ATTACHMENT B

HYDROBASIN TECHNICAL MANUAL

HydroBasin Technical Manual

Southern California Edison

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Time To Decide

HydroBasin Technical Manual

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Introduction

This manual is intended to give an overview of the technical structure underlying the HydroBasin flow routing model. HydroBasin is a software package that models much of the Big Creek and Upper San Joaquin river network, including the reservoirs, diversions and conveyances that have been built over the last century to generate power. HydroBasin is intended to allow users to examine the effects of increasing constraints on this system, and allows them to do scenario-based comparisons of constraint changes.

HydroBasin has been under development for almost a decade, and has been undergoing calibration for much of the last year to ensure that the model routes water in a fashion that is consistent with current Southern California Edison (SCE) practice. The current version of the HydroBasin application has been calibrated against a number of historic water years, and has baselines available for scenario comparison for each of the representative water year types observed in the last twenty years of operation. During this calibration, several artifacts have been noted as effects of the modeling, and will be discussed at length later in this manual.

In the last six months a website has been developed to allow stakeholders access to the HydroBasin model so that they can examine the effects of suggested constraints without requiring intimate knowledge of either the Big Creek network, the existing constraints on the system, or SCE's operating practices. The result of this has been the HydroBasin website, which interacts with the HydroBasin application and reports on reaches of interest and overall effects of constraint changes, without overwhelming users with the exact flows for every minor reach and diversion in the system.

The HydroBasin Application

The HydroBasin application is designed to build, analyze and compare different scenarios for the Big Creek network. A scenario is a combination of a water year, the existing constraints for that water year type, and a constraint set created defining increased release or storage constraints for specific locations at specific times. When a scenario is run, a mass-balancing algorithm is used to determine what the effects of the changed constraints would be. Reports are produced to allow analysis of these changes.

The HydroBasin application can also be used to analyze these results. Examples would include which constraints were met with a given constraint set and which were not, what the overall effects of a constraint change on generation, and whether or not a more rigorous constraint in one part of the network would cause the failure of any other constraints in the system.

The value of this application is its ability to compare results based on different assumptions. For example:

- If the Minimum Instream Flow at Bear Creek is increased, how much water is actually diverted, and how often does Bear Creek go to "Full Natural Flow" diverting no water into the Ward tunnel System?
- If the legislated reservoir level in Mammoth Pool for the September long weekend is raised, how much generation capacity is at risk? How widespread are the effects likely to be?

To assess the answers to these questions, we can compare the results of a scenario created with these possibilities, to a scenario without them.

HydroBasin's Building Blocks:

In this section we will investigate the basic building blocks that allow HydroBasin to route water. Before getting into the detailed explanation of these building blocks, a brief overview of the components is in order.

Graph Theory

Graph Theory is a mathematical field that is used to describe how things connect. HydroBasin uses some components of graph theory in the mass balance algorithms.

The Big Creek Network

The Big Creek network and upper San Joaquin River are connected in a specific manner, and most of the man-made structures in the network have designed maximum values, which cannot be safely exceeded. The specific connections of the natural and man-made components along with their physical attributes are key considerations in the HydroBasin model.

Water Years

Historic data was used to generate the baseline water years, both to calculate inflows (from the CAWG-6 unimpeded data set) and determine the historic reservoir storage levels (from USGS historic record). Water Year Data is used to determine what the baseline flows and reservoir storage values should be for each water year type.

Existing Constraints

Constraints are applied to each water year to ensure that the existing constraints are met. These constraints include the Mammoth Pool Operating Agreement, Reservoir Storage levels and existing Instream Flow constraints.

Time Step

To model water it is important that it move through time. HydroBasin uses a weekly time step, as the best compromise between computational speed, data validation and data smoothing.

