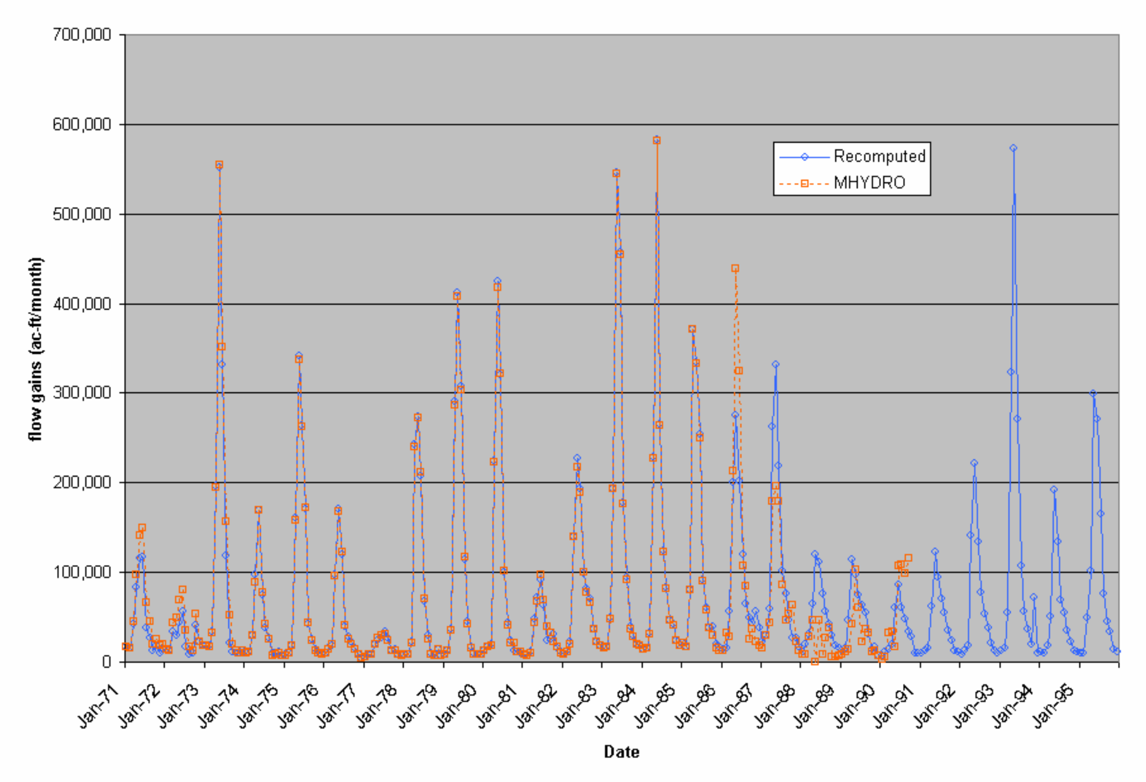
Gunnison River at Crystal Reservoir to Gunnison River near Grand Junction Reach

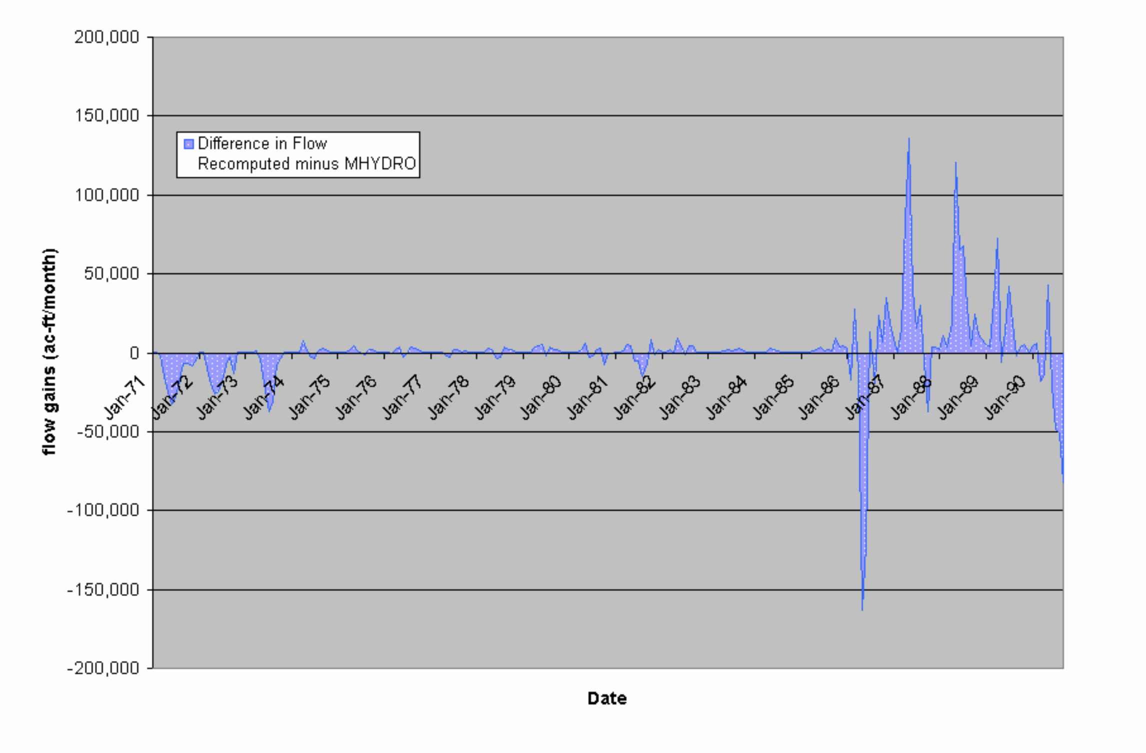


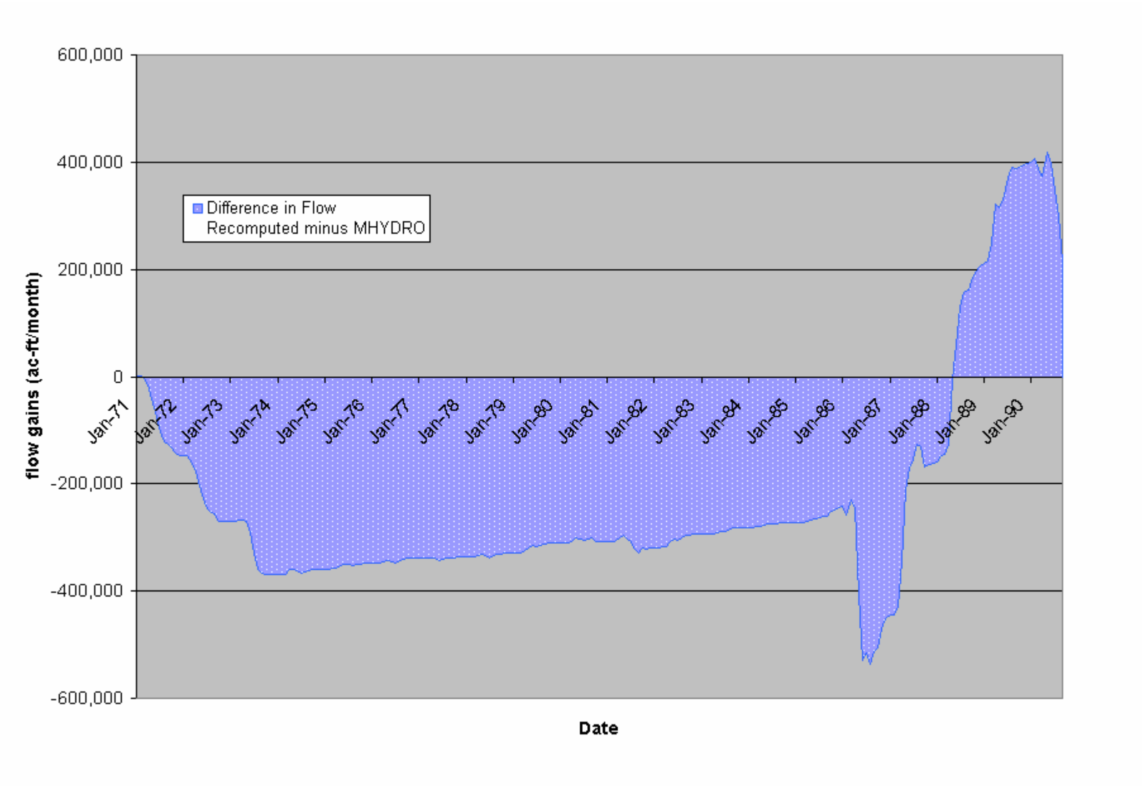

100,000
0
-100,000
-200,000
-300,000
-400,000
-500,000
-600,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow
Recomputed minus MHYDRO
Date


0
-2,000,000
-4,000,000
-6,000,000
-8,000,000
-10,000,000
-12,000,000
-14,000,000
-16,000,000
-18,000,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow
Recomputed minus MHYDRO
Date

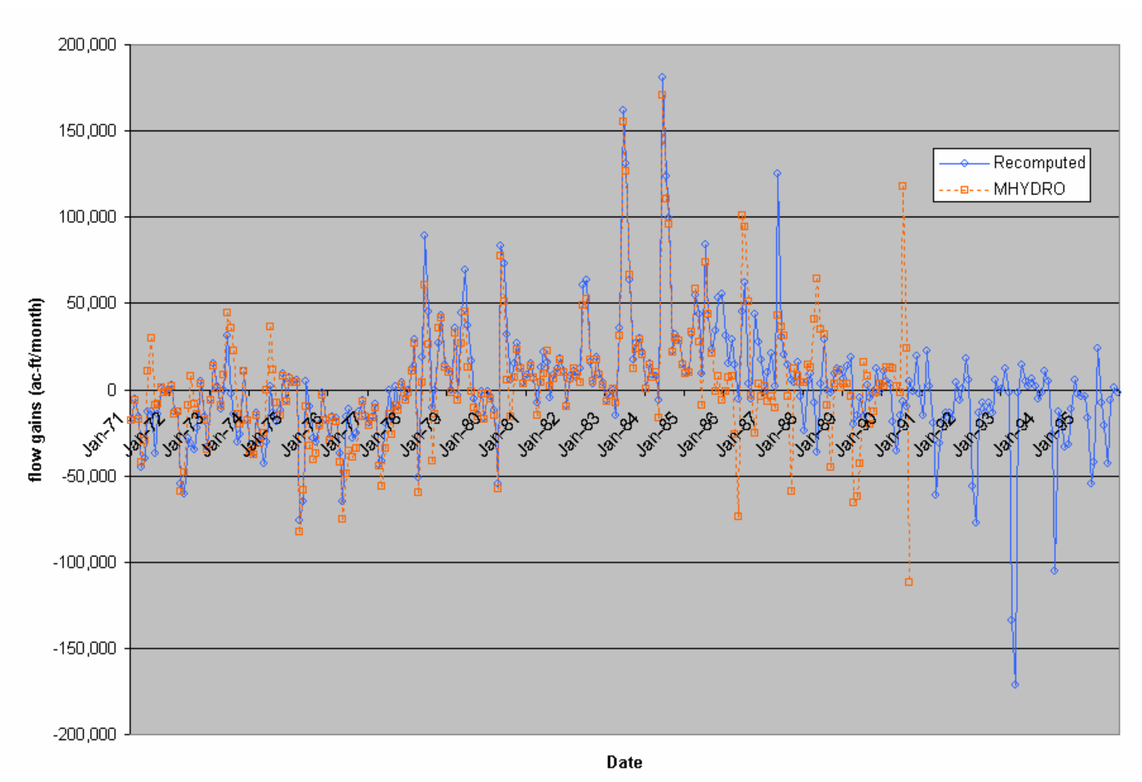
Dolores River near Cisco Reach

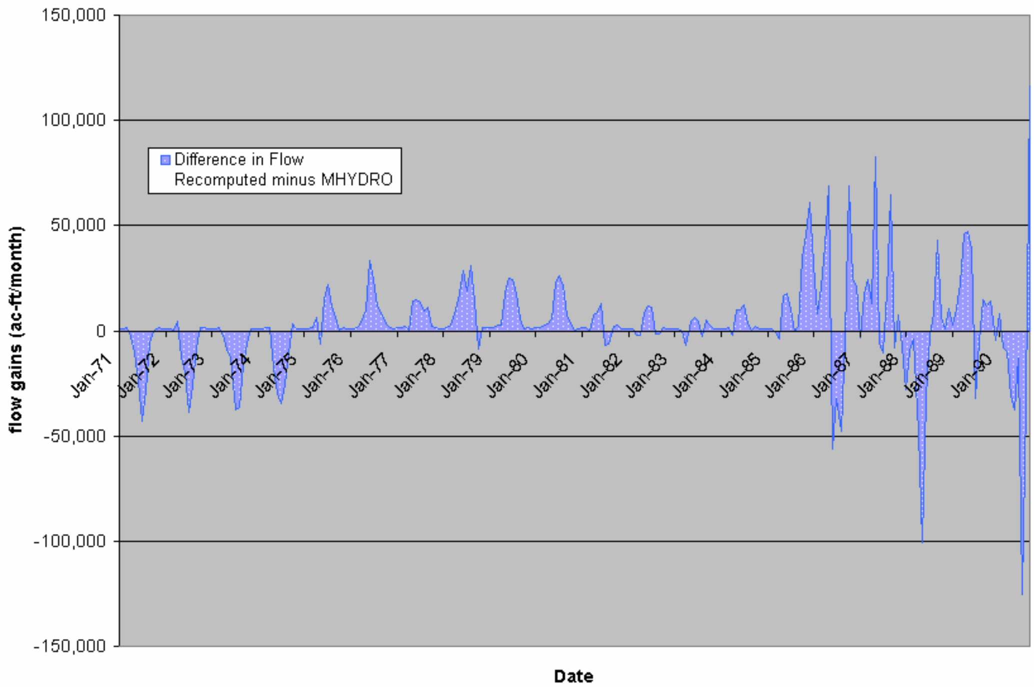


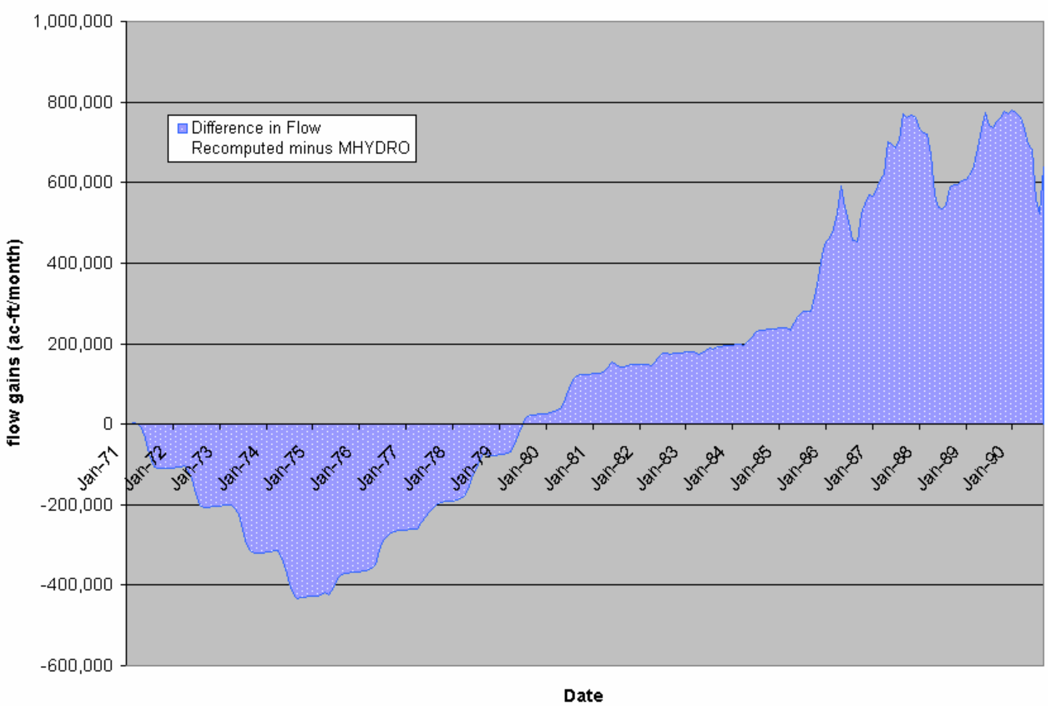




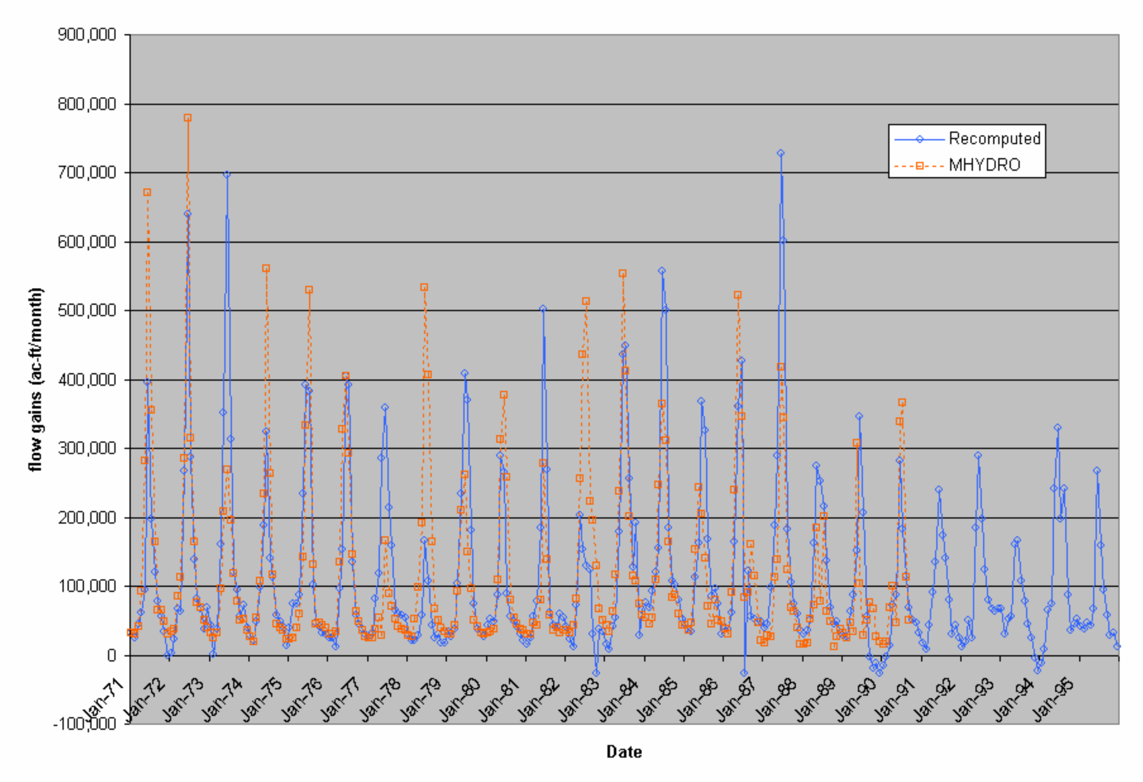
Colorado River near Cameo to Colorado River near Cisco Reach

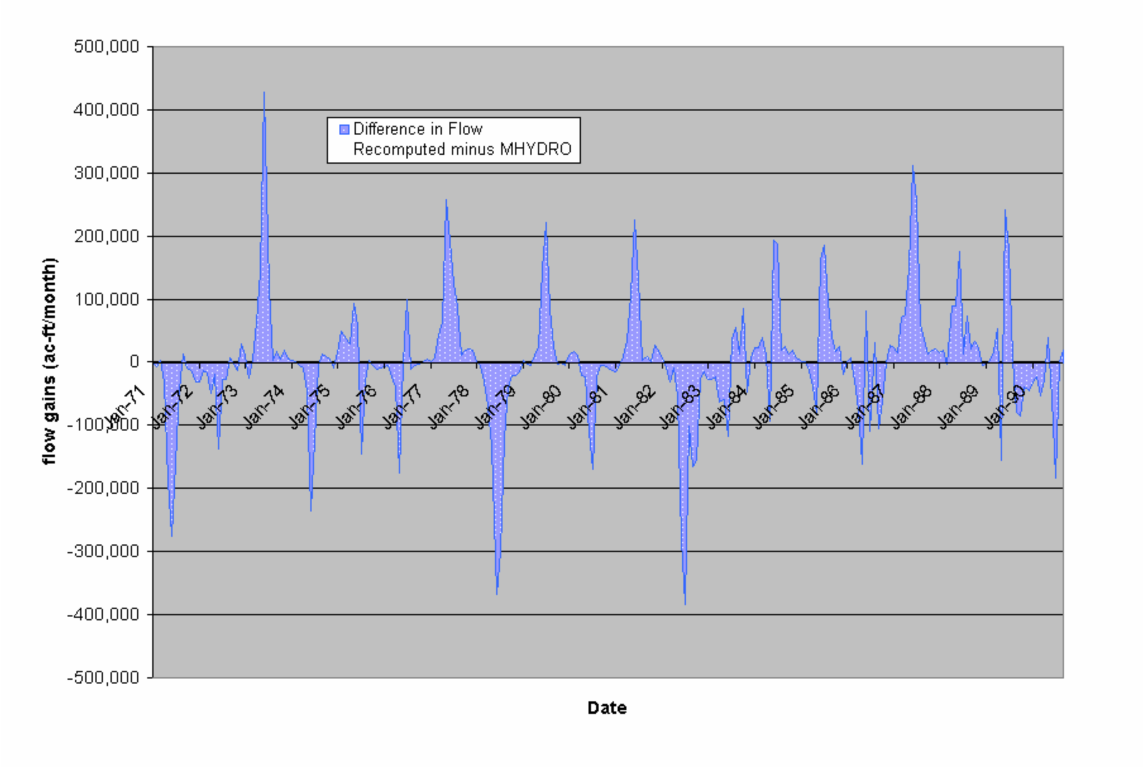


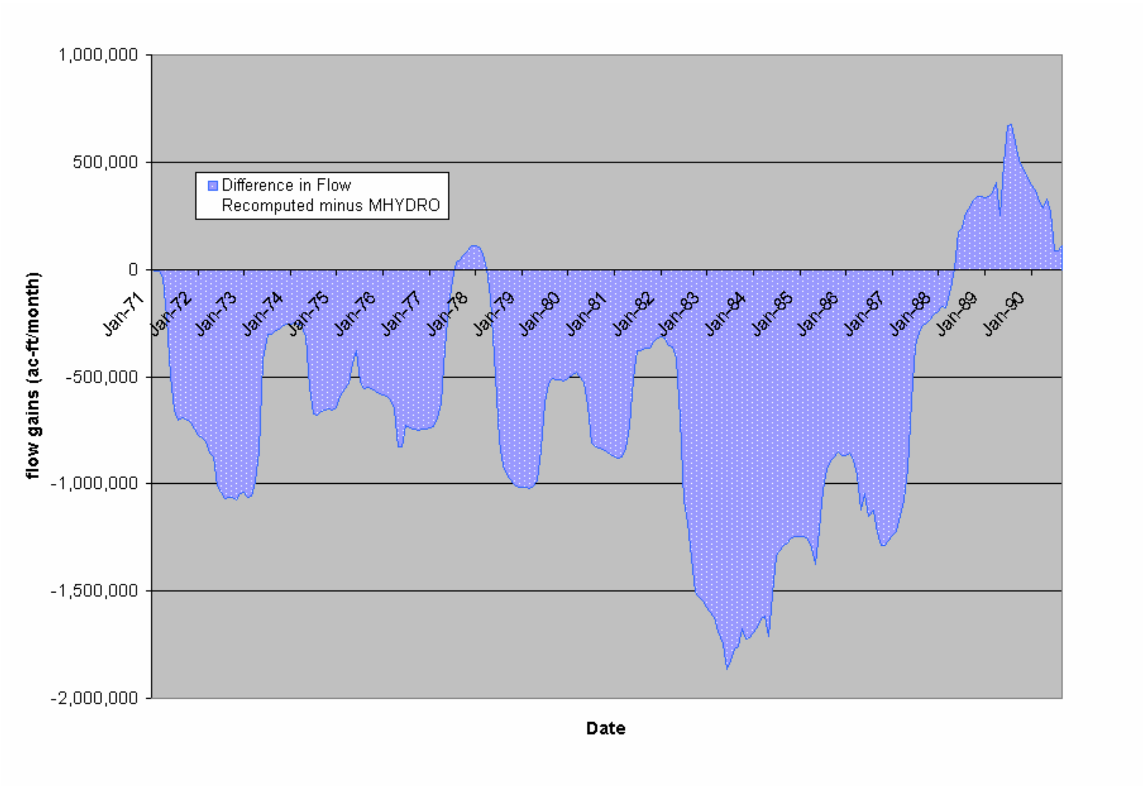

150,000
100,000
50,000
0
-50,000
-100,000
-150,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date


1,000,000
800,000
600,000
400,000
200,000
0
-200,000
-400,000
-600,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

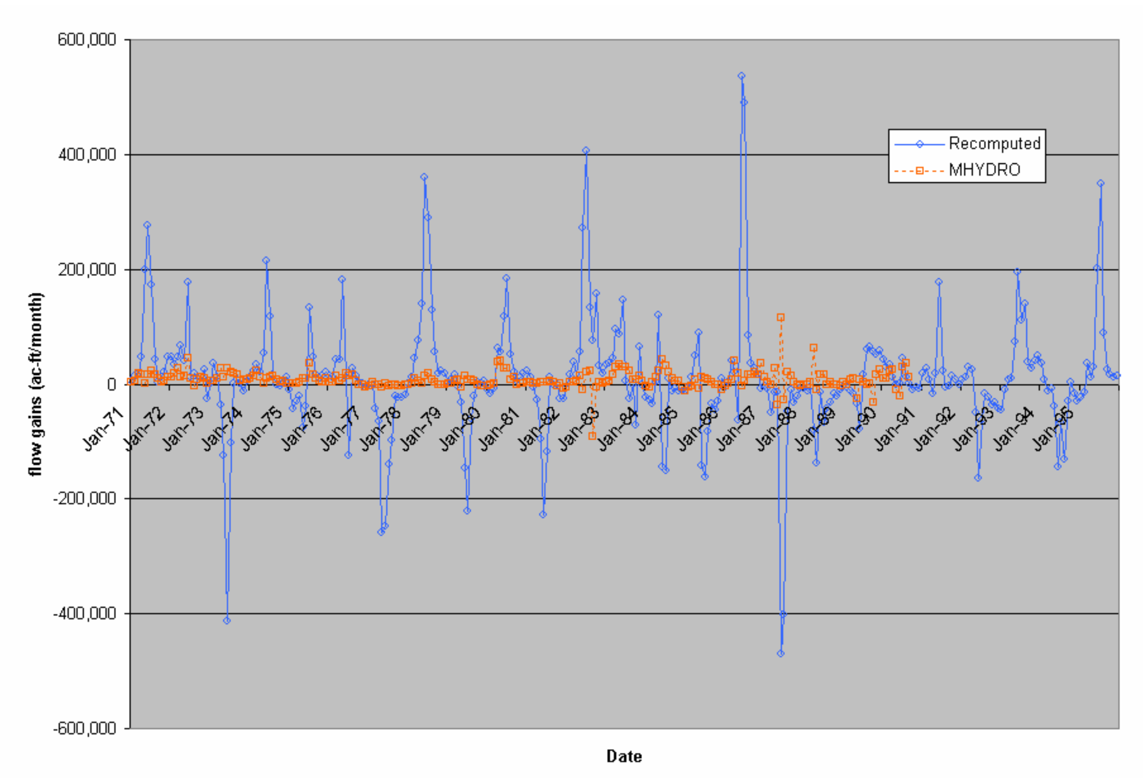
Above Green River below Fontenelle Reservoir Reach