Graph Theory

Graph Theory is a mathematical field that describes how things connect. In this section we will discuss two pieces of graph theory, "nodes" and "edges" and describe the types of nodes and edges that the HydroBasin application uses, and why. We will also discuss the simple rules that govern the behavior of these nodes

Nodes

A node is a place of interest, whether it is a reservoir, a diversion dam, a confluence or a reach break. HydroBasin uses only 5 types of nodes

- Inflow
- Outflow
- Diversion
- Confluence
- Reservoir

Edges

An edge is something that connects two nodes. Simple examples would include a reach or conduit; while more complex examples would be a powerhouse (a conveyance with a powerhouse at the end) or a storage edge, linking a reservoir at one time step with a reservoir in another time step. HydroBasin uses the following 6 edge types

- Inflow
- Outflow
- Streams
- Conveyance
- Powerhouse
- Storage

Rules:

HydroBasin uses five simple rules for water allocation

- Water can only move down defined edges
- Water must flow downstream
- Water in = Water out
- Water out is allocated to the highest priority edges
- Water cannot be allocated in excess to the maximum flow on an edge

There are two exceptions to the third rule

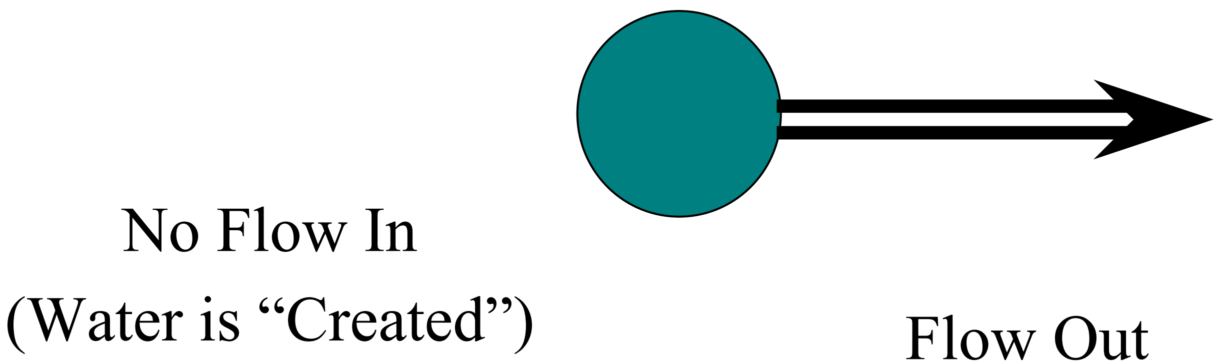
- Inflow Nodes are allowed to "Create" water
- Outflow Nodes are allowed to "Destroy" water

Nodes

The specific nodes that we use in the Hydrobasin application have the following characteristics:

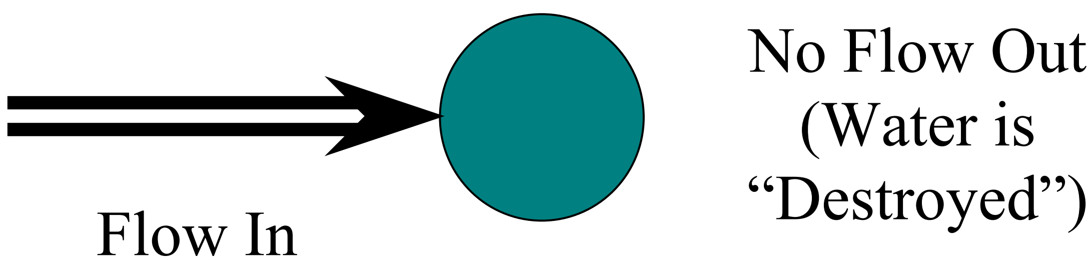
Inflow Nodes

We use inflow nodes to put all water into the system. This node type can be treated like a gage measuring water entering the system, and all water must start from an inflow node. An inflow Node is characterized by its ability to create water. A diagram of an inflow node will look like this:



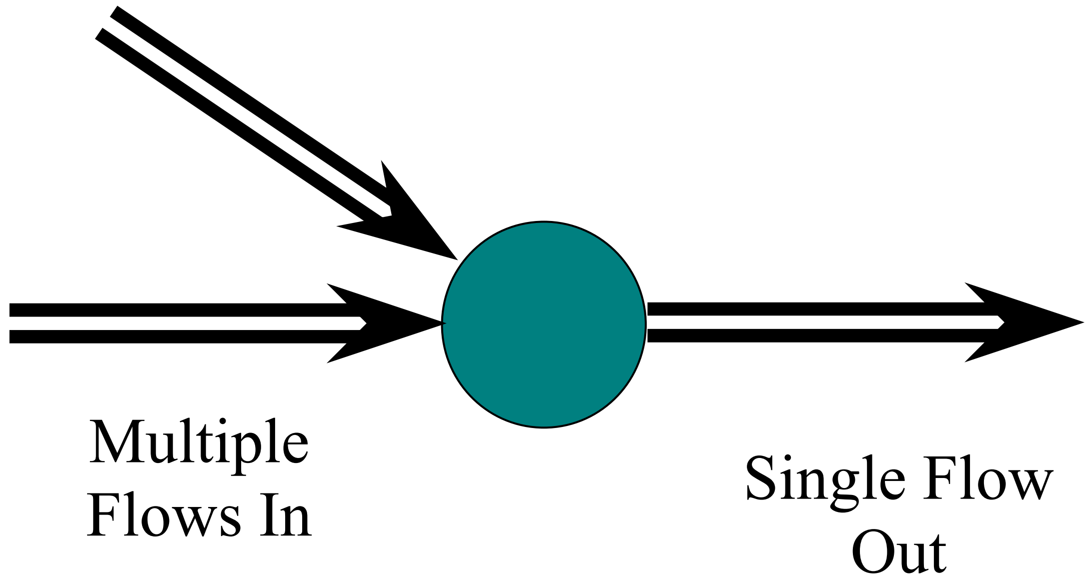
Outflow Nodes

Outflow nodes are used to move water out of the system. There are three primary outflow methods for the HydroBasin system, Evaporation, end-of-year storage, and outflow on the San Joaquin River below the outflow for Big Creek 4. A diagram of an outflow node will look like this:



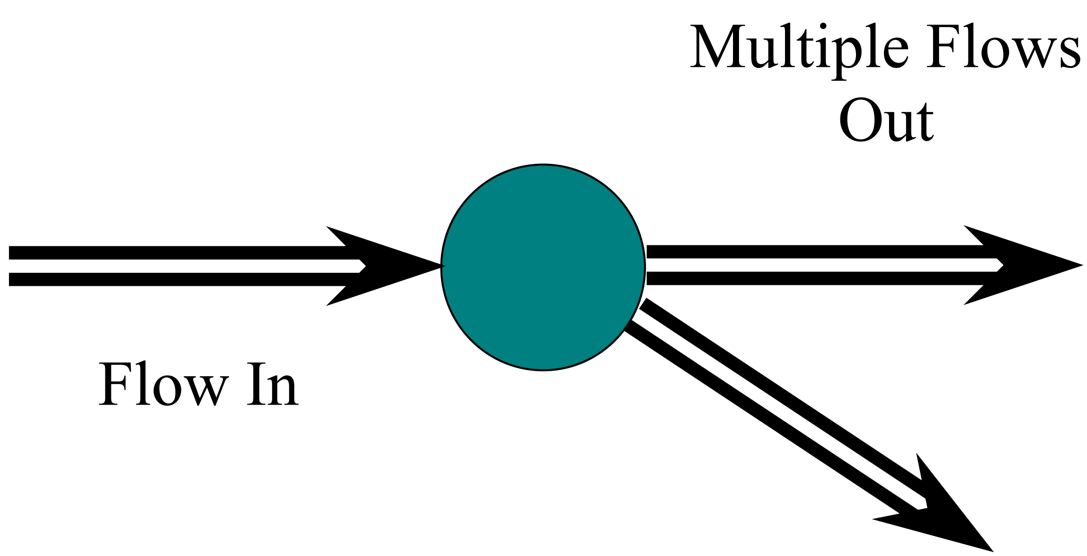
Confluences

A Confluence is where two or more upstream edges join together and form a single downstream edge. We can also use a confluence to form a reach break, although this has not been done in the HydroBasin application. . A diagram of a confluence node will look like this:



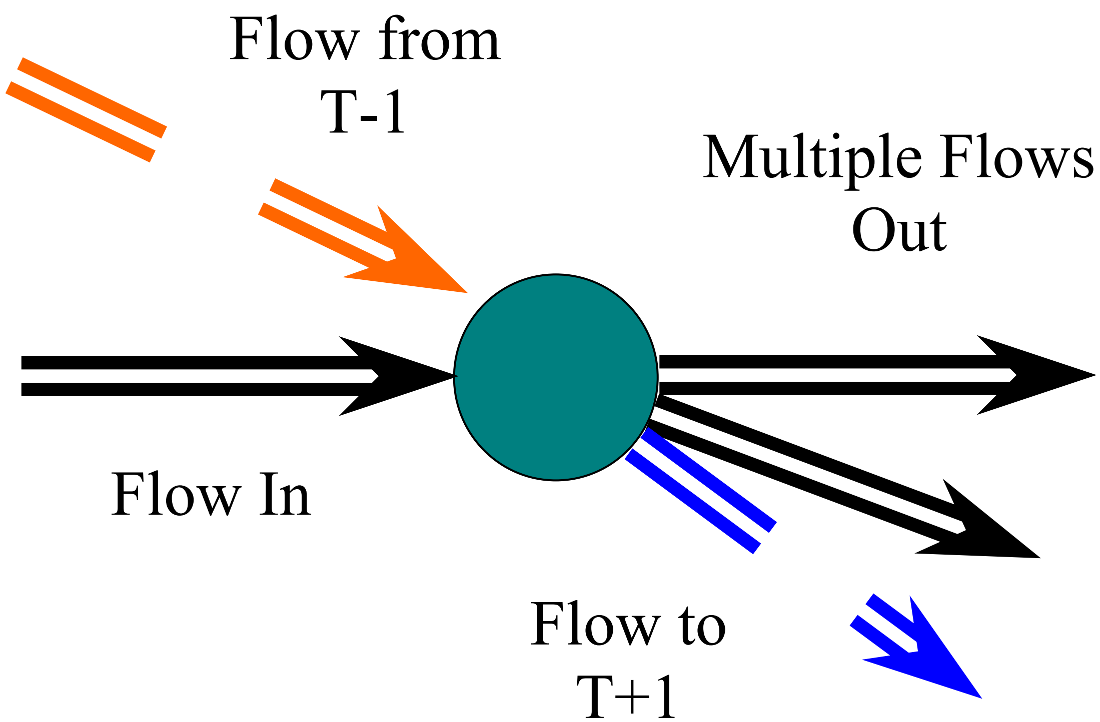
Diversions

A Diversion node is where one or more upstream edges split apart into two or more downstream edges. The only difference between a diversion and a reservoir is that reservoirs can store appreciable amounts of water and diversions cannot. A diagram of a diversion node will look like this:



Reservoirs

A Reservoir node is characterized by having a temporal edge, and can move water from one time step into the one immediately following. By using temporal edges, we preserve the simple rule "water in = water out" because some of the "water in" comes from the previous time step, and some of the "water out" will go to the next time step. A diagram of a reservoir node will look like this:



Edges:

The specific edges that we use in the Hydrobasin application have the following characteristics:

Inflow Edges

An inflow Edge must start at an inflow node. All water that is moved into the HydroBasin network must come through either an inflow edge. Note that storage edges from time zero (September 30 of the previous year) are considered to be inflow edges. An example would be local inflow to Huntington Lake.

Outflow Edges

An outflow edge must end at an outflow node. All water that leaves the Big Creek network must exit either through an outflow edge. Note that storage to time steps greater than the number of time steps used in the model (52 for the current weekly configuration) is considered to be an outflow edge. An example would be the San Joaquin River below Big Creek Powerhouse 4.

Conveyance Edges

These are generally pipes, tunnels, or canals through which water flows. Unless a conveyance is a natural streambed, such as Mono Creek below Edison Lake, all conveyances have a physical maximum for their flow capacity. If more water arrives at the conveyance than its capacity, it will go to a different location, either because there is no room in the pipe or because a channel will overflow and spill water into another drainage basin. An example would be the Ward Tunnel Below Florence Lake.

Power Edges

Power edges are conveyances with associated generators or set of generators used to generate power. All powerhouses have a physical maximum flow capacity. An example would be Big Creek Powerhouse 1. Power is calculated by multiplying generator efficiency (in kWh/Acre foot) by volume of water passed through the generator per unit time.

Storage Edges

A storage edge represents water that can be stored in a basin (reservoir). Storage edges are used to move water from one time step to the next (sequential) time step. All storage edges have a maximum volume representing the point at which they would spill. All of the major reservoirs are examples of this type of edge

Stream Edges

Stream edges represent the natural stream and riverbeds in the Big Creek system. Streams are used to satisfy minimum instream flows, and to carry excess water (spill) when other edge types have all reached their maximum capacity. Streams are unique because they do not have a limit on how much water you can put into them. An example would be the San Joaquin River below Mammoth Pool.