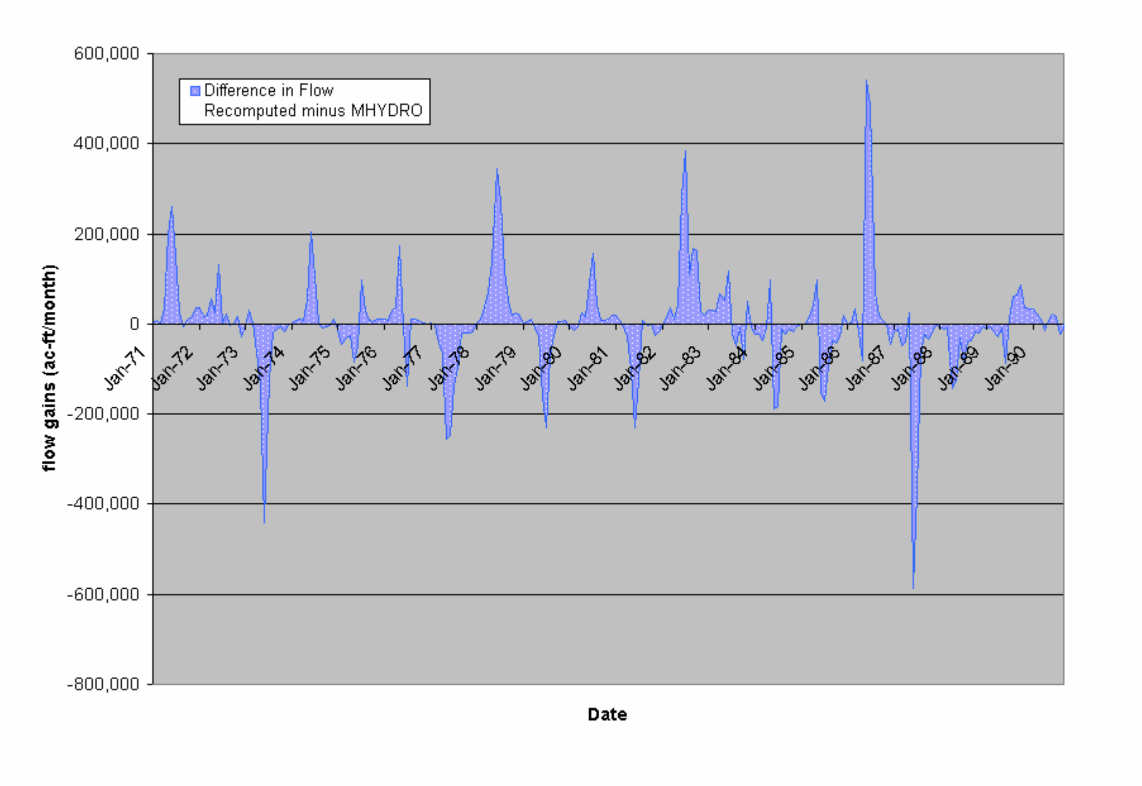


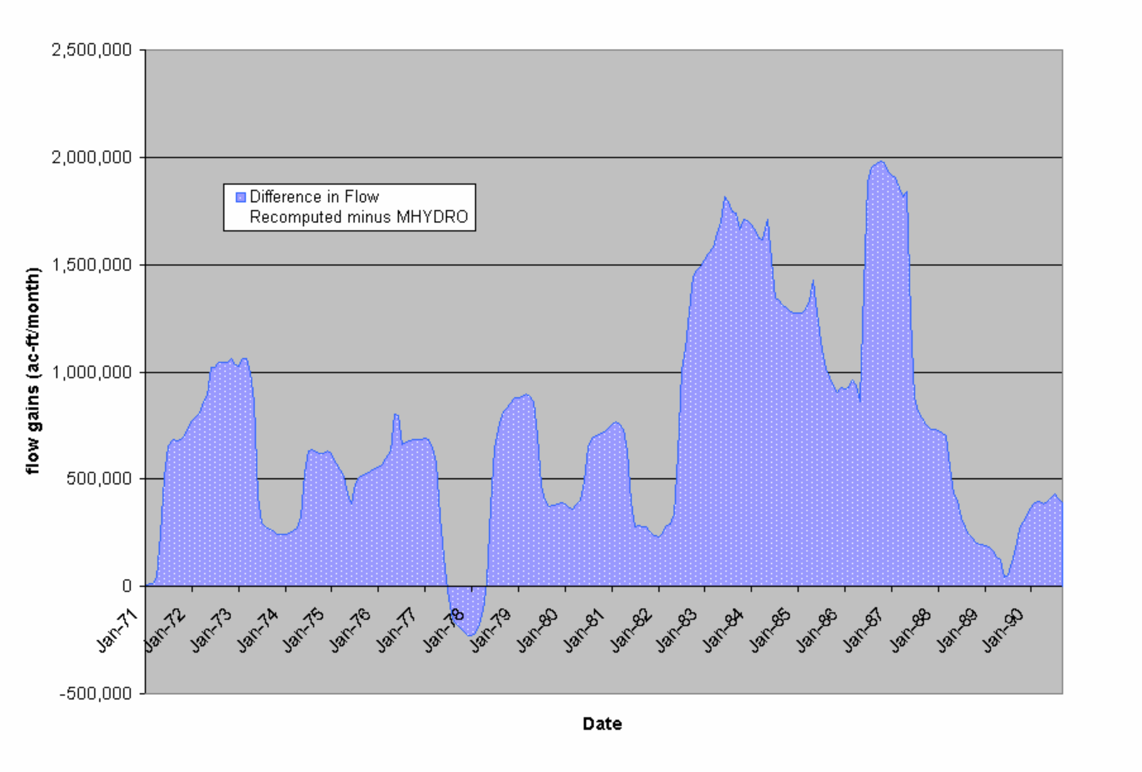




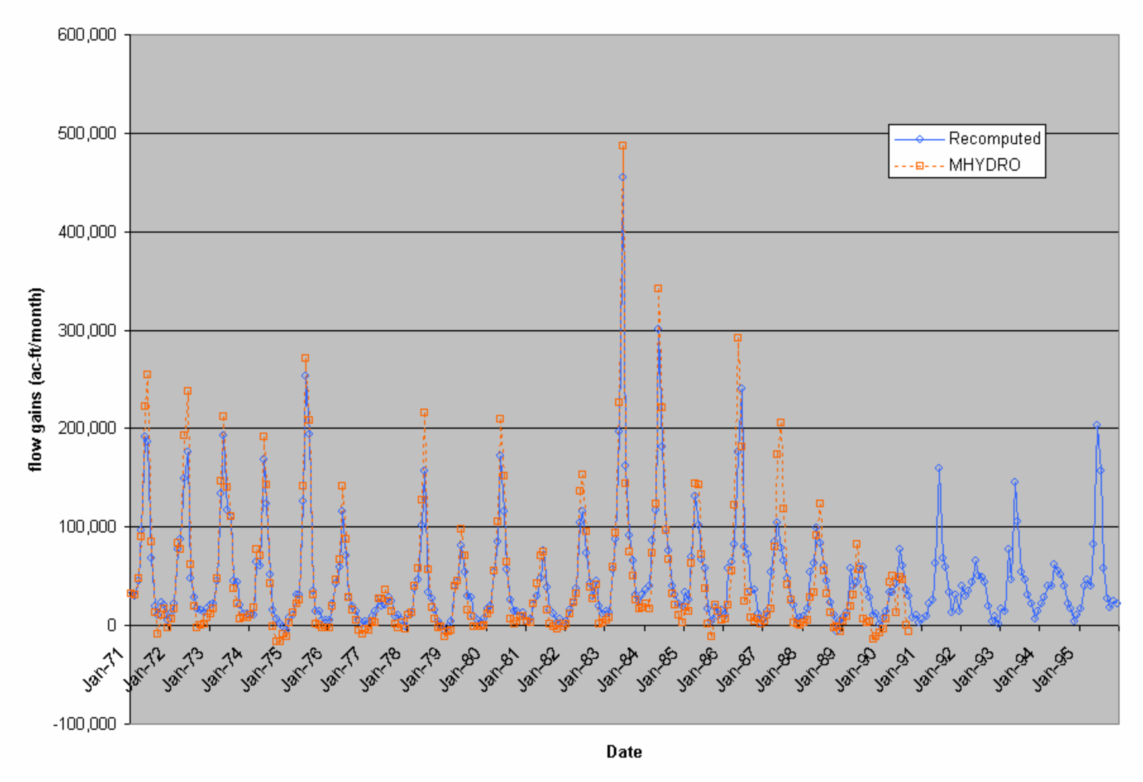
Green River below Fontenelle Reservoir To Green River near Green River, Wyoming Reach

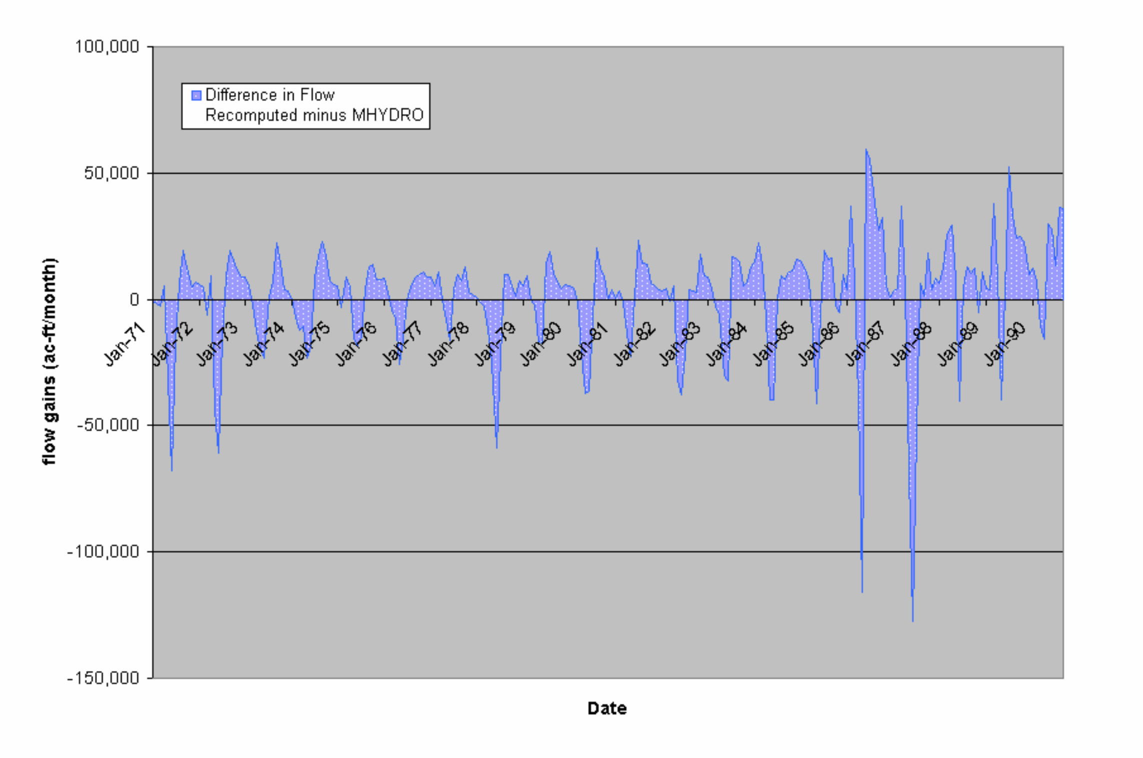


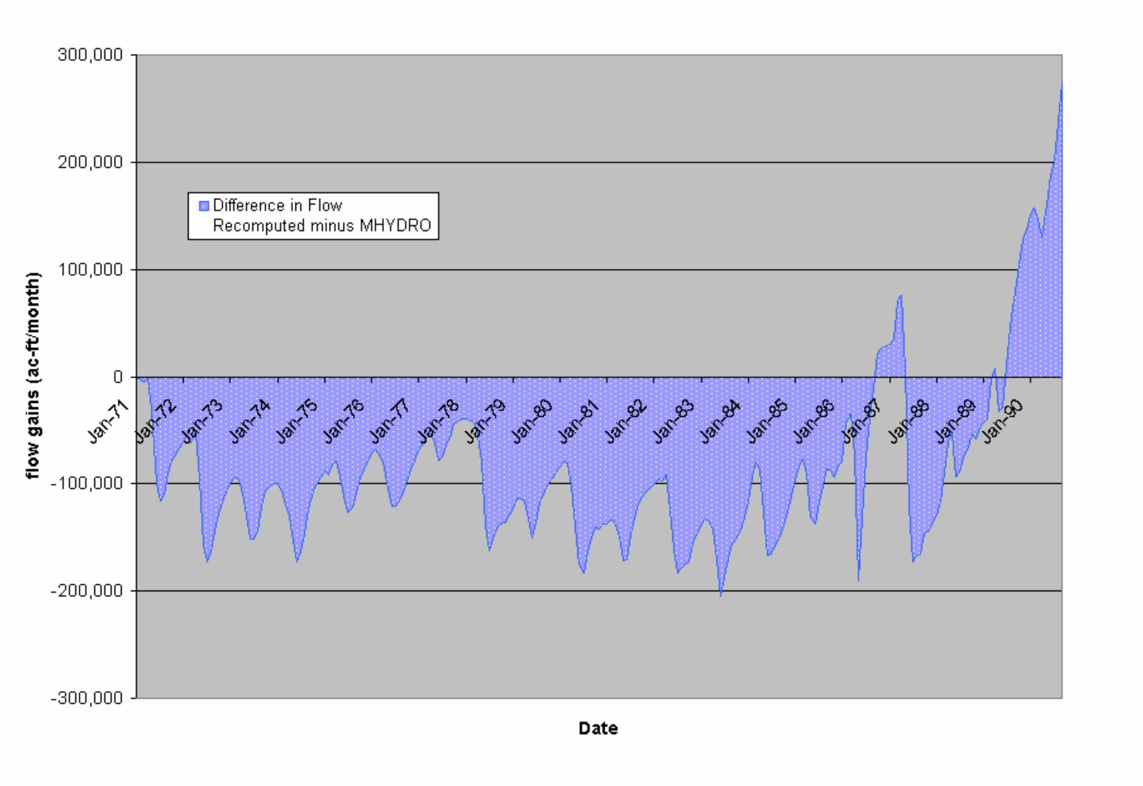

600,000
400,000
200,000
0
-200,000
-400,000
-600,000
-800,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date


2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
-500,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

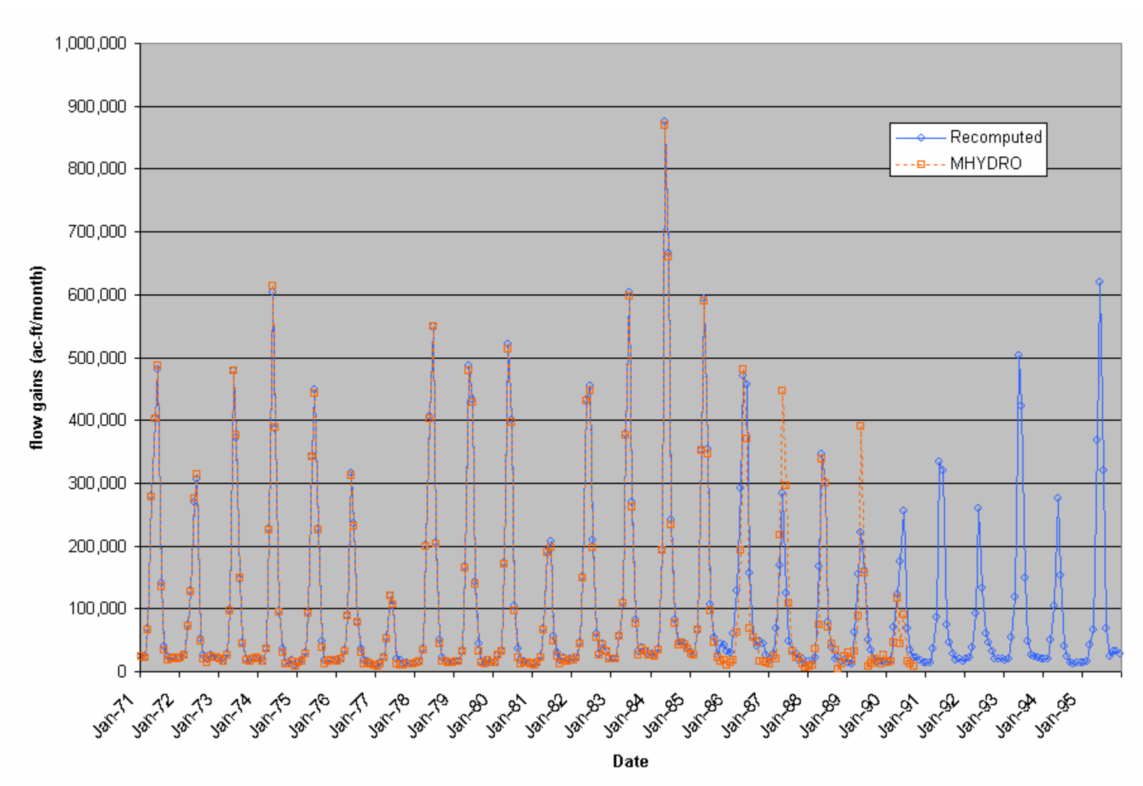
Green River near Green River, Wyoming To Green River near Greendale Reach

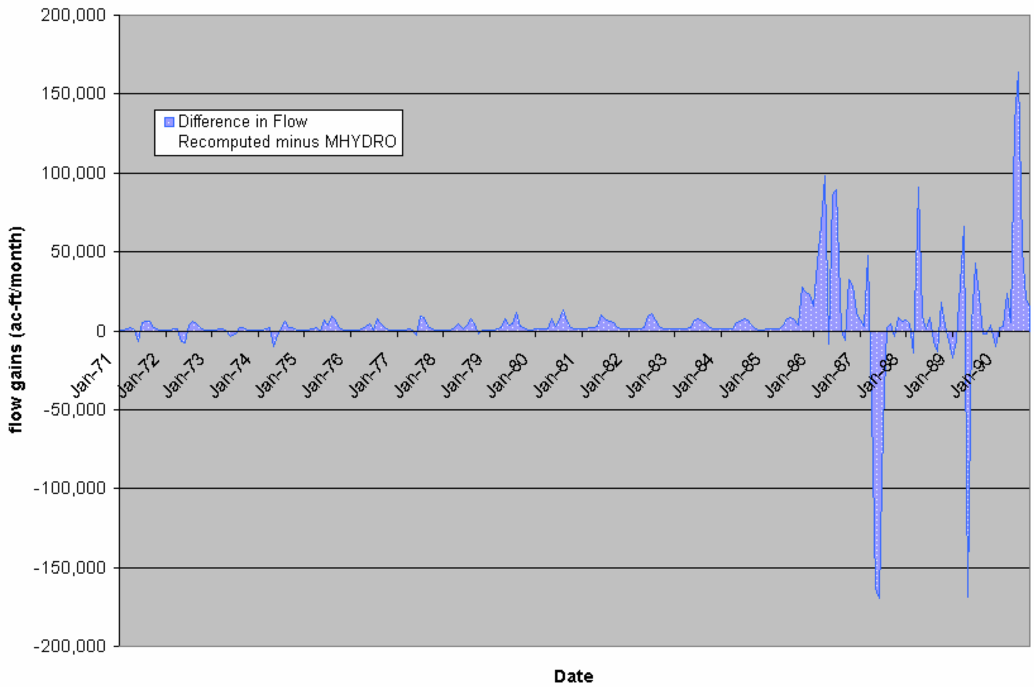




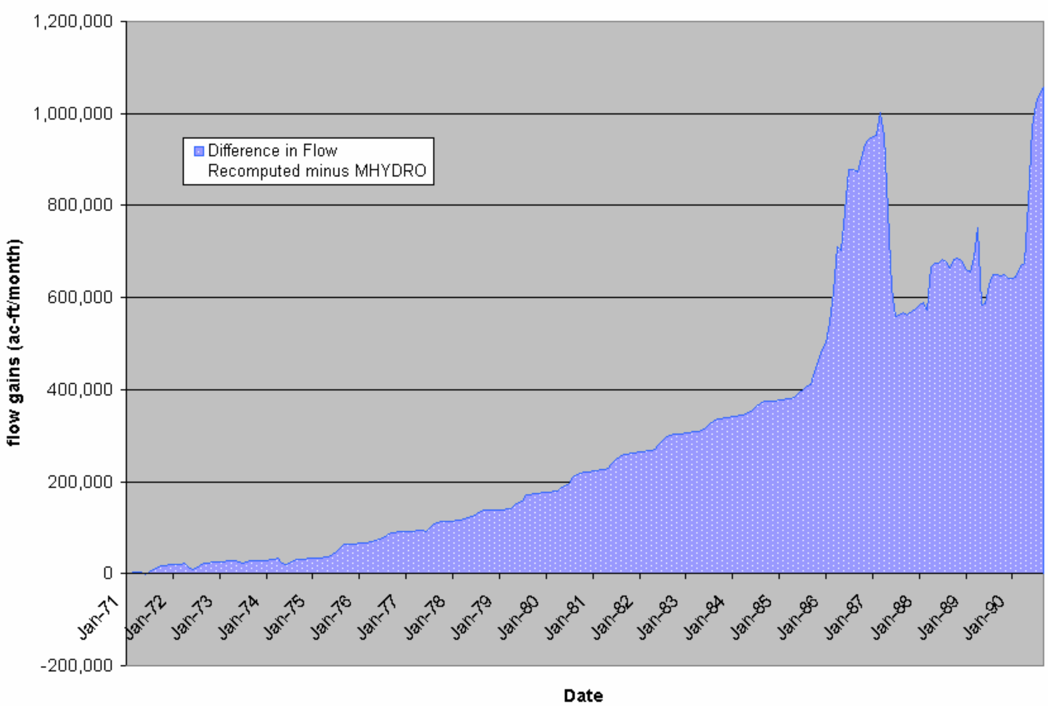


Above Yampa River near Maybell Reach



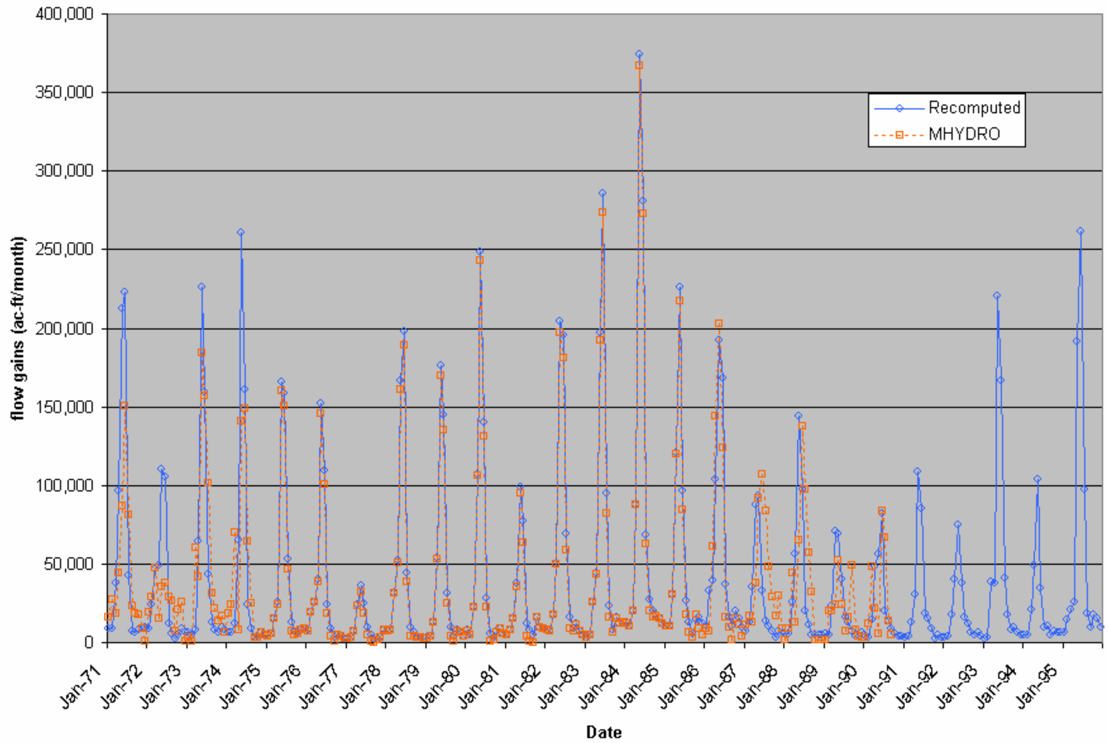


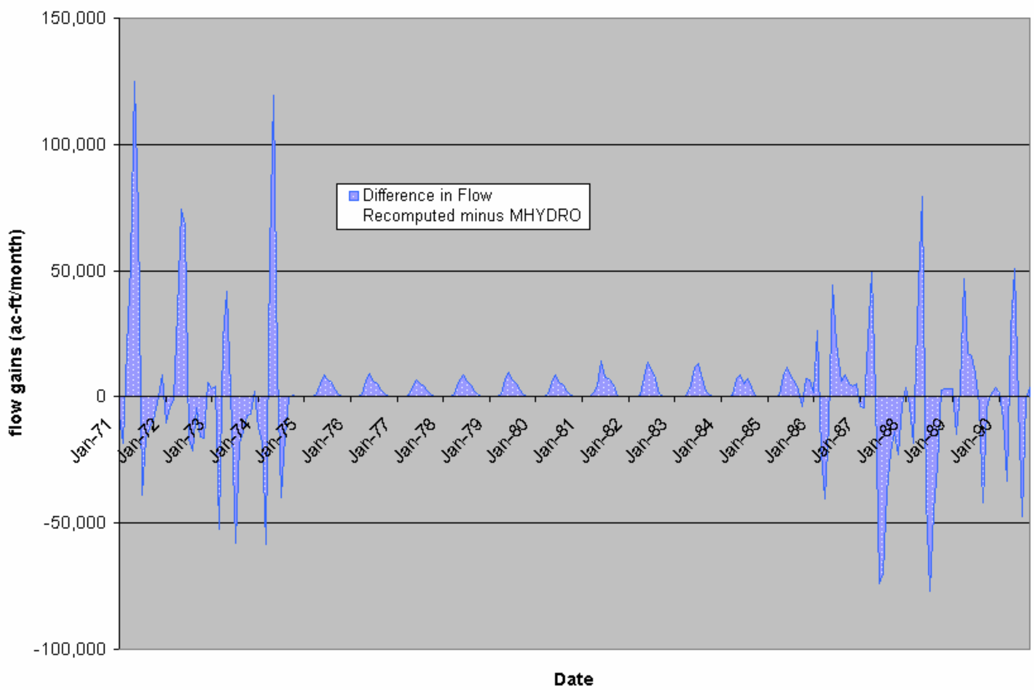
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

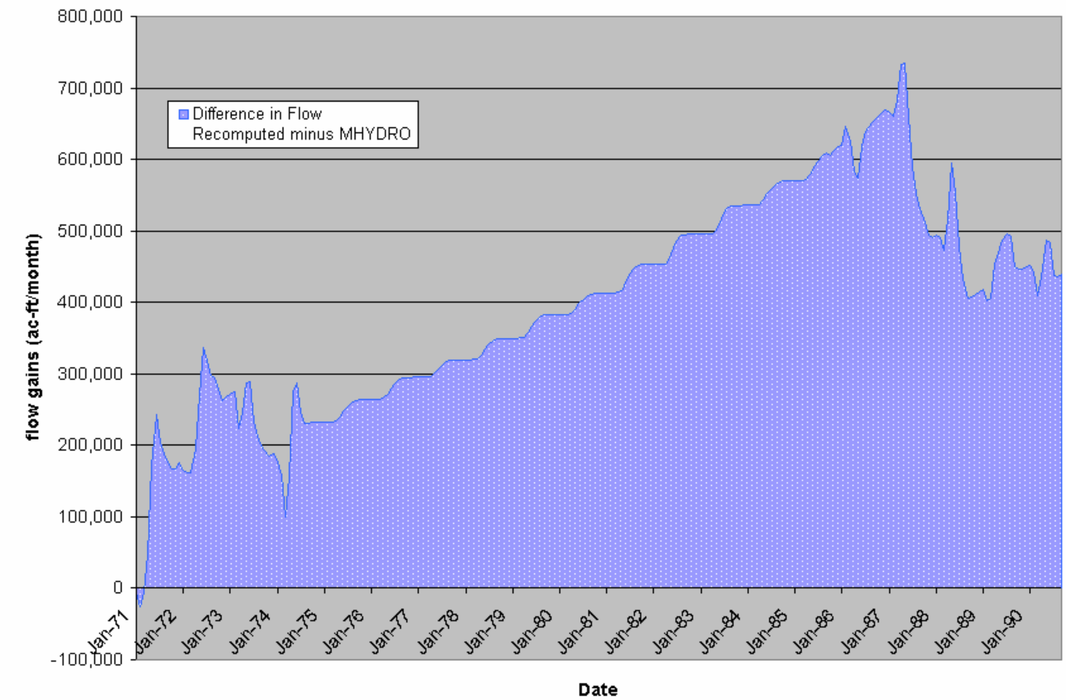


1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

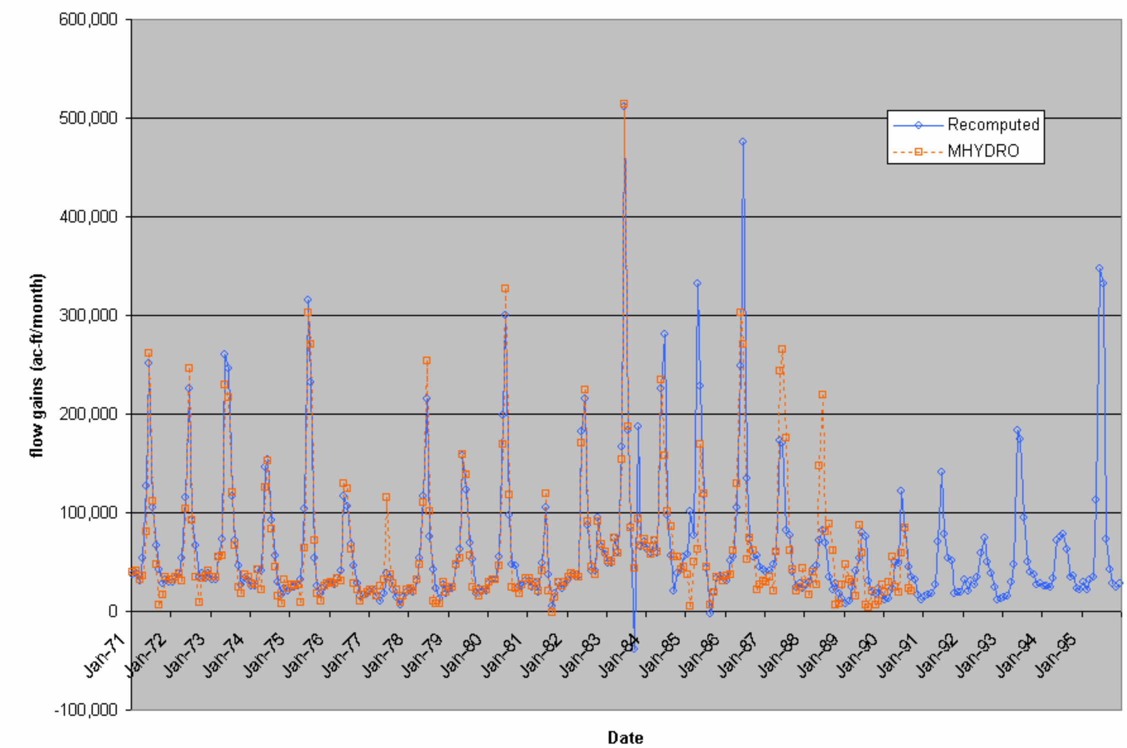
Above Little Snake River near Lily Reach

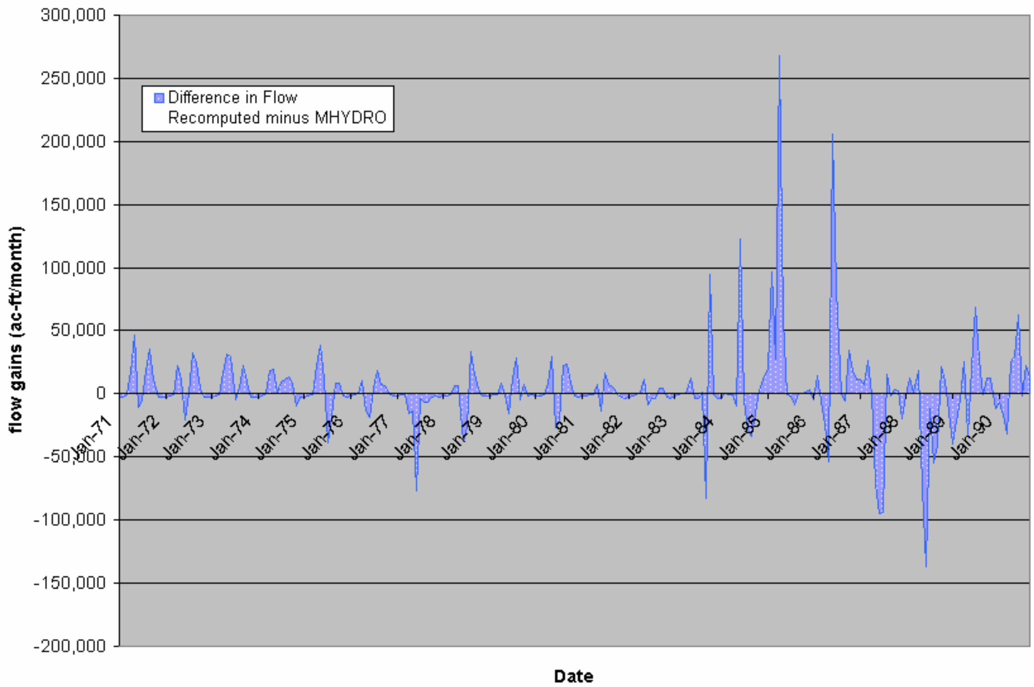


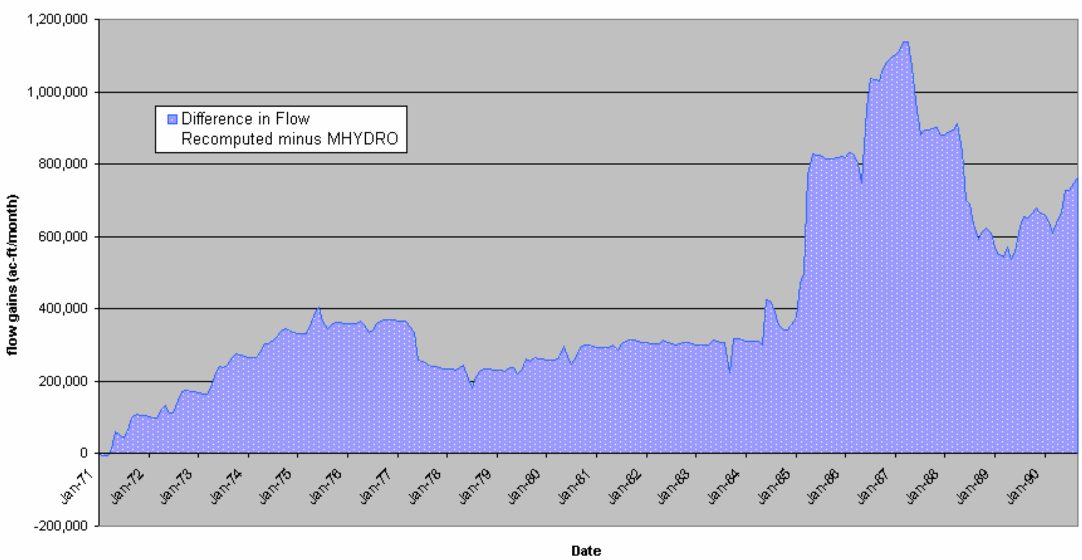




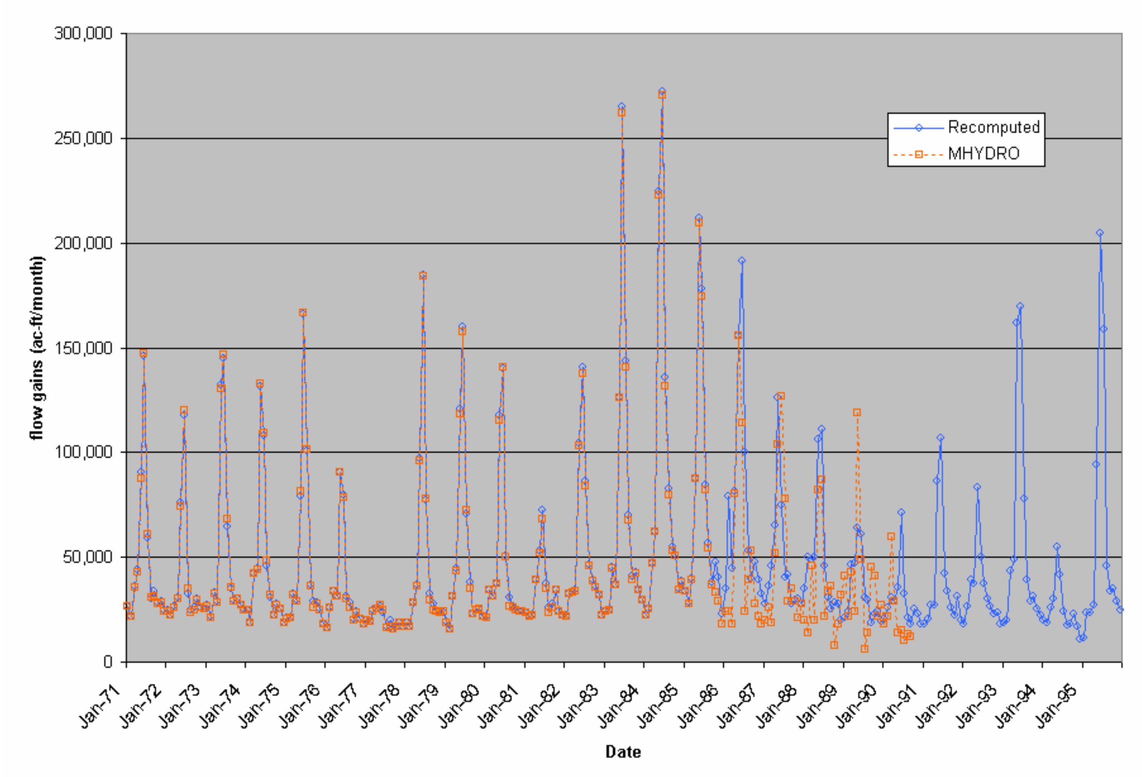
Above Duchesne River near Randlett Reach

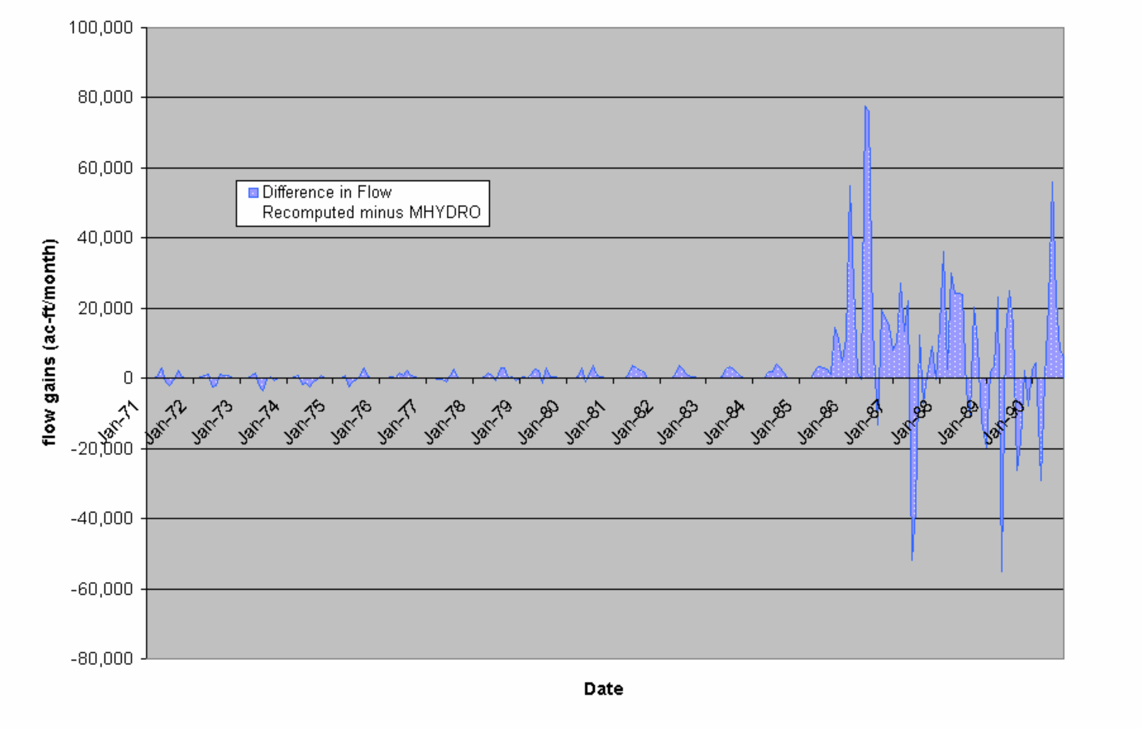


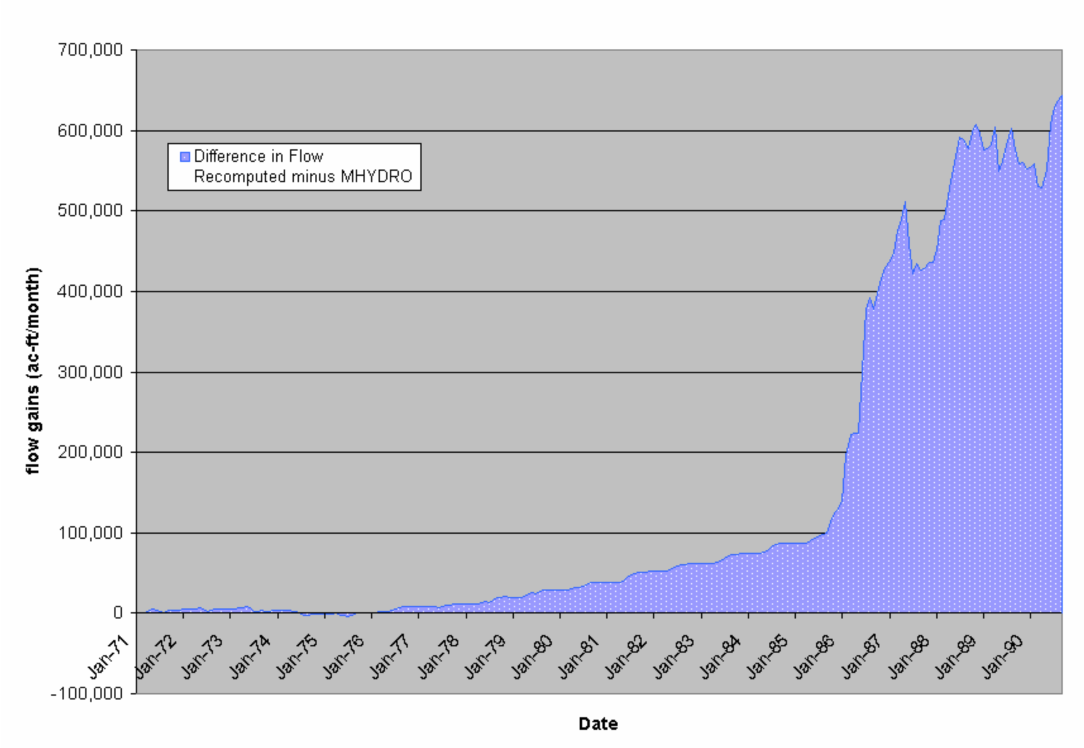

Difference in Flow
Recomputed minus MHYDRO
flow gains (ac-ft/month)
300,000
250,000
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date


Difference in Flow
Recomputed minus MHYDRO
flow gains (ac-ft/month)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

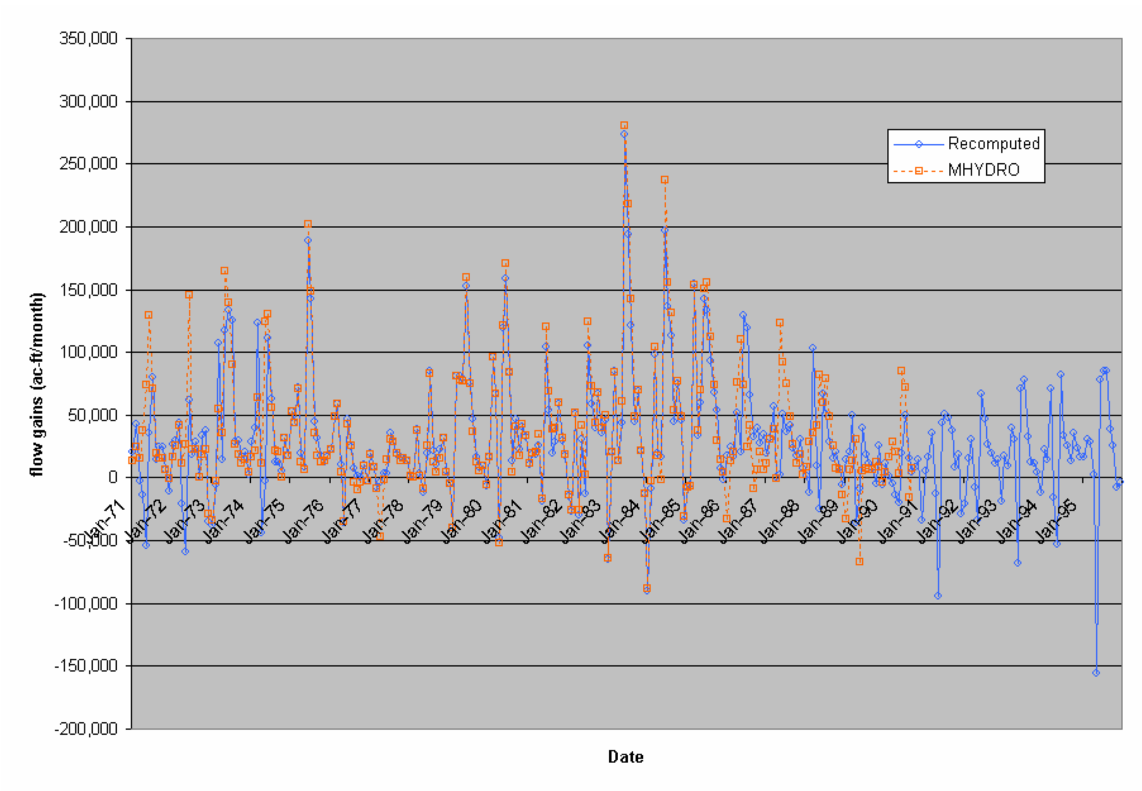
Above White River near Watson Reach

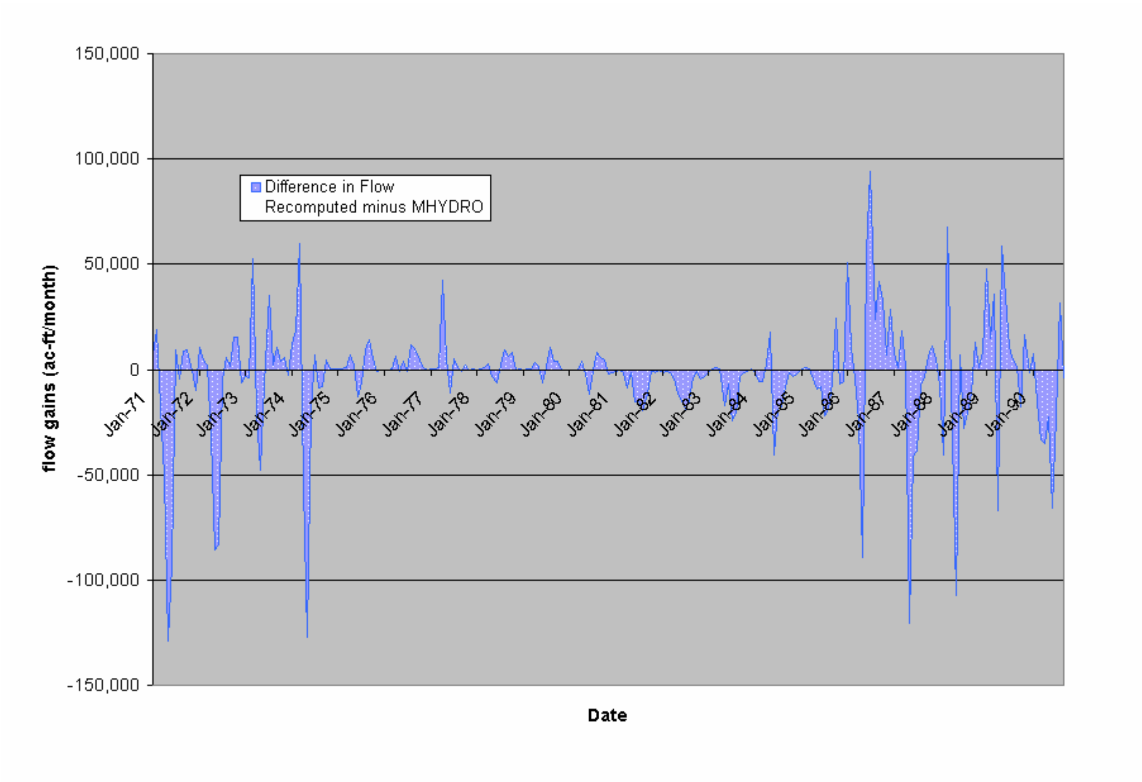


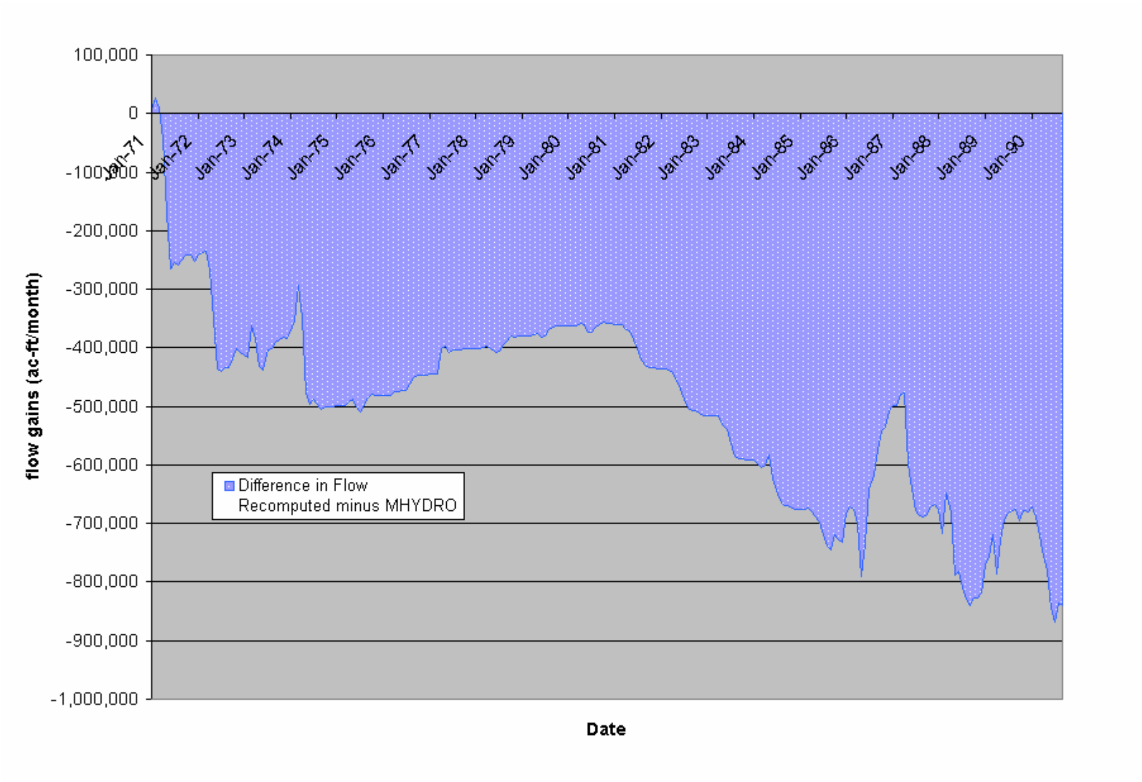




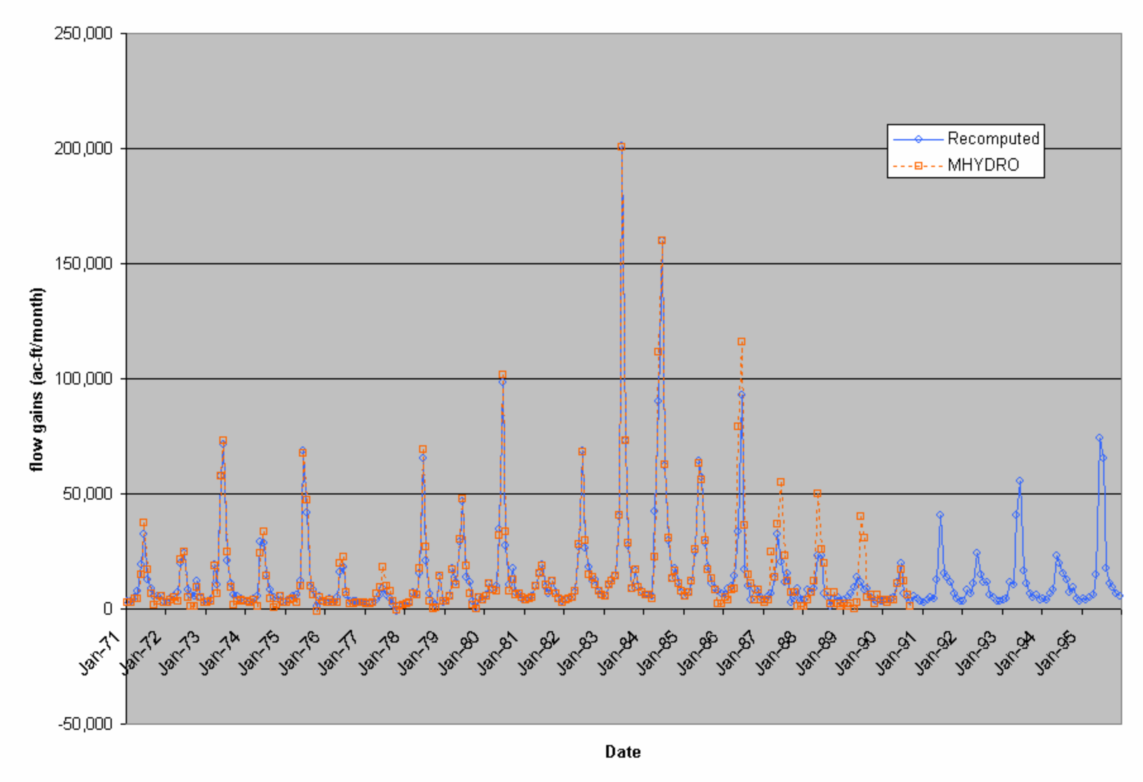
Green River near Greendale to Green River, Utah Reach