Rules:

The rules used to allocate water are worth some discussion before we move on to an example of water allocation in the HydroBasin Application

Water can only move down defined edges

This is an important rule to ensure that the network behaves in a manner consistent with the physical infrastructure of the Big Creek network. The edges defined in HydroBasin closely mimic those found in the Big Creek network.

Water must flow downstream

This is fairly self-evident: water from the Florence Lake flows down the South Fork San Joaquin river, through Mammoth Pool and eventually exits the network on the San Joaquin River Below Powerhouse 4.

Since we are modeling time as having an upstream and downstream direction, the "top" of the network is inflows to the reservoirs at time =0 (September 30 of the previous year) and the "bottom" of the network is water outflow and storage on week 52. The implications of this are that most edges model water flowing between two nodes of the same time step, while storage edges can move water from the current time step to the next time step.

Water in = Water out

This is one of the most important elements to the HydroBasin model, and is the reason that reservoirs are being modeled as edges: Each node must have inflows exactly equal to its outflows, and the system over the year must have total inflow equal to its total outflow.

Water out is allocated to the highest priority edges

This rule ensures that water is allocated to the most important functions first. The priority list is as follows:

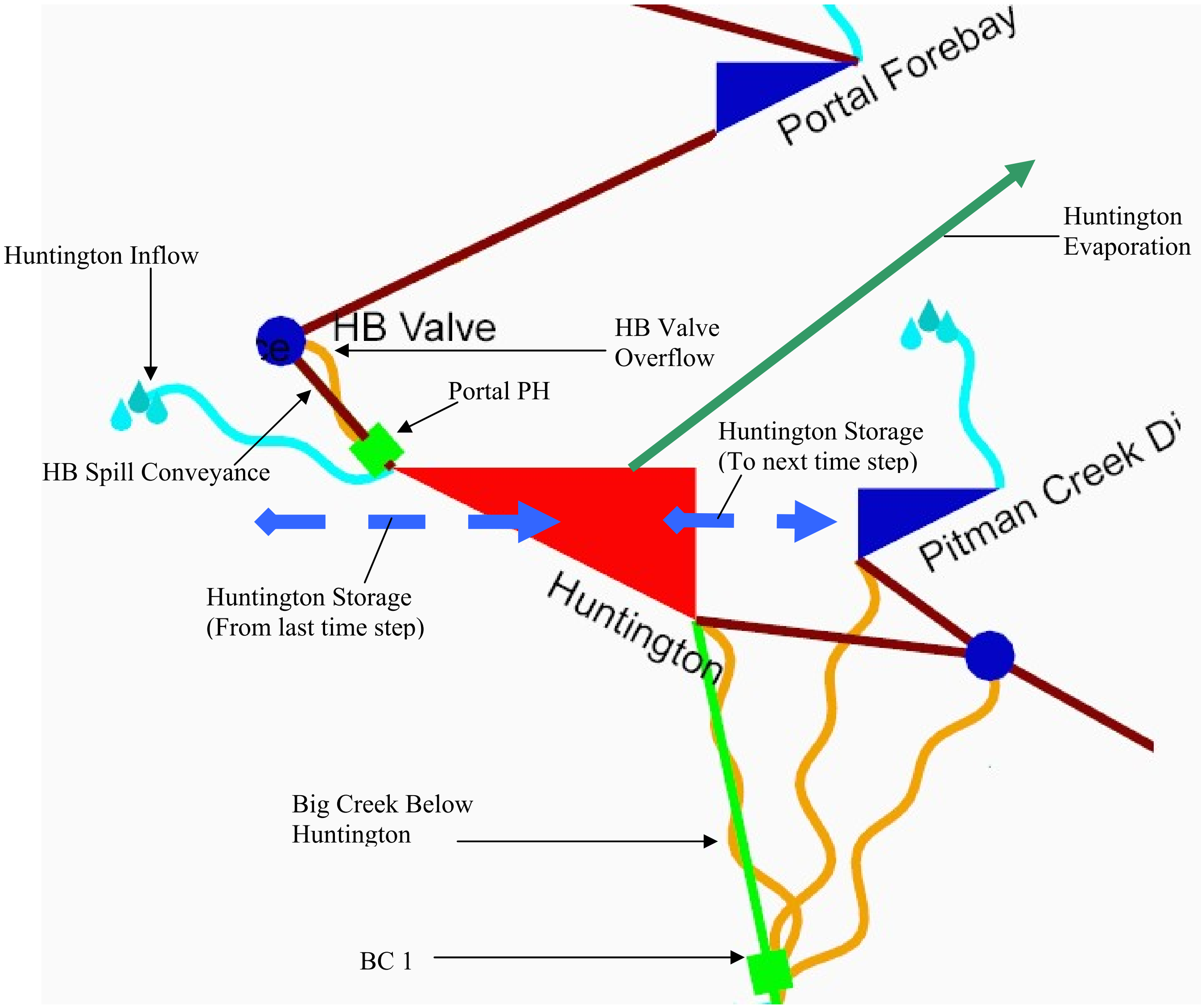
- Physical Requirements and Processes
- Instream Flow Requirements
- Reservoir Storage Constraints
- Power and Conveyances
- Shifts in Generation and Conveyance Patterns
- Reservoirs to Maximum Storage
- Spill