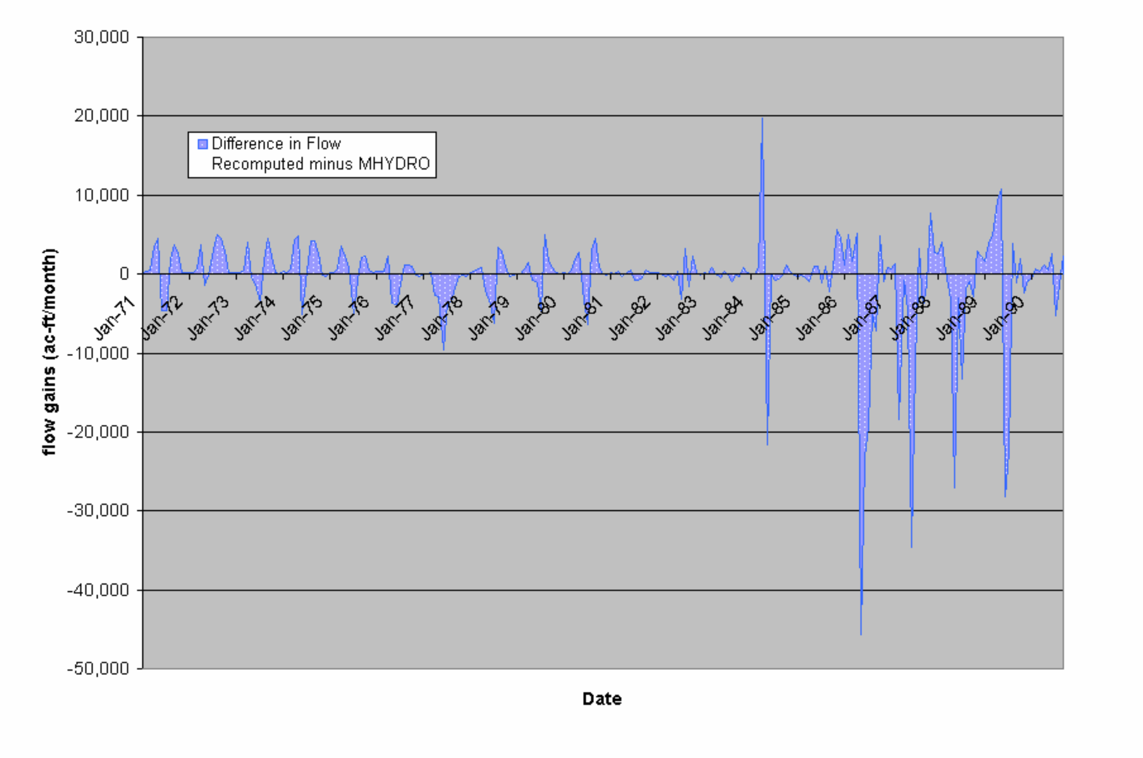


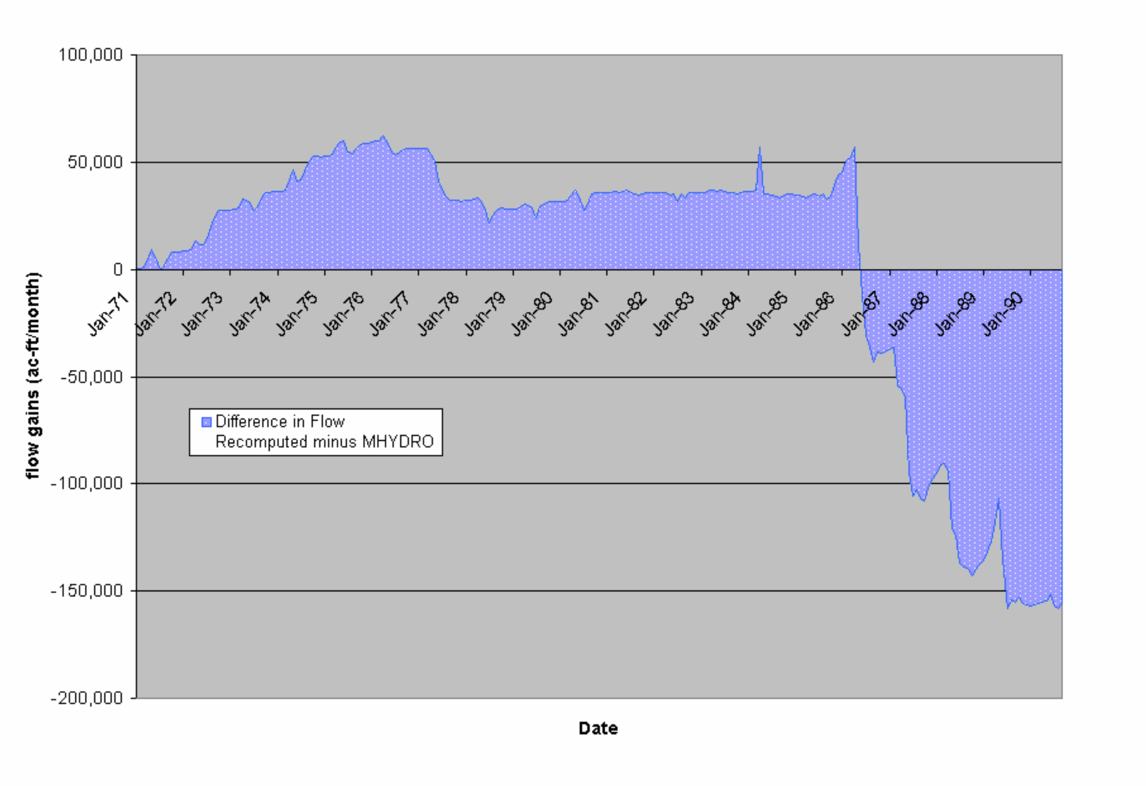

150,000
100,000
50,000
0
-50,000
-100,000
-150,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date


100,000
0
-100,000
-200,000
-300,000
-400,000
-500,000
-600,000
-700,000
-800,000
-900,000
-1,000,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

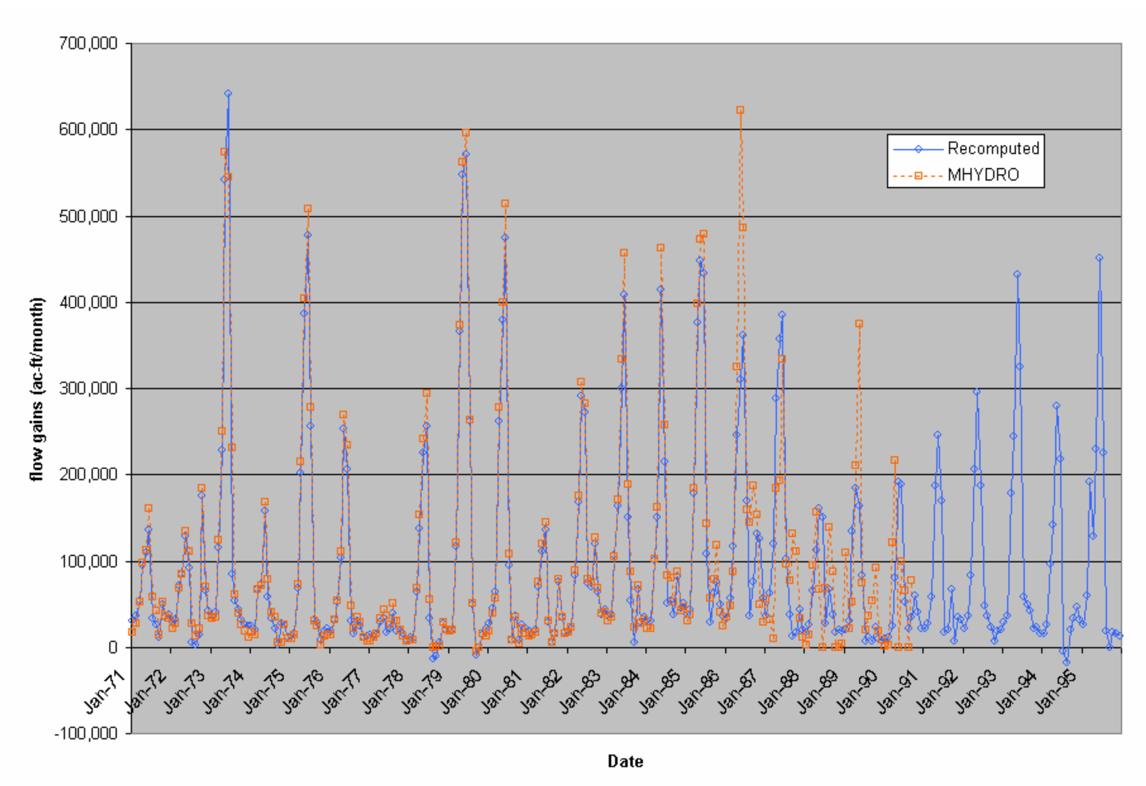
Above San Rafael River near Green River, Utah Reach

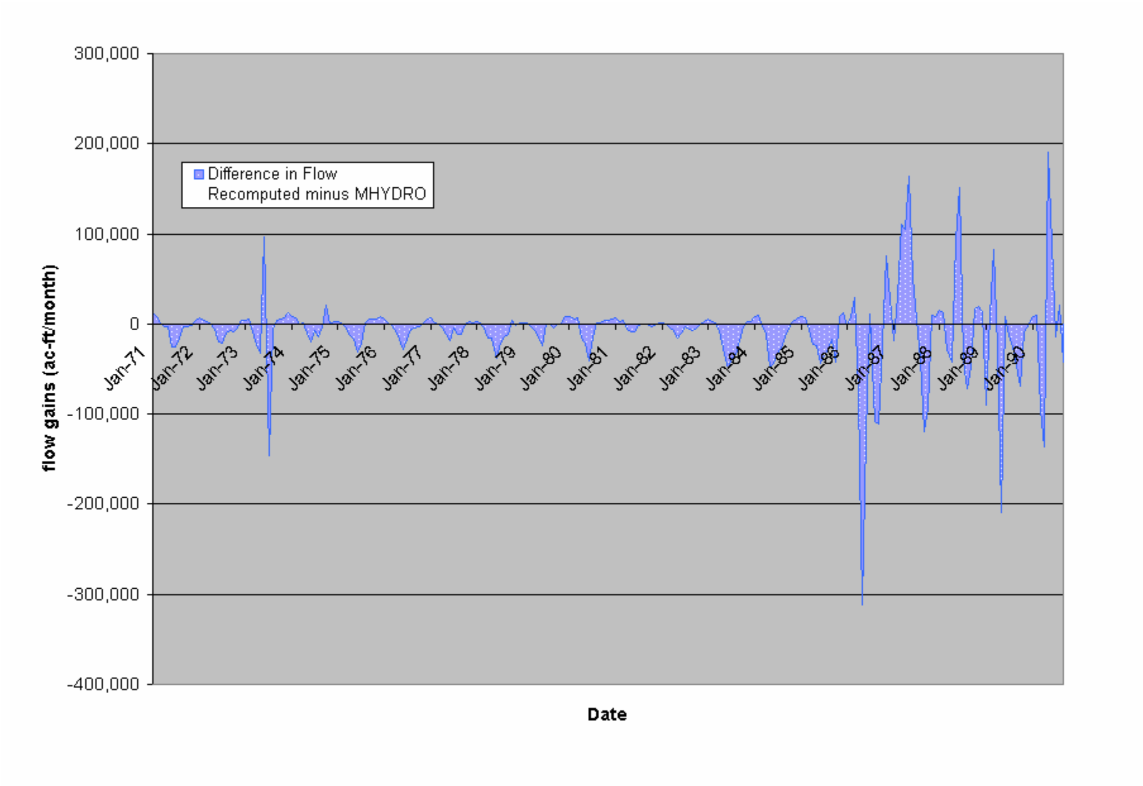


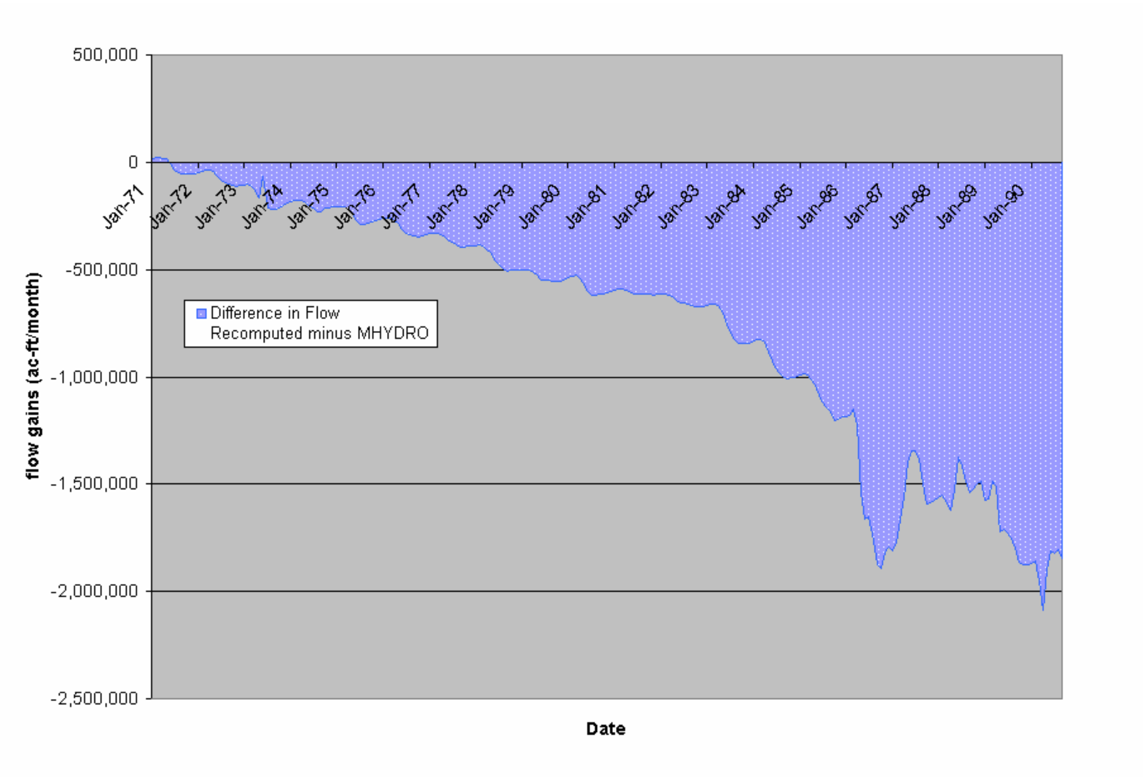




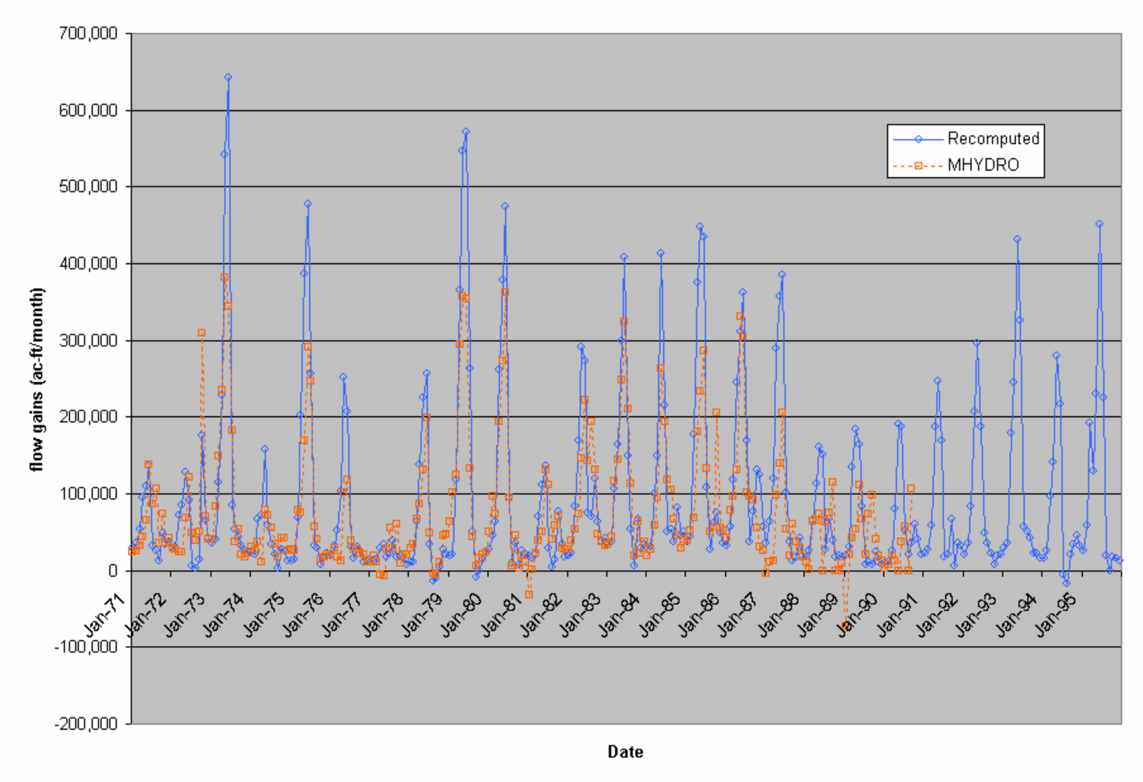
Above San Juan River near Archuletta Reach

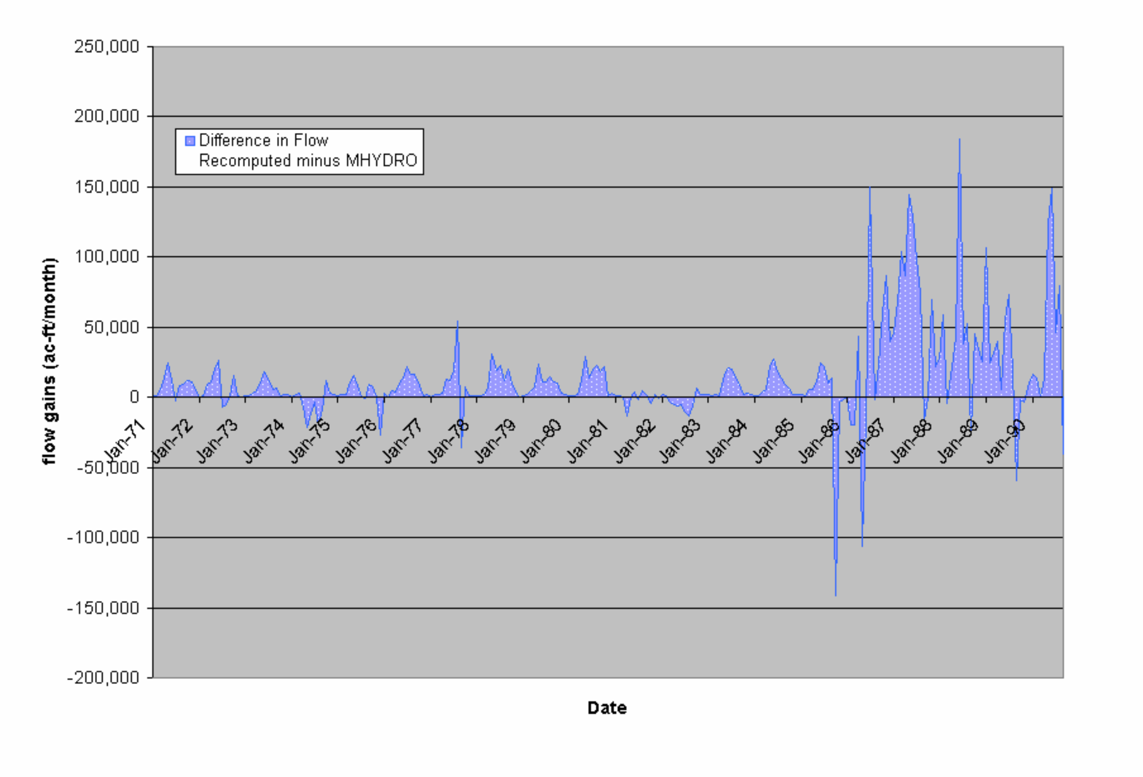


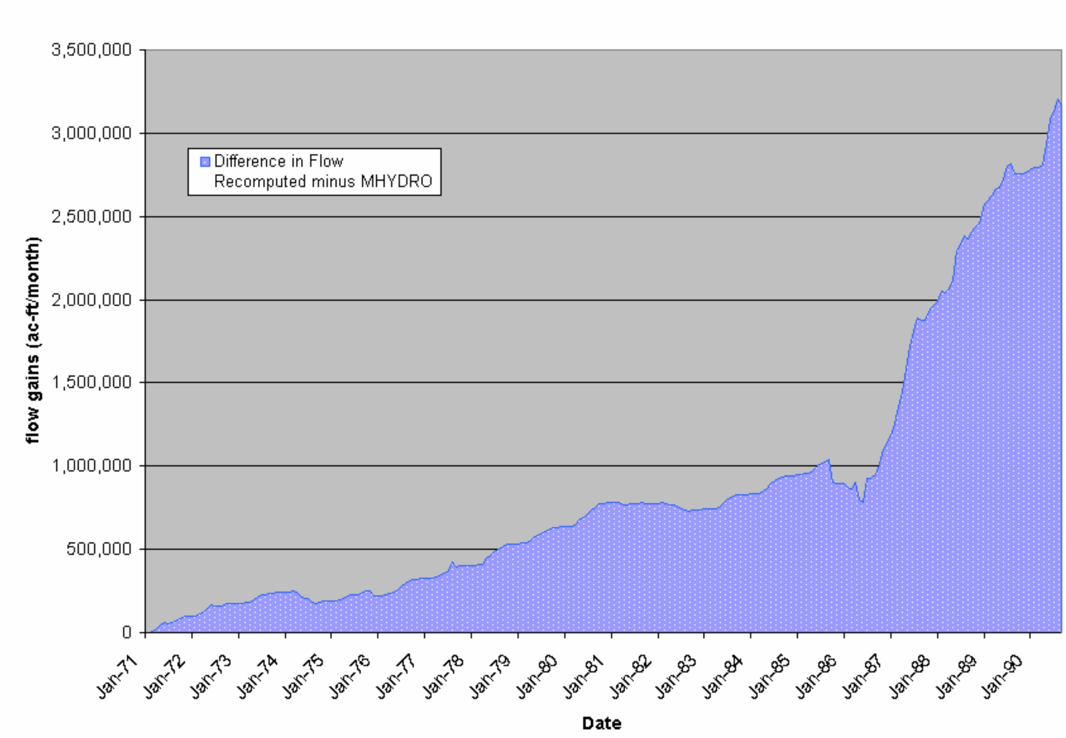

300,000
200,000
100,000
0
-100,000
-200,000
-300,000
-400,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date


500,000
0
-500,000
-1,000,000
-1,500,000
-2,000,000
-2,500,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Date

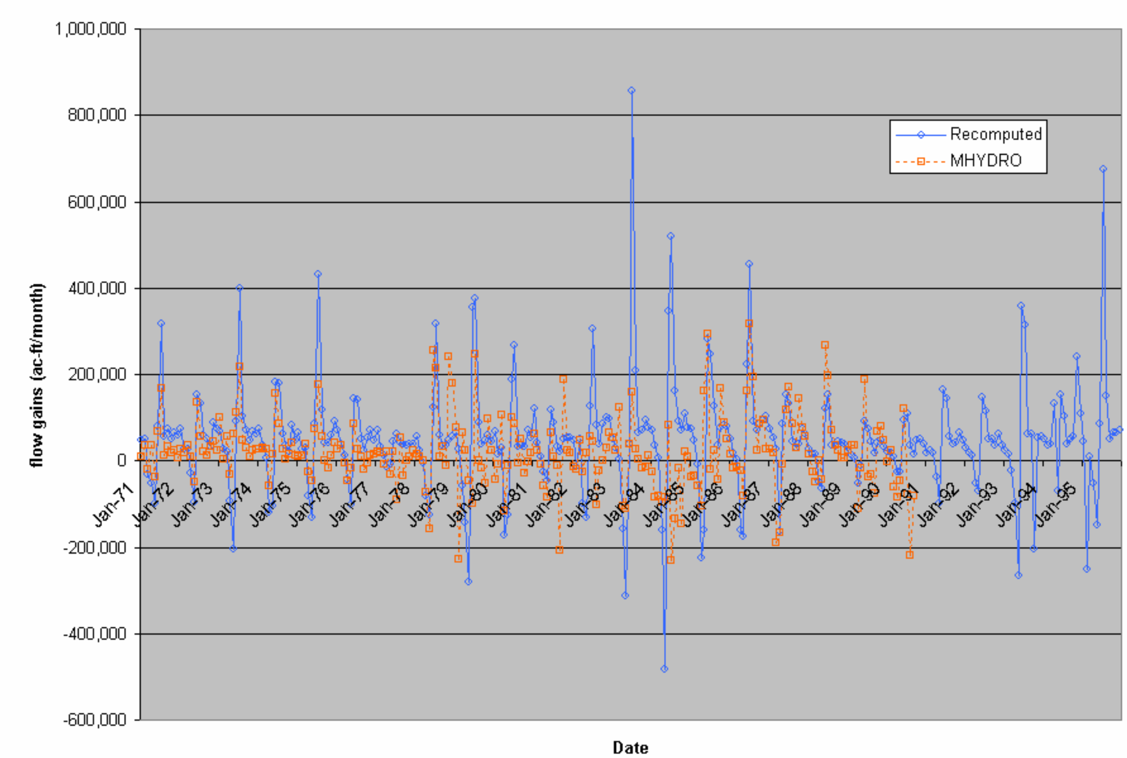
San Juan River near Archuletta to San Juan River near Bluff

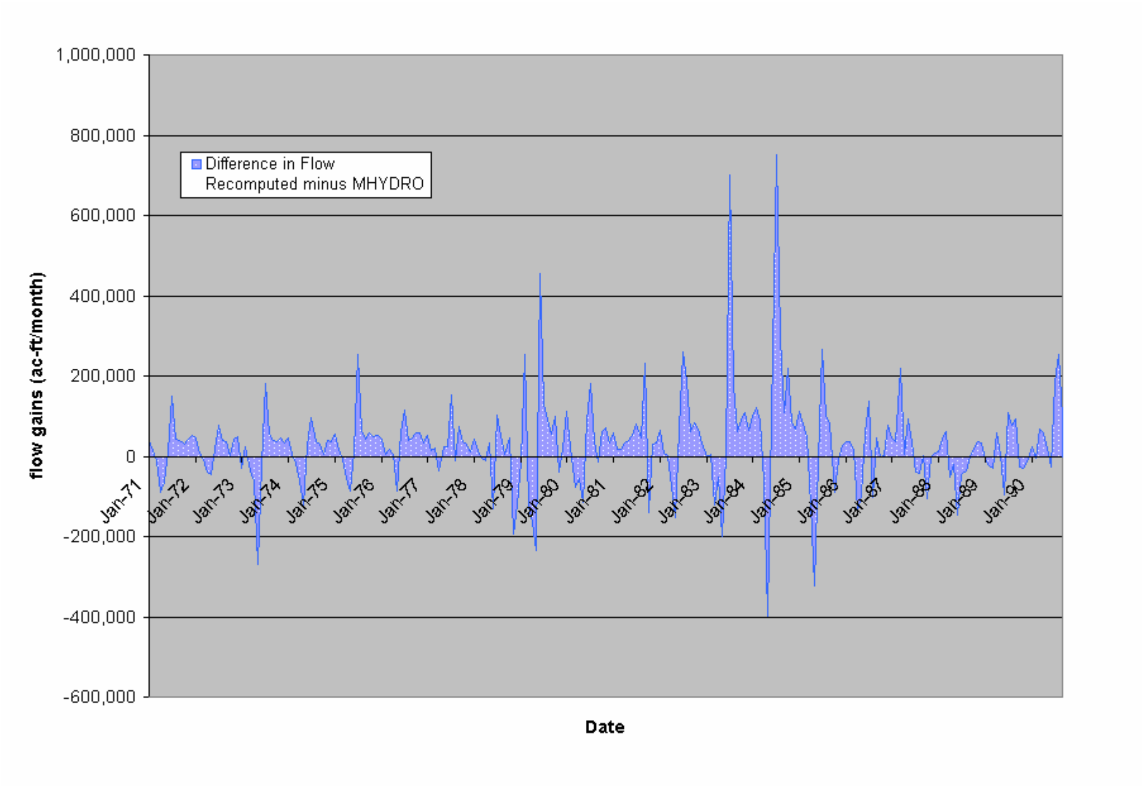




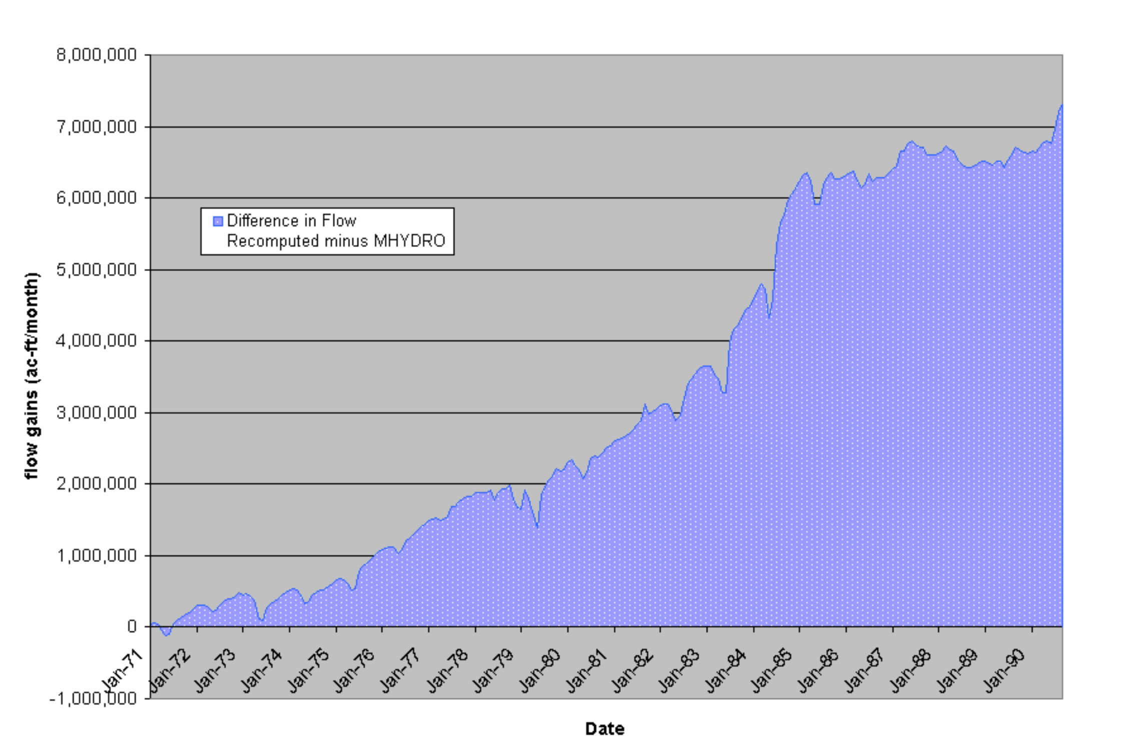


Reach above Colorado River at Lees Ferry





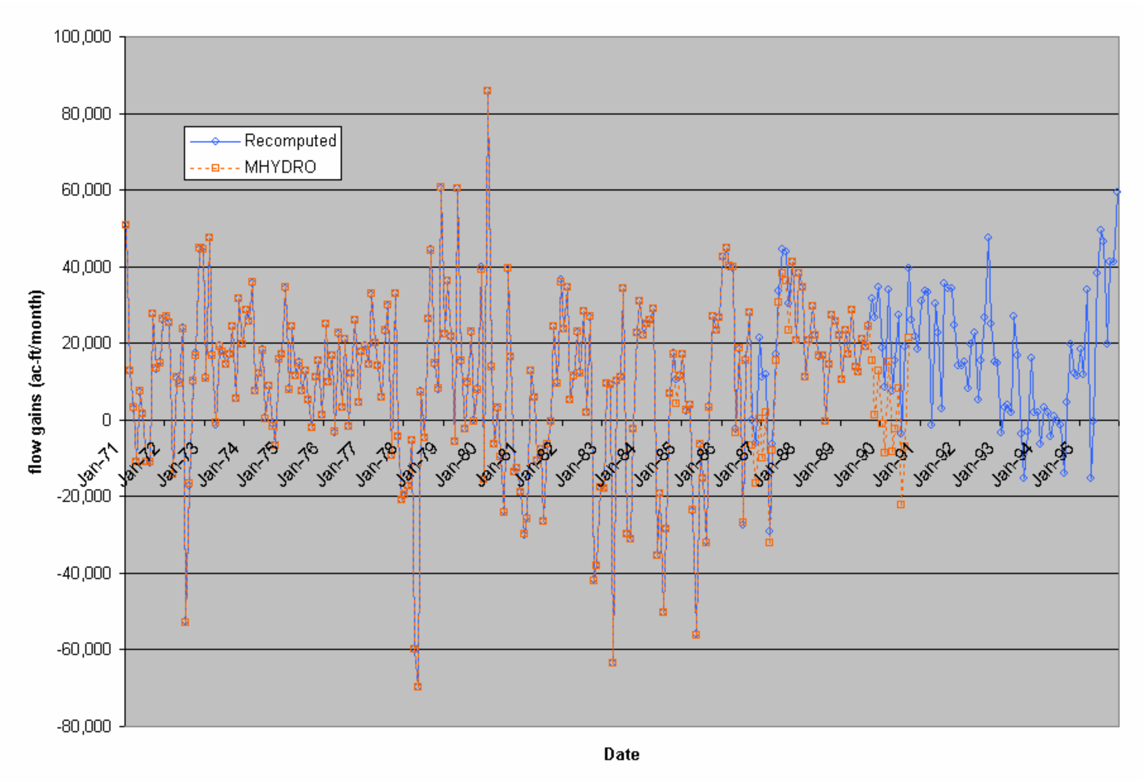
1,000,000
800,000
600,000
400,000
200,000
0
-200,000
-400,000
-600,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71 Jan-72 Jan-73 Jan-74 Jan-75 Jan-76 Jan-77 Jan-78 Jan-79 Jan-80 Jan-81 Jan-82 Jan-83 Jan-84 Jan-85 Jan-86 Jan-87 Jan-88 Jan-89 Jan-90
Date

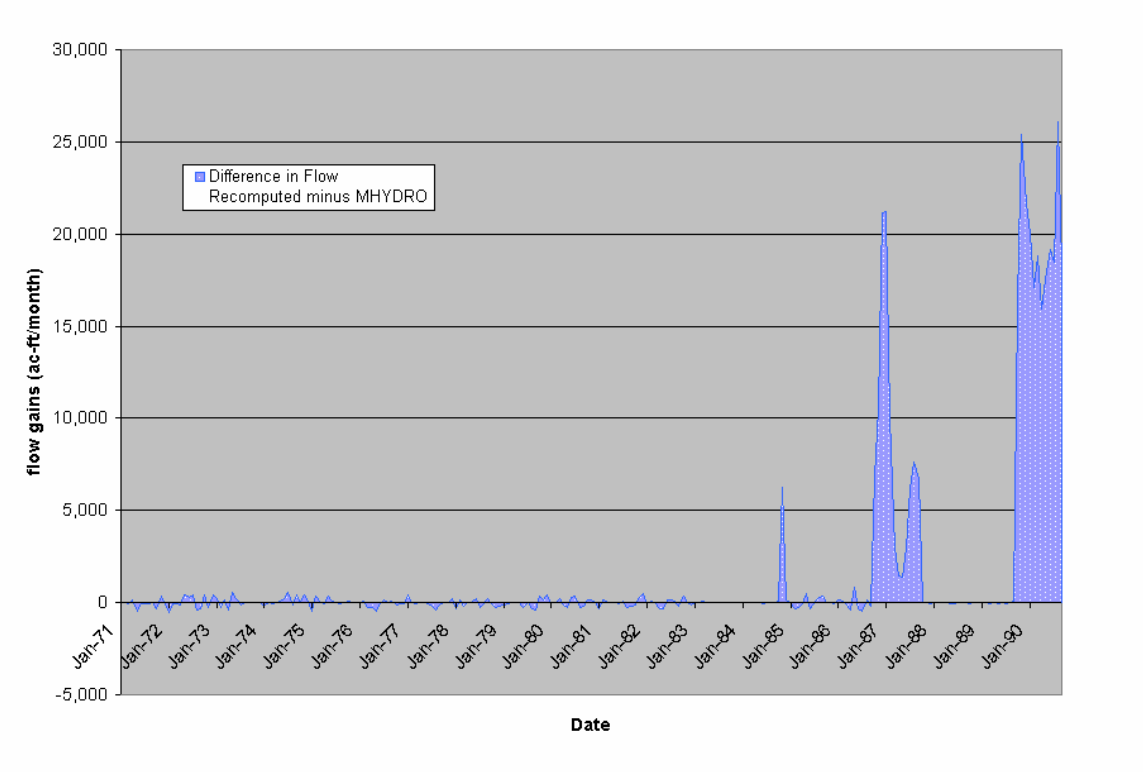


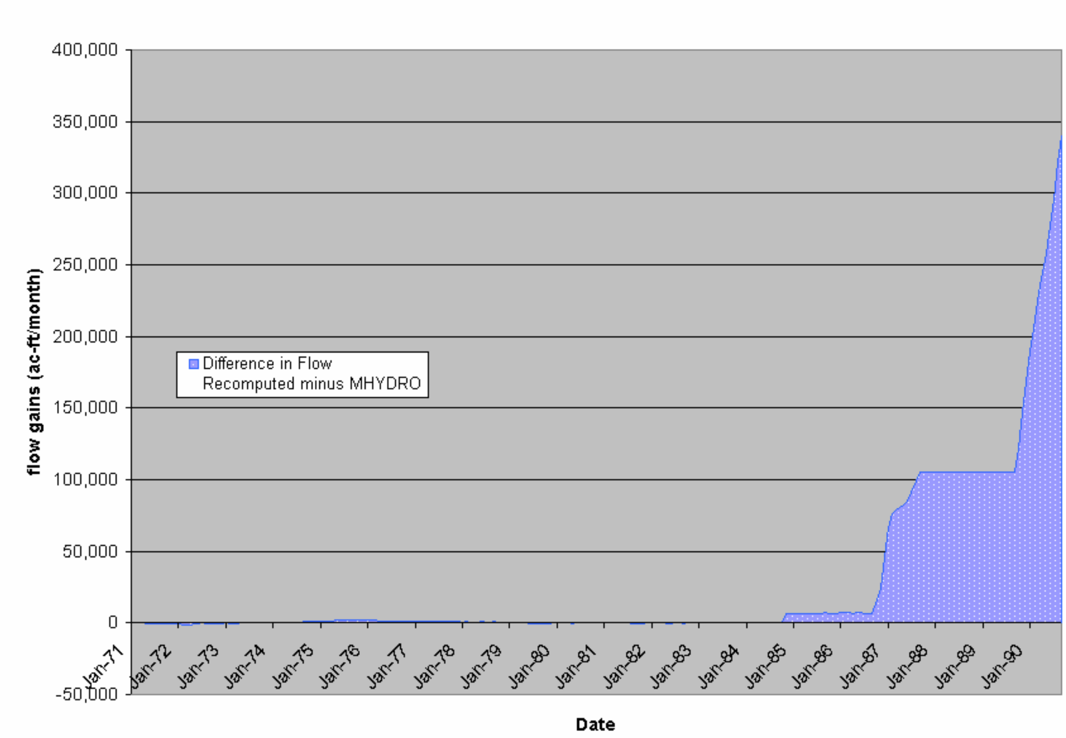
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
-1,000,000
flow gains (ac-ft/month)
Difference in Flow
Recomputed minus MHYDRO
Jan-71 Jan-72 Jan-73 Jan-74 Jan-75 Jan-76 Jan-77 Jan-78 Jan-79 Jan-80 Jan-81 Jan-82 Jan-83 Jan-84 Jan-85 Jan-86 Jan-87 Jan-88 Jan-89 Jan-90
Date

Lower Basin

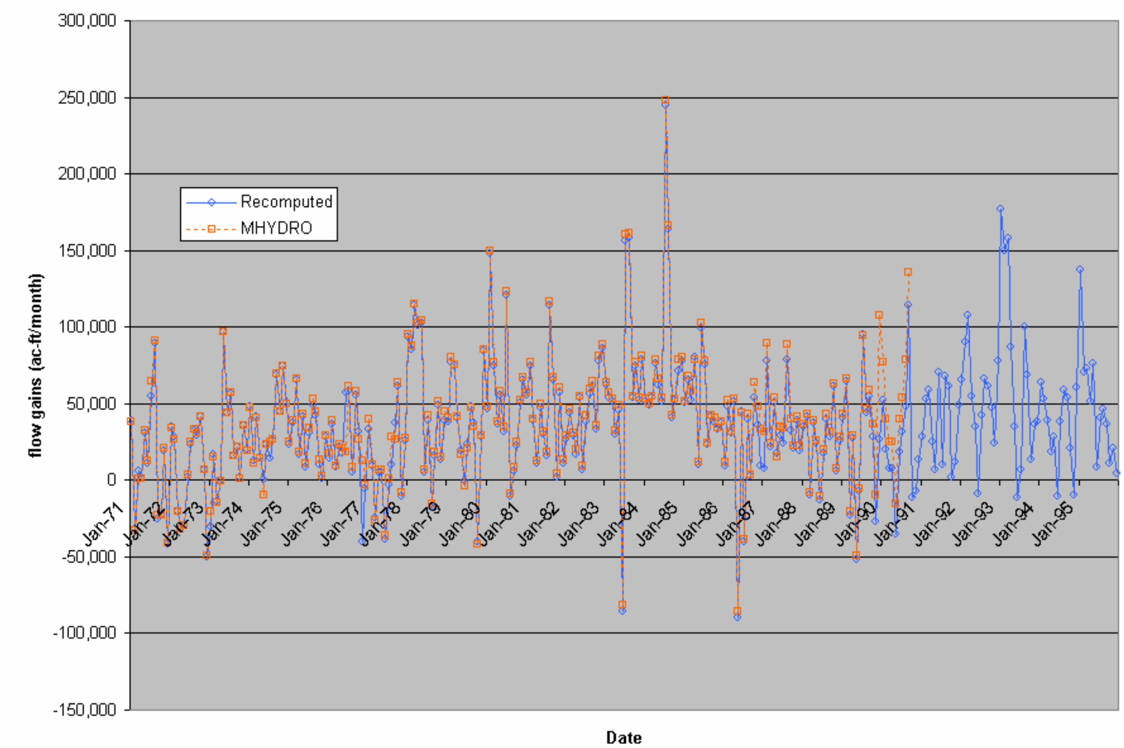
Colorado River at Lees Ferry to Colorado River near Grand Canyon Reach

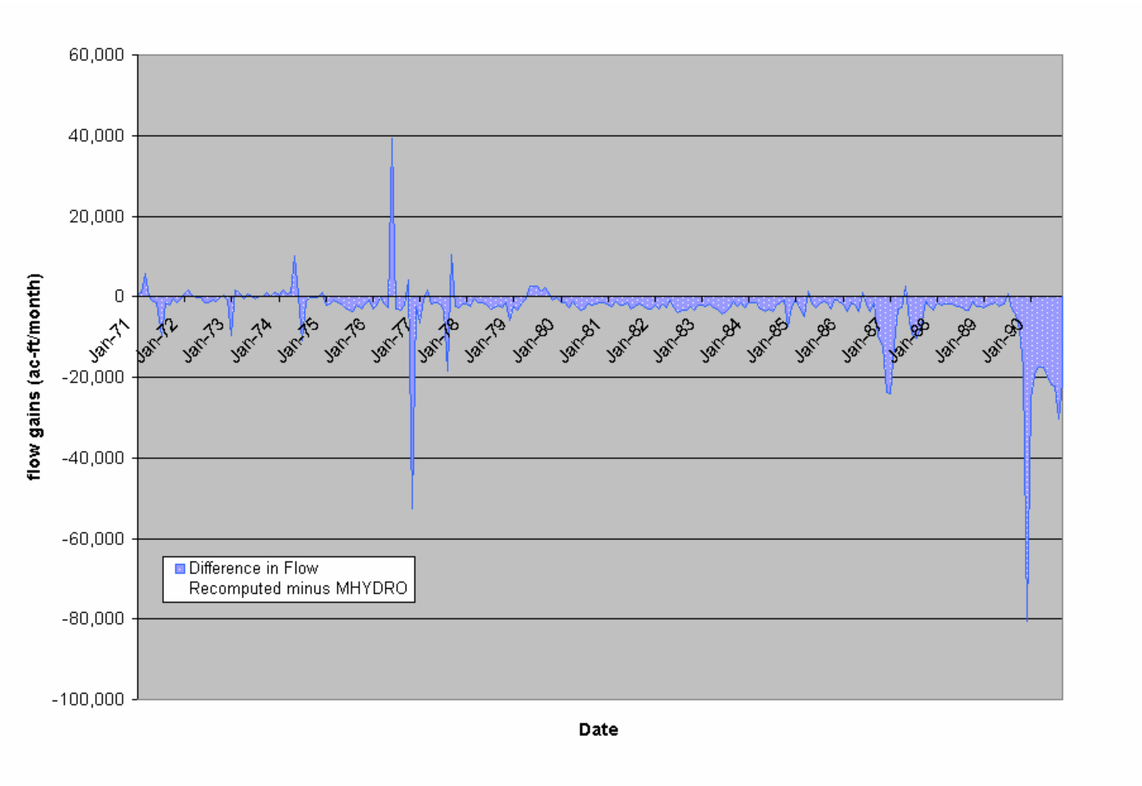




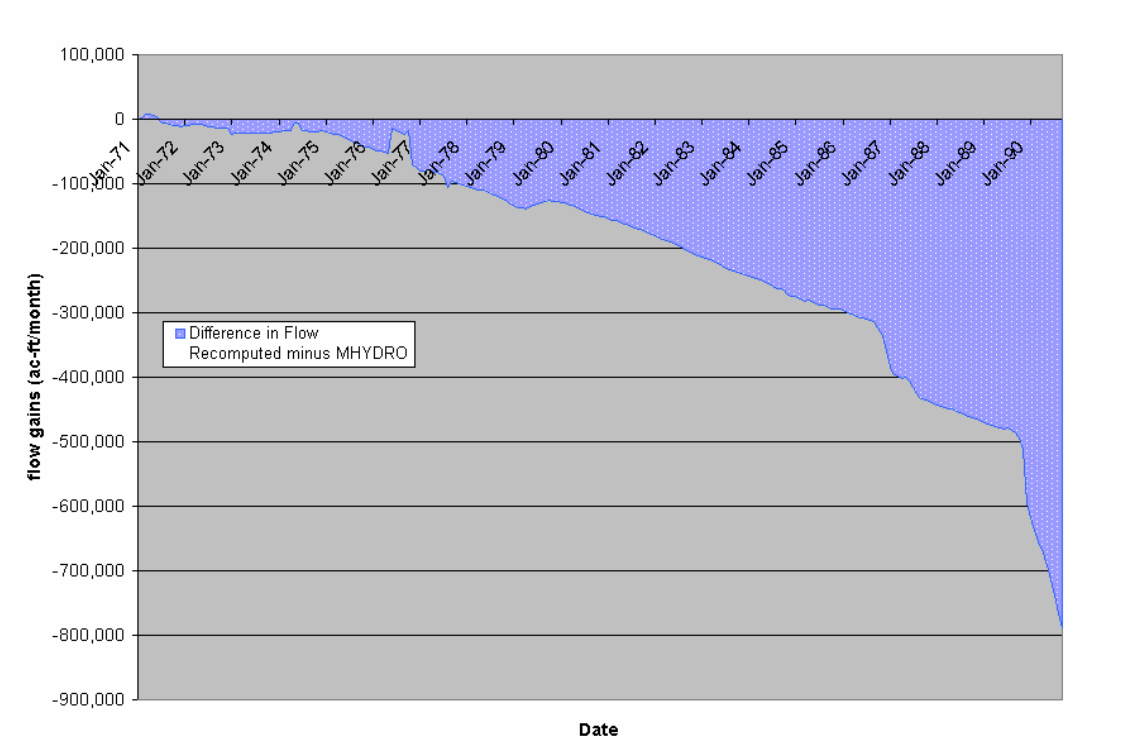


Colorado River near Grand Canyon to Colorado River below Hoover Dam Reach



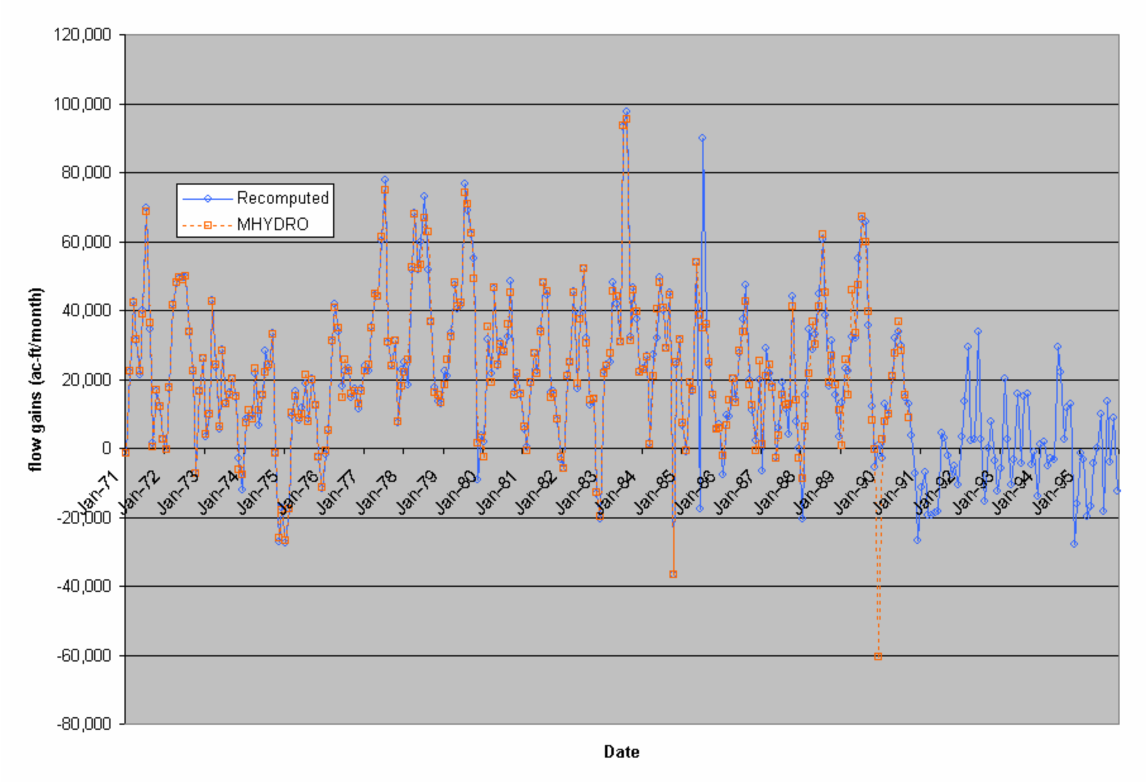


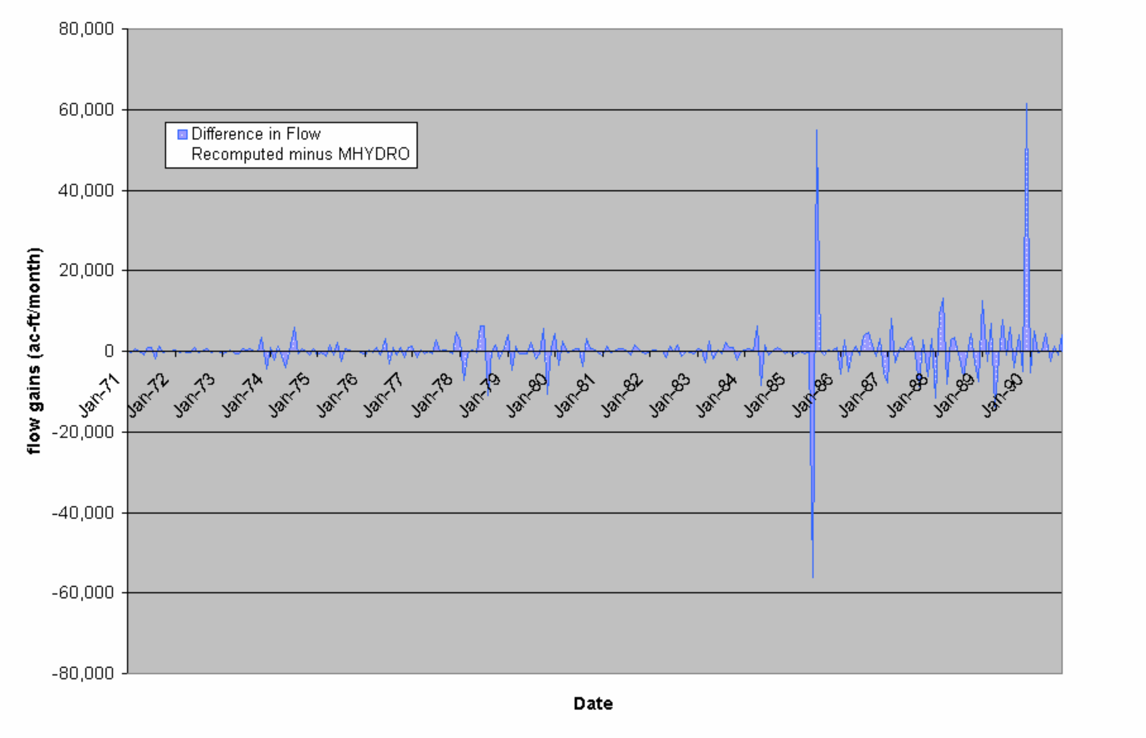
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow
Recomputed minus MHYDRO
Date