Water cannot be allocated in excess to the maximum flow on an edge

This rule ensures that powerhouses, conveyances and reservoirs are not operated past their physical capacities. It is also important to ensure that reservoirs spill if there is too much water for the physical plant of the Big Creek network to handle.

The Nodes and Edges displayed on the Network Schematic:

A concrete example of the operation of the various edges can be shown by looking at the section of the Big Creek network Centered on Huntington Lake: this image is taken from the website and slightly cleaned up to make the area around Huntington Lake a bit easier to interpret.



Note that the Evaporation and storage edges are not displayed on the Schematic display, and are included for the sake of clarity in the example.

For this example we will look at a sample (Critically Dry) baseline water year during week 37 and 38, which correspond to June 18th to July 1.

Storage:

The storage volumes in the example spreadsheet are shown highlighted in yellow. Note that the volume “Out” for week 38 is equal to the volume “In” on week 39

Inflow Edges

The Huntington inflow edges all start at the inflow node shown on the network diagram as water droplets. You can also see the Pitman Diversion inflow node in this diagram

Outflow Edges

Huntington Evaporation is shown as a green line: Evaporation edges are not displayed in the network schematic. The “maximum” displayed in the spreadsheet is large enough to ensure that calculated evaporation never exceeds the maximum.

Conveyance Edges

The HPS Conduit below Huntington and the HB Spill Conveyance are both shown on this schematic. Also shown on this schematic (although not labeled) are several sections of the ward Tunnel, the HPS conduit above Balsam Forebay, and the Pitman Conveyance

Power Edges

Big Creek Powerhouse 1 and Portal Powerhouse are both shown in this schematic. Note that the Ward tunnel system can deliver water to the Portal Powerhouse in excess to its rated capacity, so the Portal HB Valve is shown in the schematic external to the actual powerhouse. Three Edges originate at this node, Portal PH, which will be allocated the first 746 cfs, “HB Valve Below Portal Spill Conveyance” which will divert the next 1,760 cfs and “HB Valve Overflow” which is an edge to ensure that water cannot be “destroyed” at this node. Since the Ward Tunnel has a maximum capacity of 1740 CFS, this last edge is never used.

Storage Edges

Storage edges are not shown on the network schematic, but the dashed blue lines show the “temporal” flow through the reservoir, with water from the last time period “filling” the reservoir, and the reservoir being “emptied” by flowing the water into the next time step.

Stream Edges

Big Creek Below Huntington is shown and labeled in the above diagram, and Pitman Creek can be seen as well. The remaining “streams” are junction overflow edges, which ensure that if a the water put into a conveyance confluence is more than can be carried out of the confluence that the water is moved to the location that it would appear had it not been diverted. Remember that water is allocated in priority order, and conveyances are higher priority than releasing water above minimum instream flow

Examples:

Sample Node Balance Worksheet (Baseline)

virtual edge	source time	Baseline Volume	Calculated Volume	maximum	minimum	dir
Huntington storage	Week 37	86,601.0 AF	86,601.00	89,166.0 AF	0.0 AF	In
Huntington inflow	Week 38	1,047.0 AF	1,047.00	100,000.0 AF	0.0 AF	In
HB Valve Overflow (release)	Week 38	0.0 AF	0	24,437.0 AF	0.0 AF	In
Portal Powerhouse (power)	Week 38	10,360.0 AF	10,360.00	10,360.0 AF	0.0 AF	In
HB Spill Conveyance (conveyance)	Week 38	4,606.7 AF	4,606.70	24,437.0 AF	0.0 AF	In
huntington storage	Week 38	86,176.0 AF	86,176.00	89,166.0 AF	0.0 AF	Out
Big Creek Below Huntington (release)	Week 38	27.8 AF	27.8	700,000.0 AF	27.8 AF	Out
HPS Conduit Below Huntington (conveyance)	Week 38	9,411.4 AF	9,411.40	20,552.0 AF	0.0 AF	Out
BC1 (power)	Week 38	6,841.0 AF	6,841.00	9,583.0 AF	0.0 AF	Out
Huntington Evaporation (outflow)	Week 38	158.5 AF	158.5	1,000.0 AF	0.0 AF	Out
		IN	102,614.70			
		OUT	102,614.70			
Huntington storage	Week 38	86,176.0 AF	86,176.00	89,166.0 AF	0.0 AF	In
Huntington inflow	Week 39	1,147.0 AF	1,147.00	100,000.0 AF	0.0 AF	In
HB Valve Overflow (release)	Week 39	0.0 AF	0	24,437.0 AF	0.0 AF	In
Portal Powerhouse (power)	Week 39	10,360.0 AF	10,360.00	10,360.0 AF	0.0 AF	In
hbSpillConveyance conveyance	Week 39	575.9 AF	575.9	24,437.0 AF	0.0 AF	In
huntington storage	Week 39	86,530.0 AF	86,530.00	89,166.0 AF	0.0 AF	Out
Big Creek Below Huntington (release)	Week 39	27.8 AF	27.8	700,000.0 AF	27.8 AF	Out
HPS Conduit Below Huntington (conveyance)	Week 39	5,723.8 AF	5,723.80	20,552.0 AF	0.0 AF	Out
BC1 (power)	Week 39	5,809.6 AF	5,809.60	9,583.0 AF	0.0 AF	Out
Huntington Evaporation (outflow)	Week 39	167.7 AF	167.7	1,000.0 AF	0.0 AF	Out
		IN	98,258.90			
		OUT	98,258.90			

For each time step (weeks 38 and 39) the total water into Huntington is exactly equal to the water out of Huntington, and the water moved from Huntington storage in week 38 is inflow to Huntington in week 39.

The entire network operates in this fashion, with inflows from the "downstream" nodes being equal to the outflows from upstream nodes, plus local inflows, which are calculated from the unimpaired CAWG-6 data set. If we increase the minimum instream flow below Huntington to 40 cfs, (from the previous 2 cfs) we will see the following results:

Sample Node Balance Worksheet (40 cfs below Huntington)