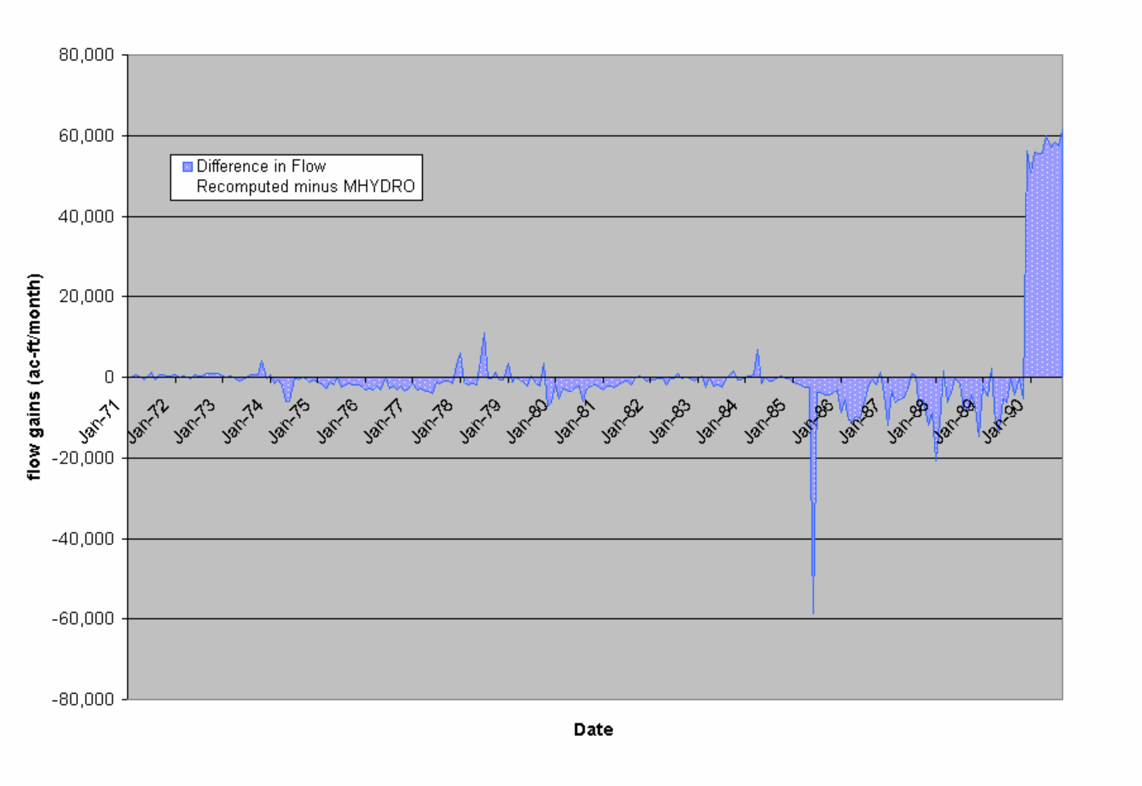


100,000
0
-100,000
-200,000
-300,000
-400,000
-500,000
-600,000
-700,000
-800,000
-900,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow
Recomputed minus MHYDRO
Date

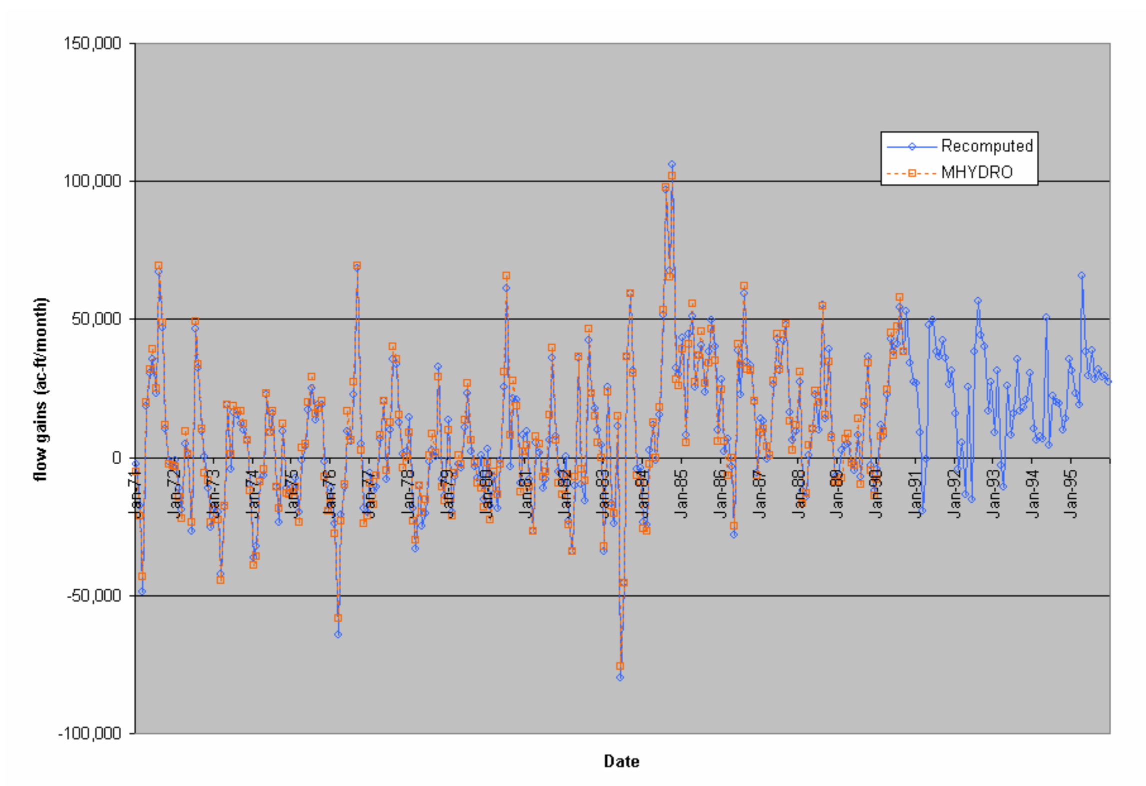
Colorado River below Hoover Dam to Colorado River below Davis Dam Reach

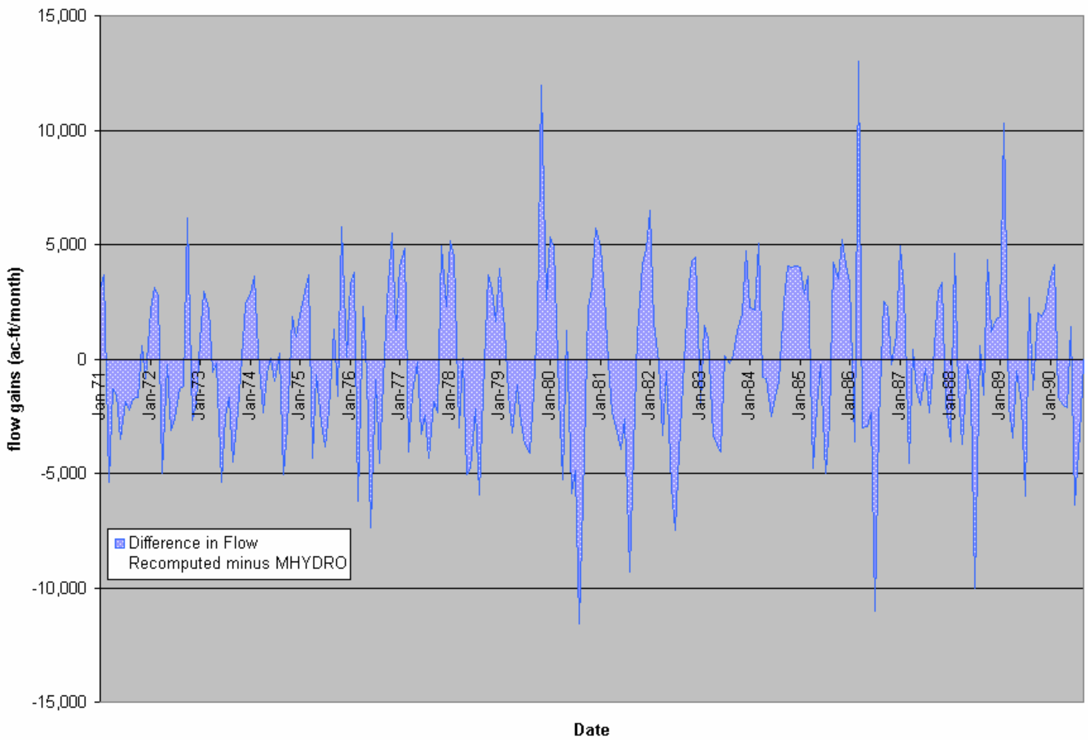




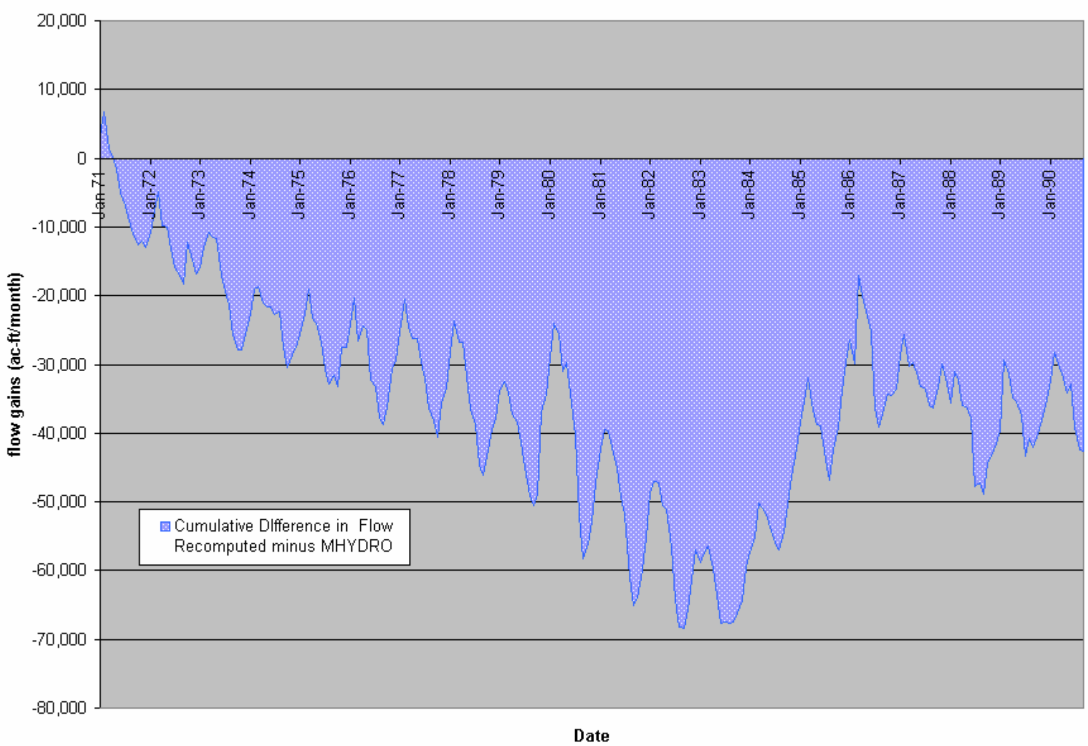


Colorado River below Davis Dam to Colorado River below Parker Reach



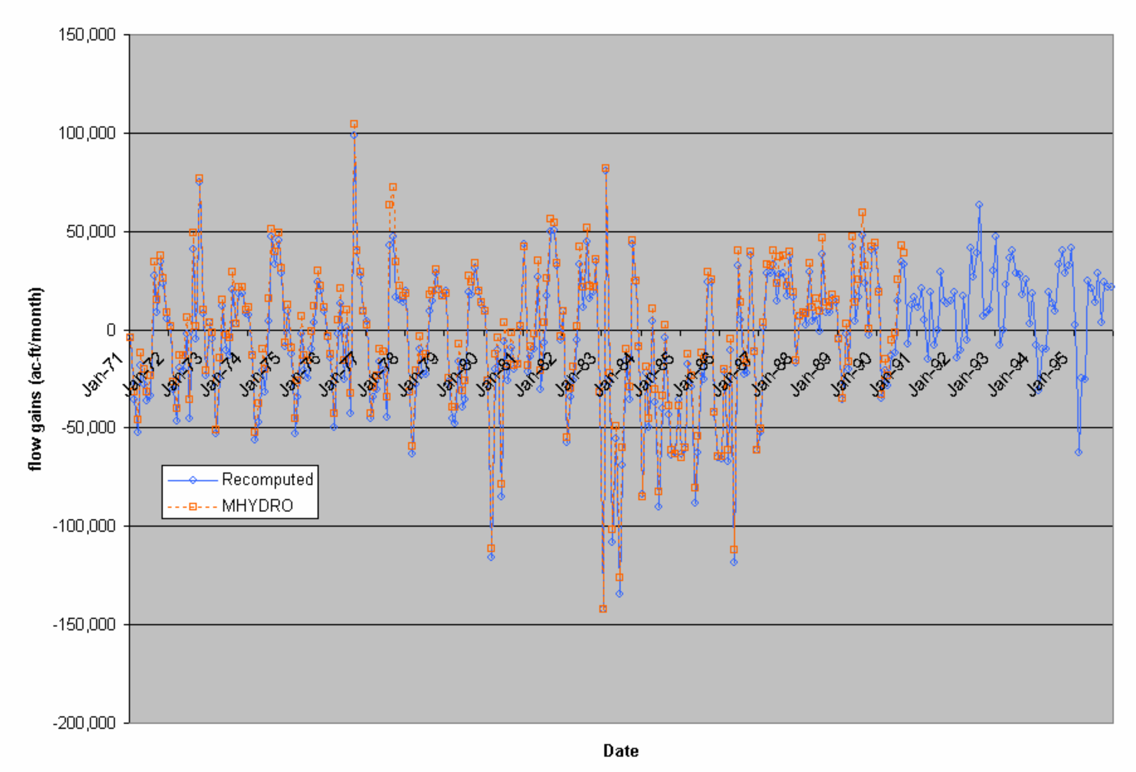


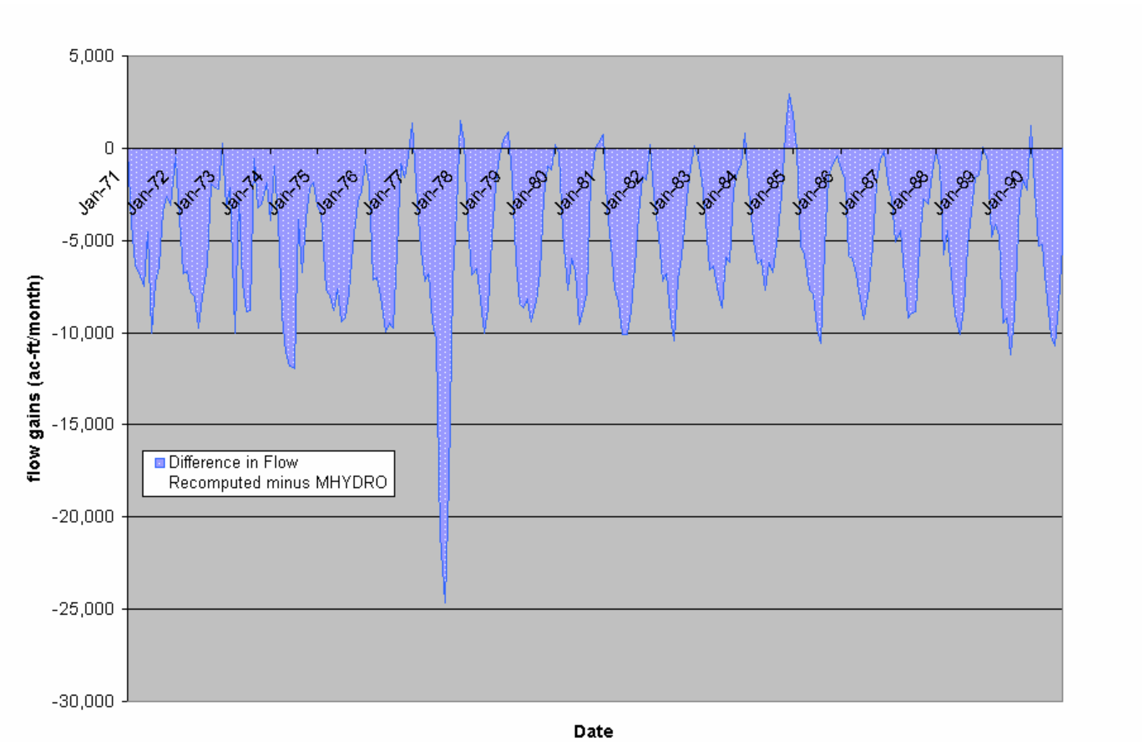
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow
Recomputed minus MHYDRO
Date

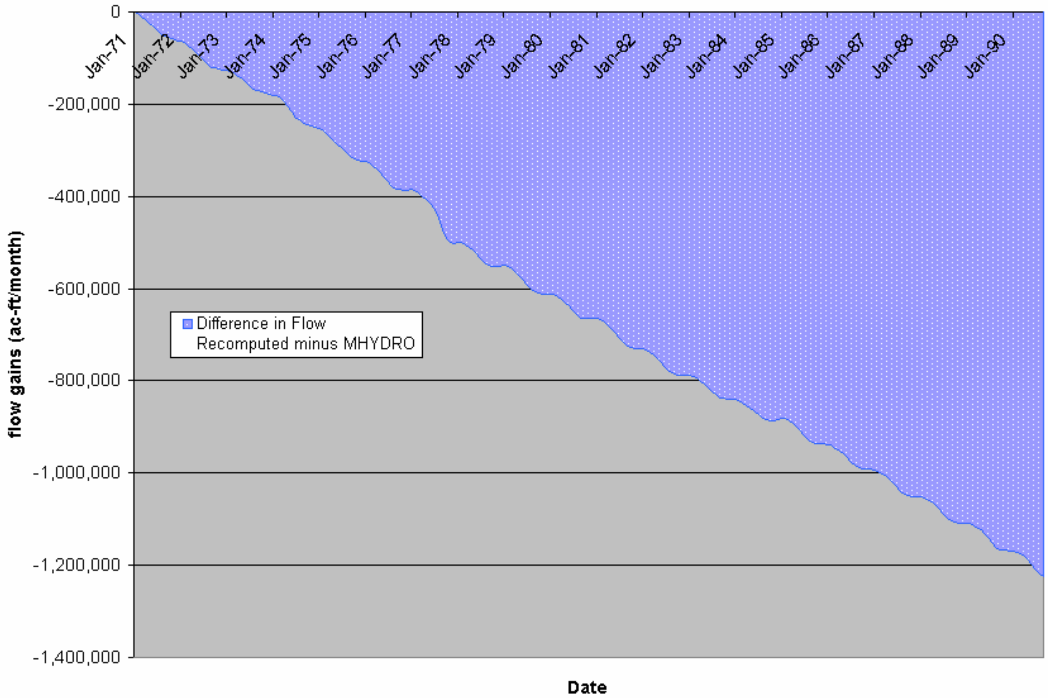


20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
-60,000
-70,000
-80,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Cumulative DIfference in Flow
Recomputed minus MHYDRO
Date

Colorado River below Parker Dam to Colorado River above Imperial Reach







0
-200,000
-400,000
-600,000
-800,000
-1,000,000
-1,200,000
-1,400,000
flow gains (ac-ft/month)
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Difference in Flow Recomputed minus MHYDRO
Date

Appendix C: Upper Basin Salt Model Regressions

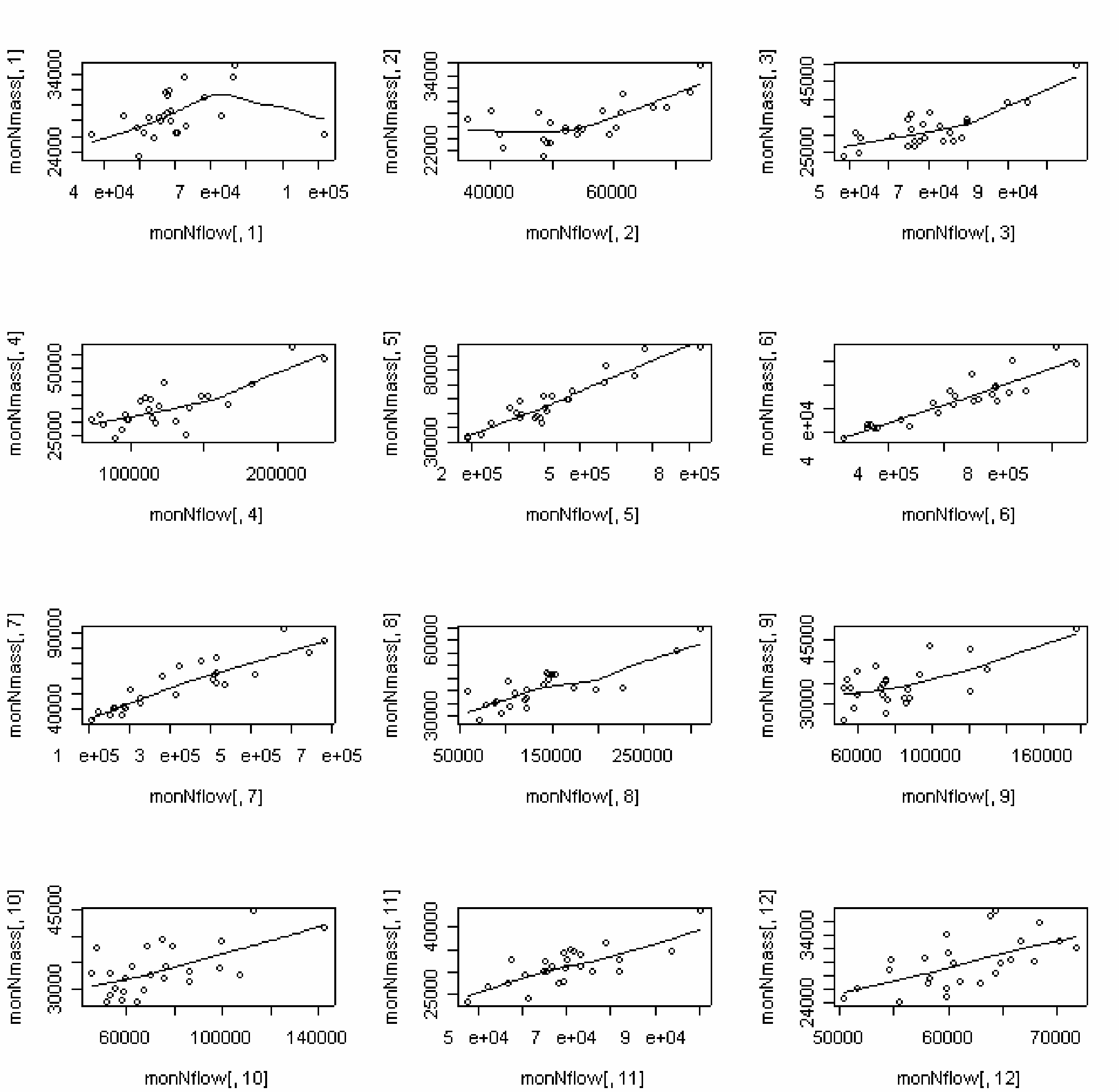


Figure 10. Monthly regression relationships for Colorado River at Glenwood Springs, Colorado

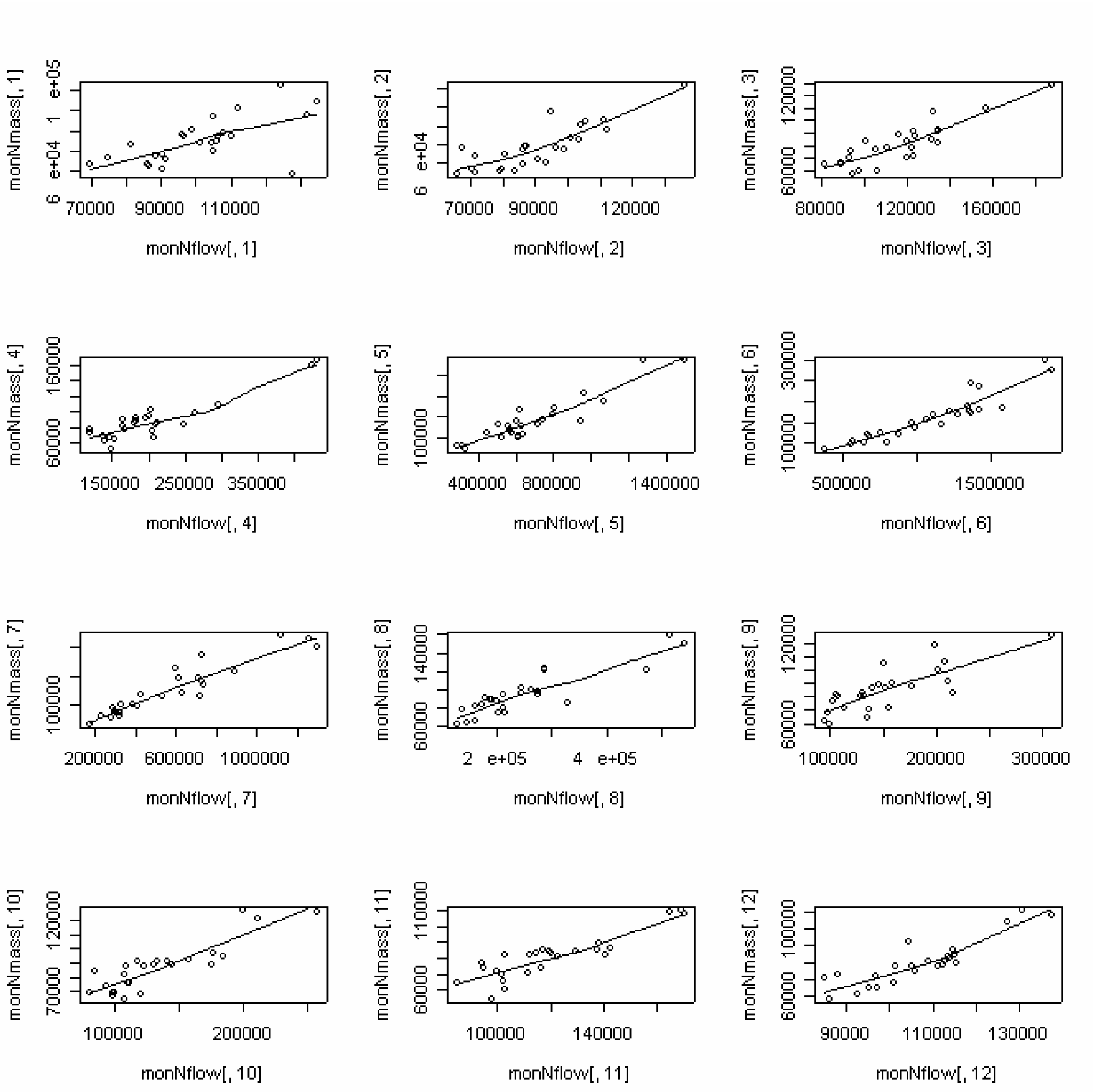


Figure 11. Monthly regression relationships for Colorado River near Cameo, Colorado

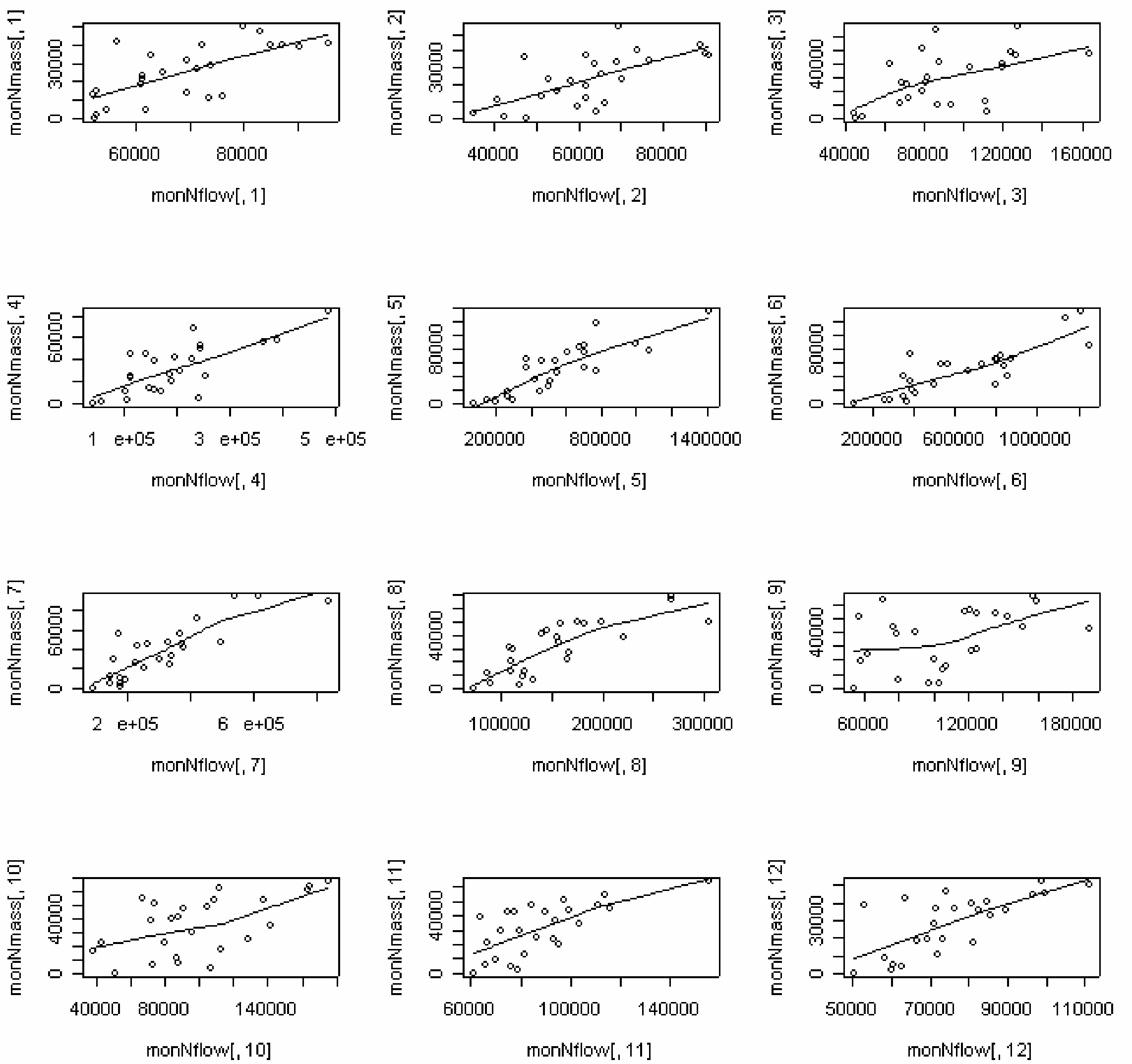


Figure 12. Monthly regression relationships for Colorado River near Grand Junction, Colorado

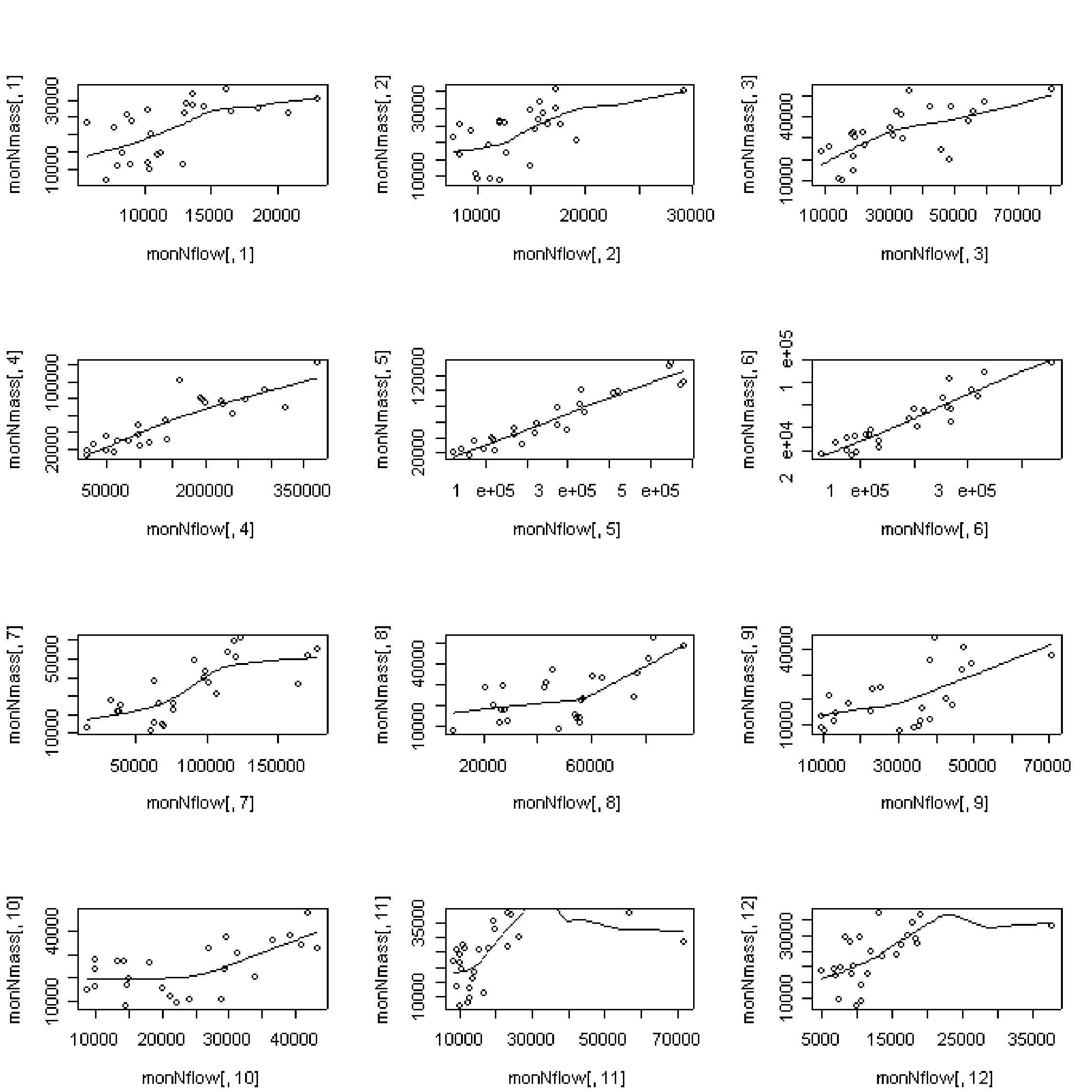


Figure 13. Monthly regression relationships for Dolores River near Cisco, Utah

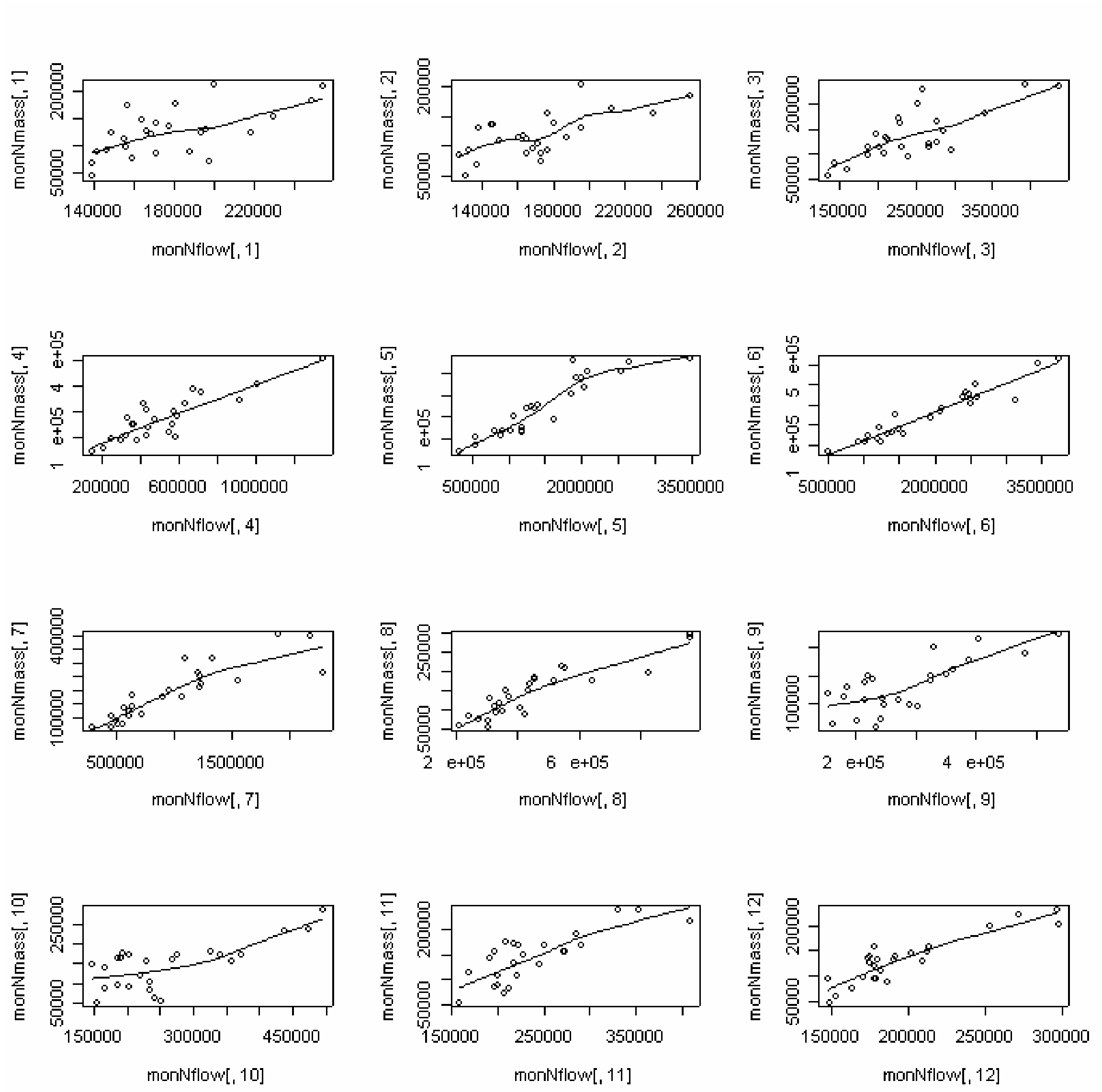


Figure 14. Monthly regression relationships for Colorado River near Cisco, Utah

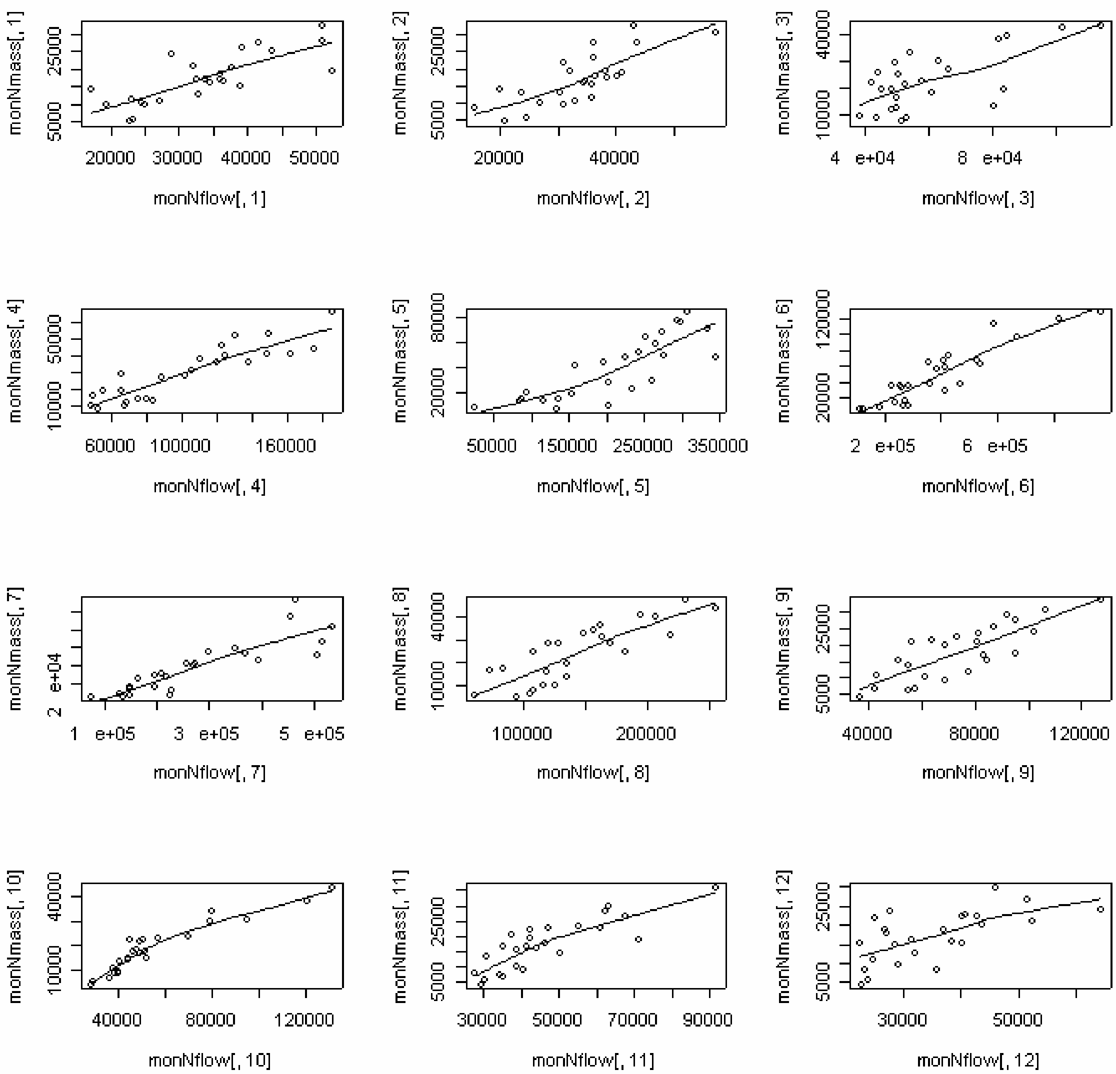


Figure 15. Monthly regression relationships for Green River near Green River, Wyoming

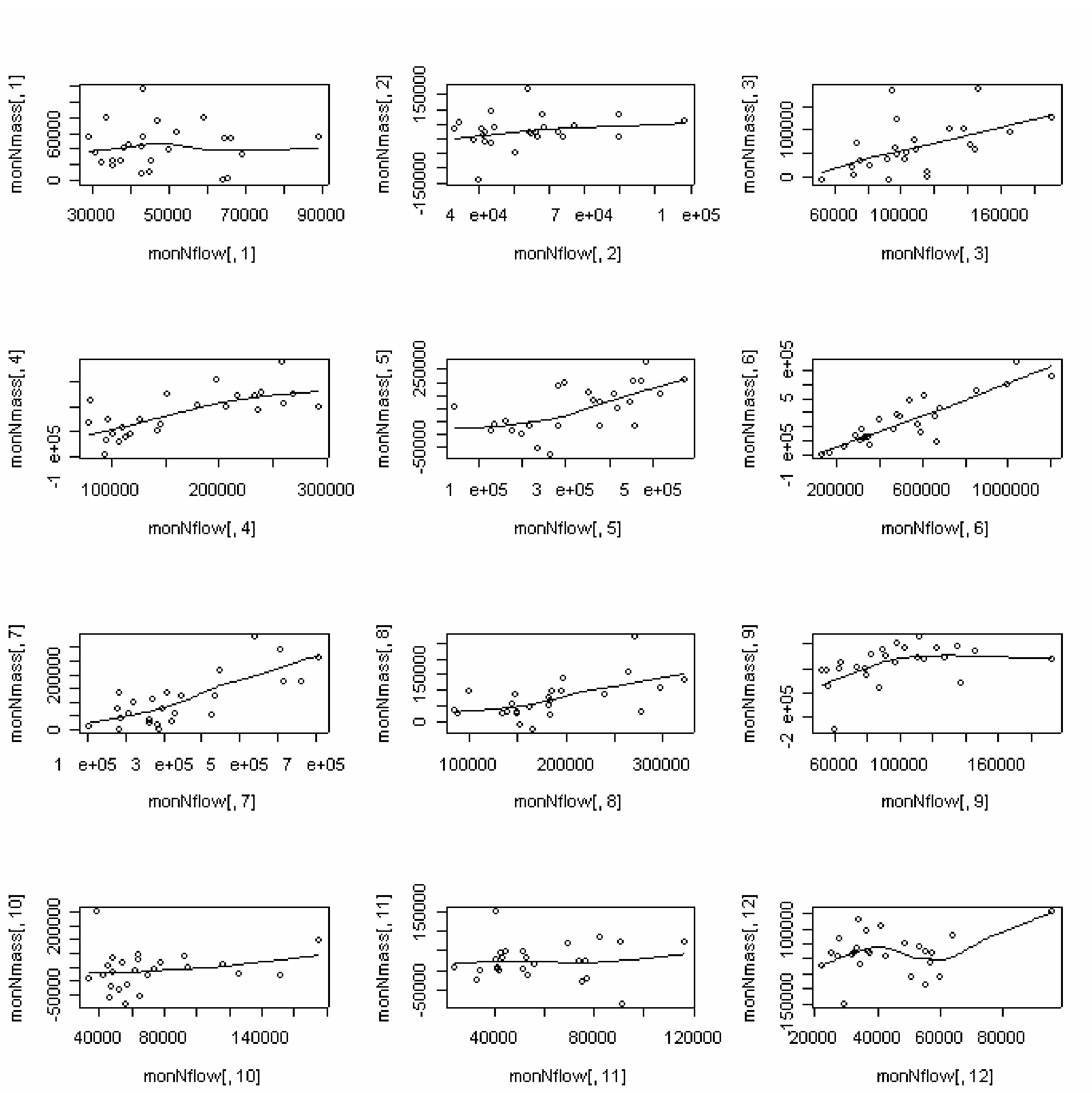


Figure 16. Monthly regression relationships for Green River near Greendale, Utah

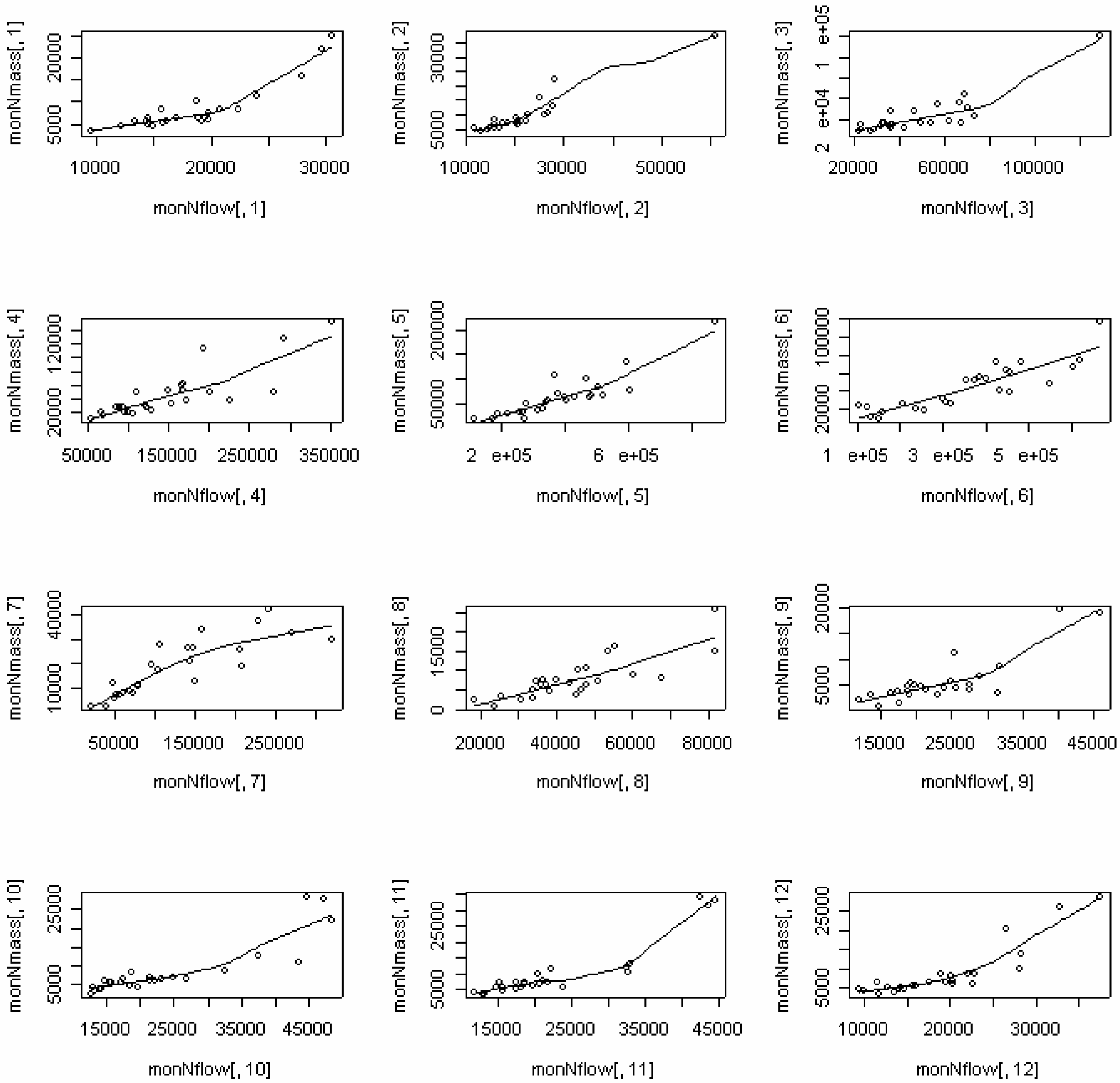


Figure 17. Monthly regression relationships for Yampa River near Maybell, Colorado

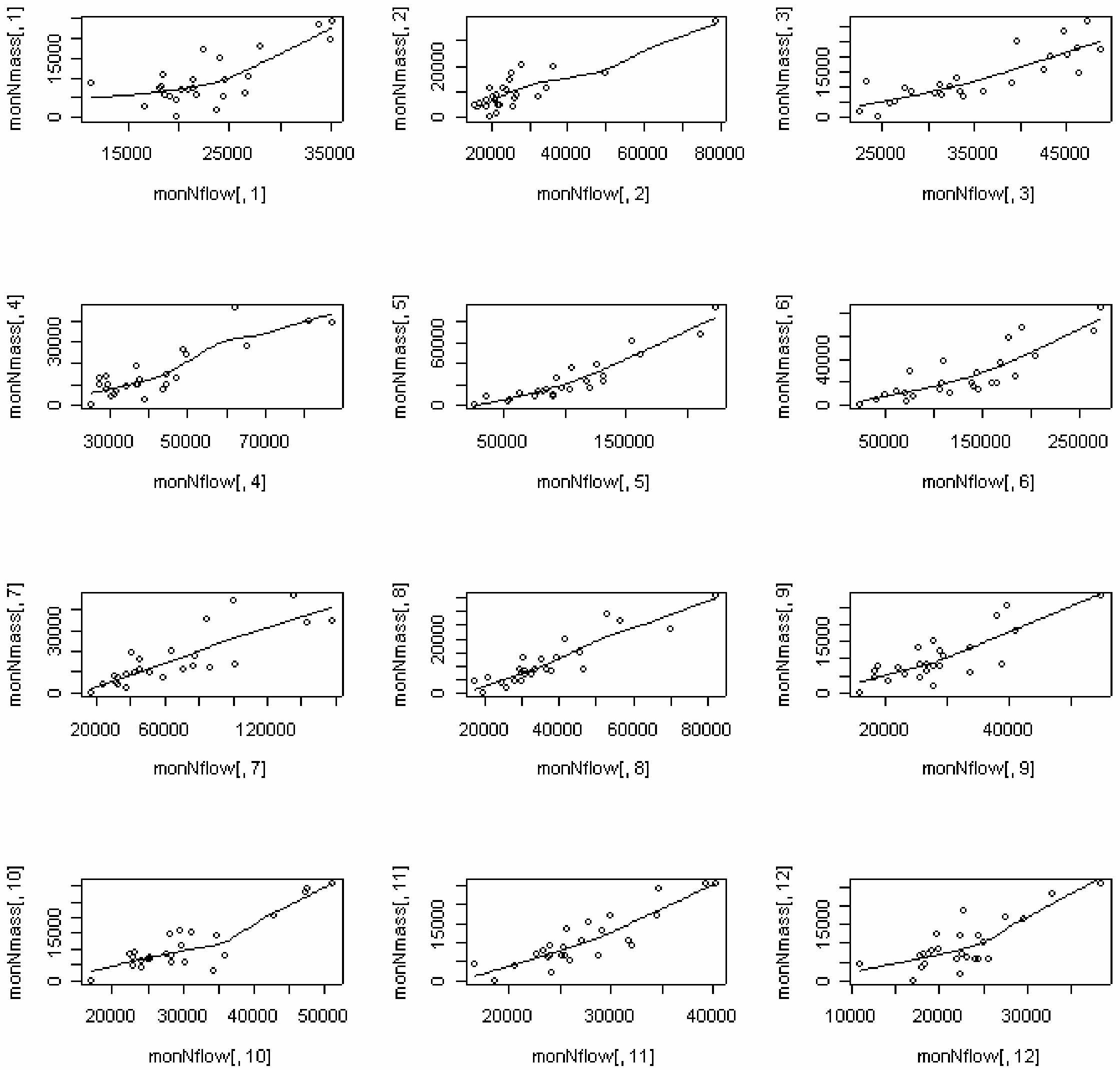


Figure 18. Monthly regression relationships for White River near Watson, Utah

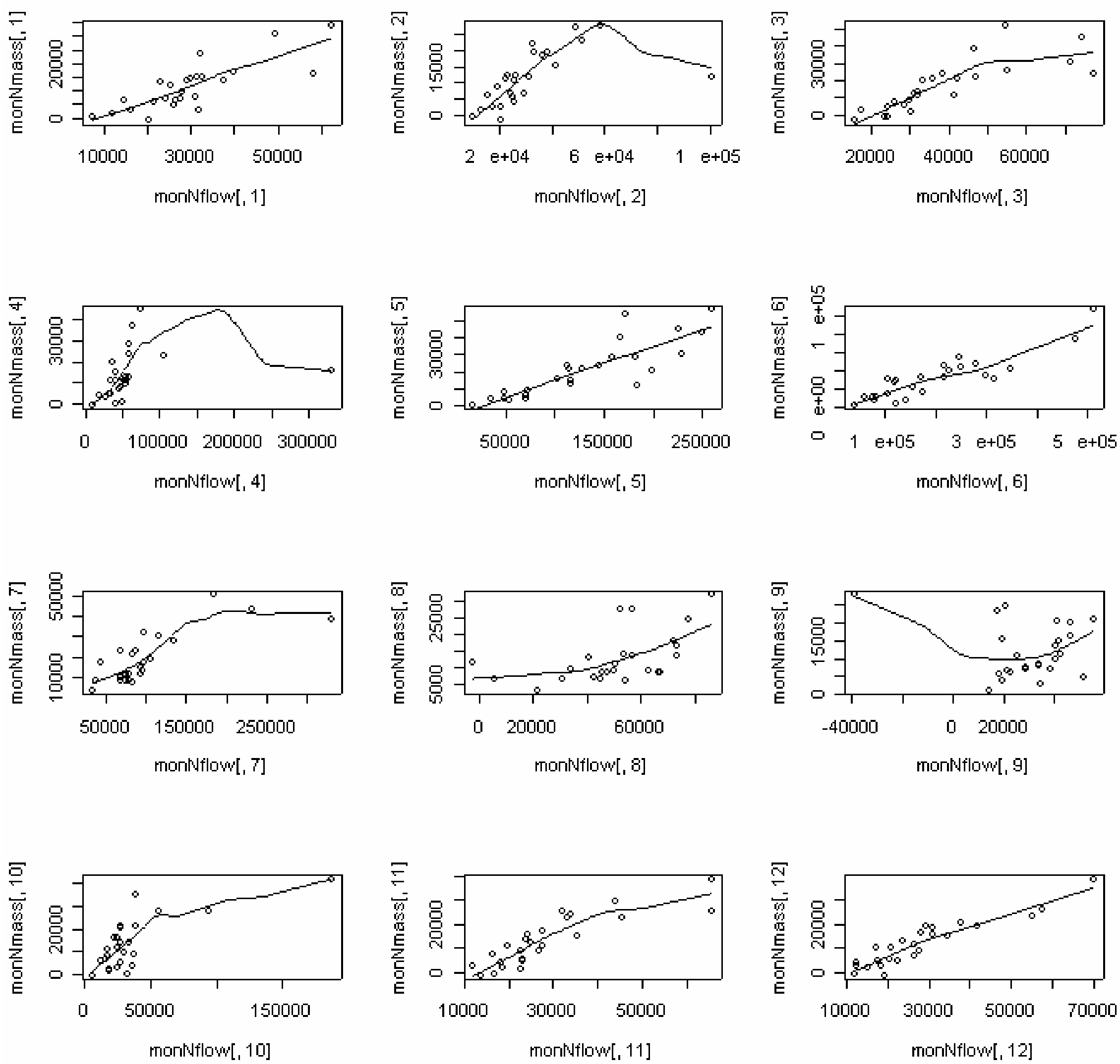


Figure 19. Monthly regression relationships for Duchesne River near Randlett, Utah

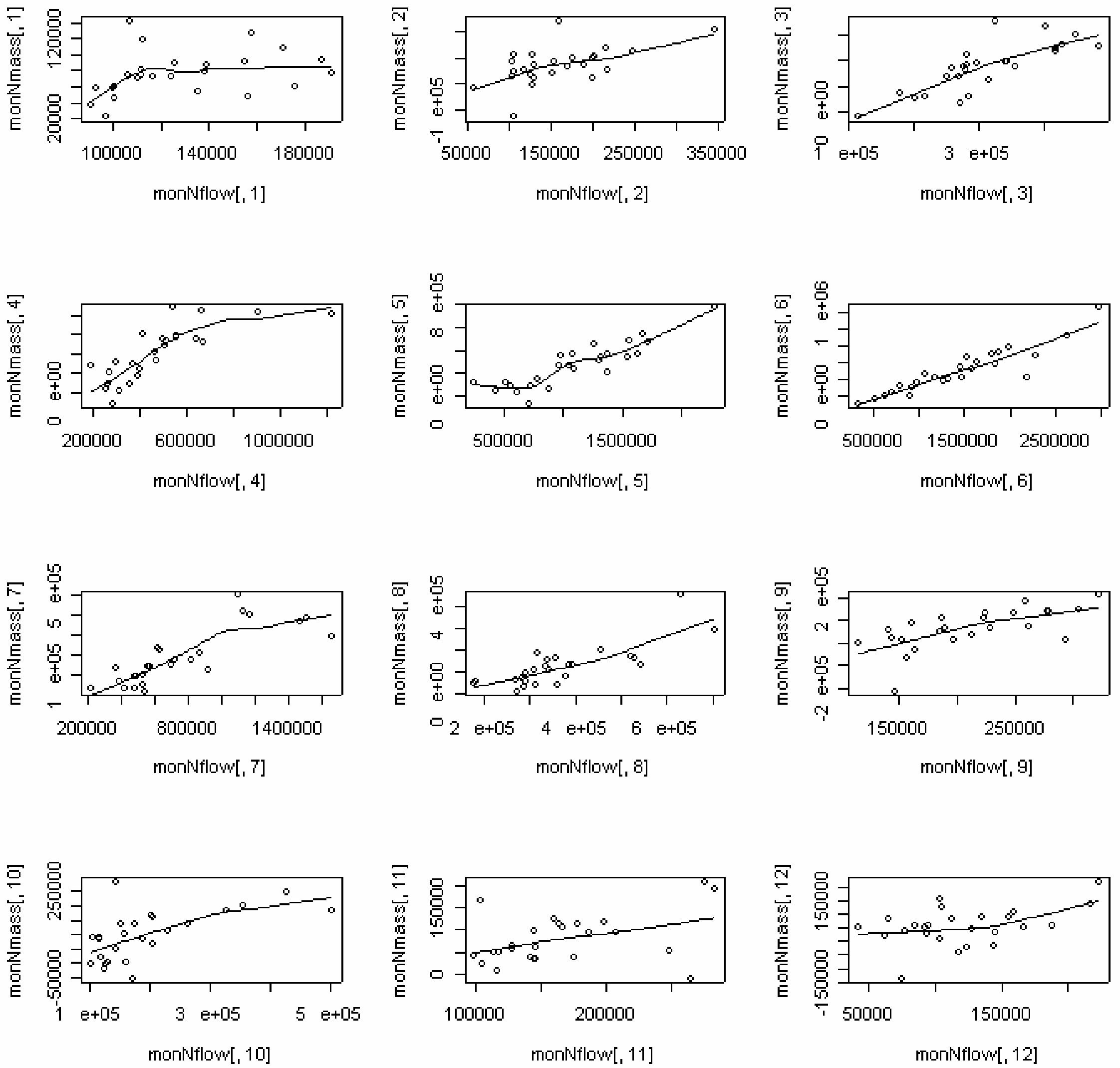


Figure 20. Monthly regression relationships for Green River at Green River, Utah

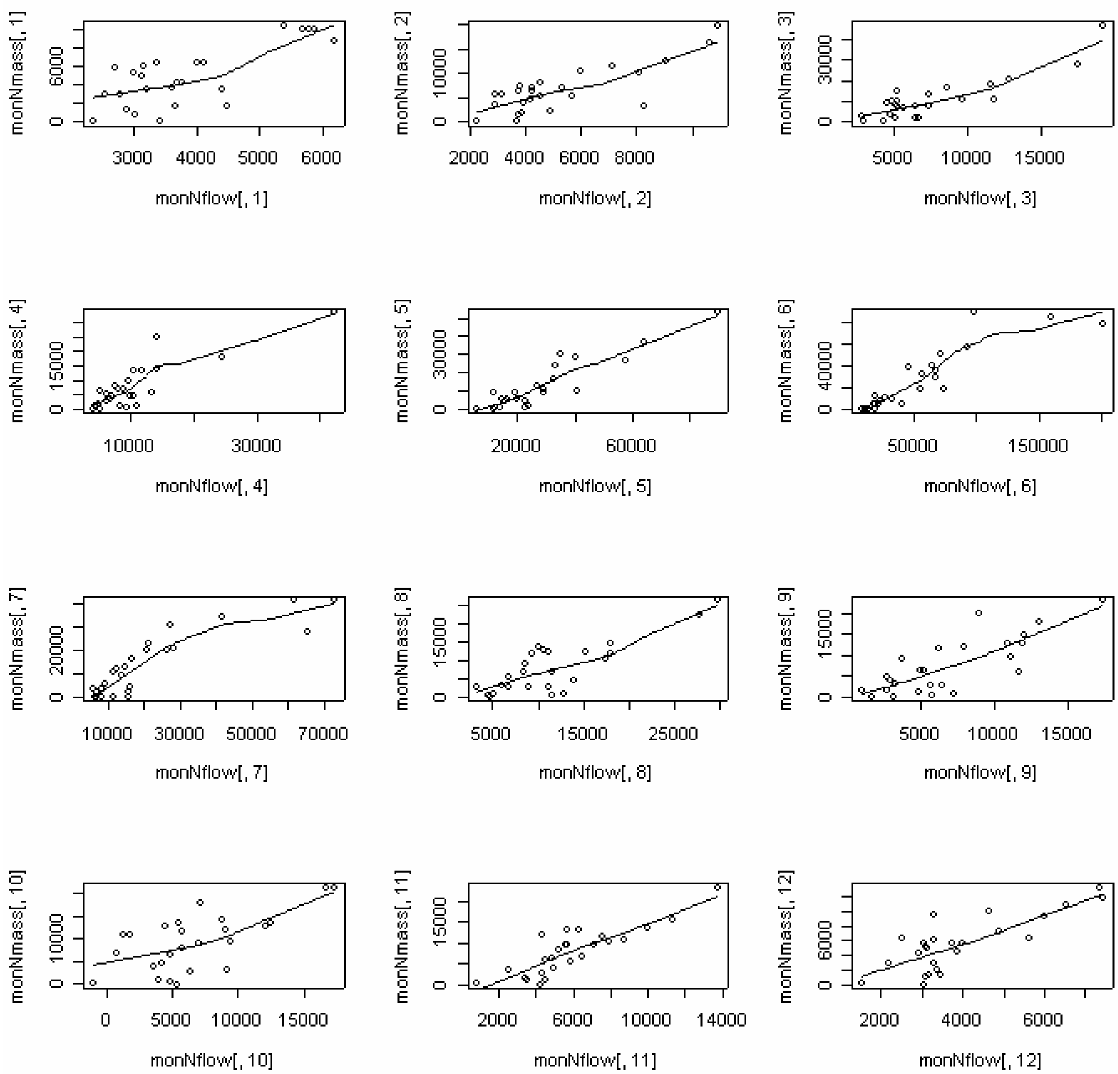


Figure 21. Monthly regression relationships for San Rafael River near Green River, Utah

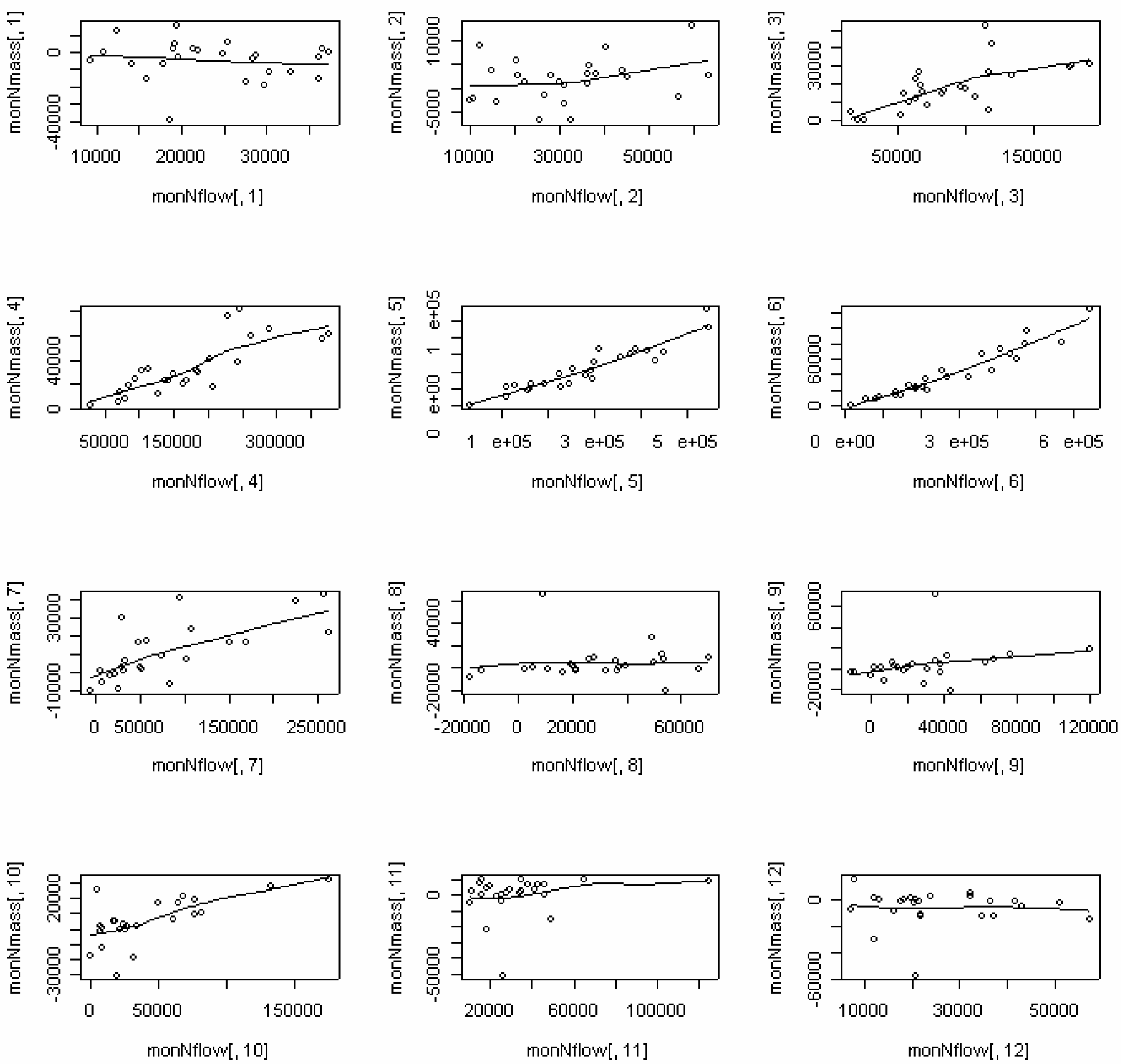


Figure 22. Monthly regression relationships for San Juan River near Archuletta, New Mexico

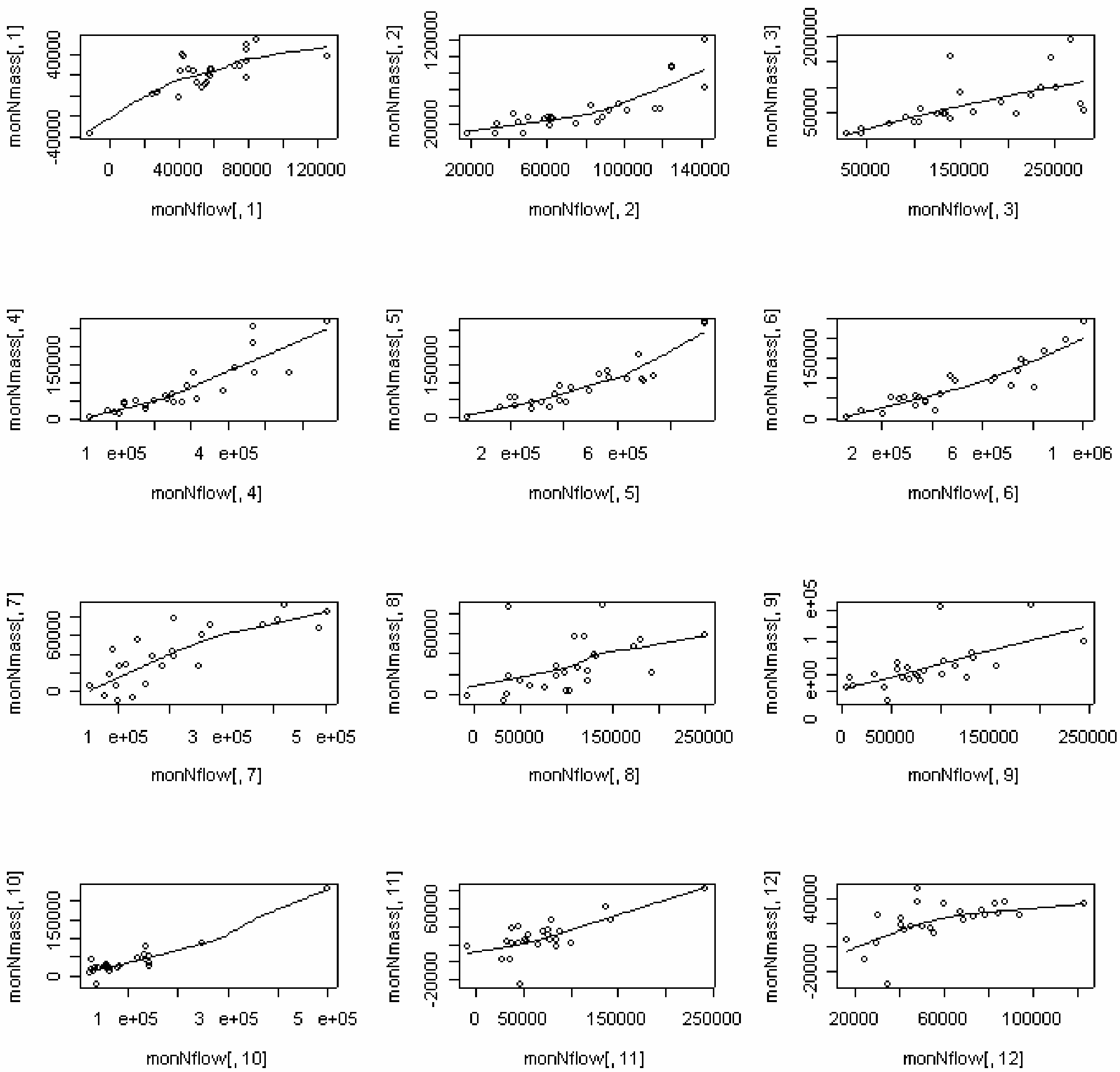


Figure 23. Monthly regression relationships for San Juan River near Bluff, Utah

Appendix D: Lower Basin Decree Users Above Imperial Dam

Name of Decree User	Datatype	SDID
AbvLakeMeadNRA:LakeMeadNV	Depletion Requested	3287
AbvLakeMeadNRA:LakeMeadNV	Diversion Requested	3009
AbvLakeMeadNRA:TempleBarAZ	Depletion Requested	3139
AbvLakeMeadNRA:TempleBarAZ	Diversion Requested	2899
AdditionalDecreeDiversions:BigBendWaterDistrict	Depletion Requested	3021
AdditionalDecreeDiversions:BigBendWaterDistrict	Diversion Requested	3019
AdditionalDecreeDiversions:BullheadCity	Depletion Requested	2902
AdditionalDecreeDiversions:BullheadCity	Diversion Requested	3148
AdditionalDecreeDiversions:GoldenShoresWaterConservationDist	Depletion Requested	3163
AdditionalDecreeDiversions:GoldenShoresWaterConservationDist	Diversion Requested	2909
AdditionalDecreeDiversions:MohaveWaterConservation	Depletion Requested	3151
AdditionalDecreeDiversions:MohaveWaterConservation	Diversion Requested	2905
AdditionalDiversion:CibolaValleyIrrigationDistrict	Depletion Requested	3187
AdditionalDiversion:CibolaValleyIrrigationDistrict	Diversion Requested	2920
AdditionalDiversion:EhrenburgImprovementAssn	Depletion Requested	3184
AdditionalDiversion:EhrenburgImprovementAssn	Diversion Requested	2919
Blythe:CityOfBlythe	Depletion Requested	3336
Blythe:CityOfBlythe	Diversion Requested	3333
Blythe:EastBlytheCountyWaterDistrict	Depletion Requested	3340
Blythe:EastBlytheCountyWaterDistrict	Diversion Requested	3337
BrookeConsolidatedWaterUtilities	Total Depletion Requested	3178
BrookeConsolidatedWaterUtilities	Total Diversion Requested	2906
CAPDiversion	Total Depletion Requested	3172
CAPDiversion	Total Diversion Requested	3132
CityOfNeedlesBenardinoCounty:CityofNeedles	Depletion Requested	2968
CityOfNeedlesBenardinoCounty:CityofNeedles	Diversion Requested	2966
CityOfNeedlesBenardinoCounty:SanBernardinoCounty	Depletion Requested	3332
CityOfNeedlesBenardinoCounty:SanBernardinoCounty	Diversion Requested	3329
ColoradoRiverIndianReservation:ColoradoRiverIndianReservationAZ	Depletion Requested	2918
ColoradoRiverIndianReservation:ColoradoRiverIndianReservationAZ	Diversion Requested	2916
ColoradoRiverIndianReservation:ColoradoRiverIndianReservationCA	Depletion Requested	2975
ColoradoRiverIndianReservation:ColoradoRiverIndianReservationCA	Diversion Requested	3257
FtMohaveReservation:AZ	Depletion Requested	3160
FtMohaveReservation:AZ	Diversion Requested	2908
FtMohaveReservation:CA	Depletion Requested	2970
FtMohaveReservation:CA	Diversion Requested	3245
FtMohaveReservation:NV	Depletion Requested	3316
FtMohaveReservation:NV	Diversion Requested	3022
HavasuNWR:TopockM	Depletion Requested	2913
HavasuNWR:TopockM	Diversion Requested	3164
LCRDDavisDam	Total Depletion Requested	3141
LCRDDavisDam	Total Diversion Requested	2901
LakeHavasuIDDChemhueveIndianRes:ChemhueveIndianRes	Depletion Requested	3256
LakeHavasuIDDChemhueveIndianRes:ChemhueveIndianRes	Diversion Requested	2969
LakeHavasuIDDChemhueveIndianRes:LakeHavasuIandD	Depletion Requested	3169
LakeHavasuIDDChemhueveIndianRes:LakeHavasuIandD	Diversion Requested	2910
LakeMeadNRA:LakeMohaveAZ	Depletion Requested	3138
LakeMeadNRA:LakeMohaveAZ	Diversion Requested	2900
LakeMeadNRA:LakeMohaveNV	Depletion Requested	3306
LakeMeadNRA:LakeMohaveNV	Diversion Requested	3010
MWDDiversion	Total Depletion Requested	2972
MWDDiversion	Total Diversion Requested	2771
MohaveSteamPlant:SouthernCalEdison	Depletion Requested	3309

Name of Decree User	Datatype	SDID
MohaveSteamPlant:SouthernCalEdison	Diversion Requested	3018
MohaveValleyIrrAndDrainDistrict	Total Depletion Requested	3154
MohaveValleyIrrAndDrainDistrict	Total Diversion Requested	2907
NWR:CibolaNationalWildlifeRefuge	Depletion Requested	3190
NWR:CibolaNationalWildlifeRefuge	Diversion Requested	2921
NWR:ImperialNationalWildlifeRefuge	Depletion Requested	3193
NWR:ImperialNationalWildlifeRefuge	Diversion Requested	2922
OtherAZUses:OtherAZUsersBelowHooverDam	Depletion Requested	3145
OtherAZUses:OtherAZUsersBelowHooverDam	Diversion Requested	3032
OthersAndMiscPresPerfRights:MiscandSumCheck	Depletion Requested	3328
OthersAndMiscPresPerfRights:MiscandSumCheck	Diversion Requested	3325
OthersAndMiscPresPerfRights:OtherAZUsersbelowDavisDam	Depletion Requested	3175
OthersAndMiscPresPerfRights:OtherAZUsersbelowDavisDam	Diversion Requested	3035
OthersAndMiscPresPerfRights:OtherCAUsersbelowDavisDam	Depletion Requested	3253
OthersAndMiscPresPerfRights:OtherCAUsersbelowDavisDam	Diversion Requested	3091
OthersAndMiscPresPerfRights:OtherNVUsersbelowDavisDam	Depletion Requested	3313
OthersAndMiscPresPerfRights:OtherNVUsersbelowDavisDam	Diversion Requested	3024
PaloVerdeIrrigationDistrict:PaloVerdeIrrigationDistrict	Depletion Requested	2982
PaloVerdeIrrigationDistrict:PaloVerdeIrrigationDistrict	Diversion Requested	2980
ParkerDamAndGovernmentCamp	Total Depletion Requested	2978
ParkerDamAndGovernmentCamp	Total Diversion Requested	2976
PumpingFromLakeMeadandReturns:BasicManagementInc	Depletion Requested	3290
PumpingFromLakeMeadandReturns:BasicManagementInc	Diversion Requested	3011
PumpingFromLakeMeadandReturns:BoulderCanyonProject	Depletion Requested	3002
PumpingFromLakeMeadandReturns:BoulderCanyonProject	Diversion Requested	3000
PumpingFromLakeMeadandReturns:CityofBoulderCityDivatHoover	Depletion Requested	3297
PumpingFromLakeMeadandReturns:CityofBoulderCityDivatHoover	Diversion Requested	3016
PumpingFromLakeMeadandReturns:CityofHendersonDivatSaddleIsle	Depletion Requested	3293
PumpingFromLakeMeadandReturns:CityofHendersonDivatSaddleIsle	Diversion Requested	3012
PumpingFromLakeMeadandReturns:CityofNorthLasVegasDivSaddleIsle	Depletion Requested	3352
PumpingFromLakeMeadandReturns:CityofNorthLasVegasDivSaddleIsle	Diversion Requested	3349
PumpingFromLakeMeadandReturns:LasVegasValleyWaterDistSaddleIsle	Depletion Requested	3356
PumpingFromLakeMeadandReturns:LasVegasValleyWaterDistSaddleIsle	Diversion Requested	3353
PumpingFromLakeMeadandReturns:LasVegasWashReturnFlows	Depletion Requested	3303
PumpingFromLakeMeadandReturns:LasVegasWashReturnFlows	Diversion Requested	3301
PumpingFromLakeMeadandReturns:NVDeptofFishAndGame	Depletion Requested	3015
PumpingFromLakeMeadandReturns:NVDeptofFishAndGame	Diversion Requested	3013
PumpingFromLakeMeadandReturns:NellisAirForceBaseDivSaddleIsle	Depletion Requested	3348
PumpingFromLakeMeadandReturns:NellisAirForceBaseDivSaddleIsle	Diversion Requested	3345
PumpingFromLakeMeadandReturns:PacificCoastBuildingProductsInc	Depletion Requested	3300
PumpingFromLakeMeadandReturns:PacificCoastBuildingProductsInc	Diversion Requested	3017
PumpingFromLakeMeadandReturns:RobertBGriffithWaterProject	Depletion Requested	3284
PumpingFromLakeMeadandReturns:RobertBGriffithWaterProject	Diversion Requested	3003
TownOfParkerAndOtherUsers:MiscellaneousAndSumCheck	Depletion Requested	3320
TownOfParkerAndOtherUsers:MiscellaneousAndSumCheck	Diversion Requested	3317
TownOfParkerAndOtherUsers:OtherAZUsersbelowParkerDam	Depletion Requested	3196
TownOfParkerAndOtherUsers:OtherAZUsersbelowParkerDam	Diversion Requested	3043
TownOfParkerAndOtherUsers:OtherCAUsersbelowParkerDam	Depletion Requested	3263
TownOfParkerAndOtherUsers:OtherCAUsersbelowParkerDam	Diversion Requested	3095
TownOfParkerAndOtherUsers:TownOfParker	Depletion Requested	2914
TownOfParkerAndOtherUsers:TownOfParker	Diversion Requested	3179