virtual edge	source time	Baseline Volume	Calculated Volume	maximum	minimum	dir
Huntington storage	Week 37	86,601.0 AF	86,601.00	89,166.0 AF	0.0 AF	In
Huntington inflow	Week 38	1,047.0 AF	1,047.00	100,000.0 AF	0.0 AF	In
HB Valve Overflow (release)	Week 38	0.0 AF	0	24,437.0 AF	0.0 AF	In
Portal Powerhouse (power)	Week 38	10,360.0 AF	10,360.00	10,360.0 AF	0.0 AF	In
HB Spill Conveyance (conveyance)	Week 38	4,606.7 AF	4,606.70	24,437.0 AF	0.0 AF	In
huntington storage	Week 38	86,176.0 AF	86,176.00	89,166.0 AF	0.0 AF	Out
Big Creek Below Huntington (release)	Week 38	27.8 AF	555.4	700,000.0 AF	555.4 AF	Out
HPS Conduit Below Huntington (conveyance)	Week 38	9,411.4 AF	9,411.40	20,552.0 AF	0.0 AF	Out
BC1 (power)	Week 38	6,841.0 AF	6,313.40	9,583.0 AF	0.0 AF	Out
Huntington Evaporation (outflow)	Week 38	158.5 AF	158.5	1,000.0 AF	0.0 AF	Out
		IN	102,614.70			
		OUT	102,614.70			
Huntington storage	Week 38	86,176.0 AF	86,176.00	89,166.0 AF	0.0 AF	In
Huntington inflow	Week 39	1,147.0 AF	1,147.00	100,000.0 AF	0.0 AF	In
HB Valve Overflow (release)	Week 39	0.0 AF	0	24,437.0 AF	0.0 AF	In
Portal Powerhouse (power)	Week 39	10,360.0 AF	10,360.00	10,360.0 AF	0.0 AF	In
hbSpillConveyance conveyance	Week 39	575.9 AF	575.9	24,437.0 AF	0.0 AF	In
huntington storage	Week 39	86,530.0 AF	86,530.00	89,166.0 AF	0.0 AF	Out
Big Creek Below Huntington (release)	Week 39	27.8 AF	555.4	700,000.0 AF	555.4 AF	Out
HPS Conduit Below Huntington (conveyance)	Week 39	5,723.8 AF	5,723.80	20,552.0 AF	0.0 AF	Out
BC1 (power)	Week 39	5,809.6 AF	5,282.00	9,583.0 AF	0.0 AF	Out
Huntington Evaporation (outflow)	Week 39	167.7 AF	167.7	1,000.0 AF	0.0 AF	Out
		IN	98,258.90			
		OUT	98,258.90			

Note that the "In" and "Out" totals are still identical, since the inflows were not changed, and outflow for each node must equal inflow. The amounts of the outflows have changed: we are now releasing 555.4 acre feet per week down Big Creek Below Huntington, and reducing the amount of generation at the BC1 powerhouse. If we increase this minimum instream flow to very high levels (2,000 acre feet per day) we will get the following effects, demonstrating the effect of priority order:

Sample Node Balance Worksheet (2,000 AF/day below Huntington)

virtual edge	source time	Baseline Volume	Calculated Volume	maximum	minimum	dir
Huntington storage	Week 37	86,601.0 AF	86,601.00	89,166.0 AF	0.0 AF	In
Huntington inflow	Week 38	1,047.0 AF	1,047.00	100,000.0 AF	0.0 AF	In
HB Valve Overflow (release)	Week 38	0.0 AF	0	24,437.0 AF	0.0 AF	In
Portal Powerhouse (power)	Week 38	10,360.0 AF	10,360.00	10,360.0 AF	0.0 AF	In
HB Spill Conveyance (conveyance)	Week 38	4,606.7 AF	4,606.70	24,437.0 AF	0.0 AF	In
huntington storage	Week 38	86,176.0 AF	84,176.00	89,166.0 AF	0.0 AF	Out
Big Creek Below Huntington (release)	Week 38	27.8 AF	14000	700,000.0 AF	14000 AF	Out
HPS Conduit Below Huntington (conveyance)	Week 38	9,411.4 AF	2,000.00	20,552.0 AF	0.0 AF	Out
BC1 (power)	Week 38	6,841.0 AF	2,280.20	9,583.0 AF	0.0 AF	Out
Huntington Evaporation (outflow)	Week 38	158.5 AF	158.5	1,000.0 AF	0.0 AF	Out
		IN	102,614.70			
		OUT	102,614.70			
Huntington storage	Week 38	86,176.0 AF	84,176.00	89,166.0 AF	0.0 AF	In
Huntington inflow	Week 39	1,147.0 AF	1,147.00	100,000.0 AF	0.0 AF	In
HB Valve Overflow (release)	Week 39	0.0 AF	0	24,437.0 AF	0.0 AF	In
Portal Powerhouse (power)	Week 39	10,360.0 AF	10,360.00	10,360.0 AF	0.0 AF	In
hbSpillConveyance conveyance	Week 39	575.9 AF	575.9	24,437.0 AF	0.0 AF	In
huntington storage	Week 39	86,530.0 AF	82,091.20	89,166.0 AF	0.0 AF	Out
Big Creek Below Huntington (release)	Week 39	27.8 AF	14000	700,000.0 AF	14000 AF	Out
HPS Conduit Below Huntington (conveyance)	Week 39	5,723.8 AF	0.00	20,552.0 AF	0.0 AF	Out
BC1 (power)	Week 39	5,809.6 AF	0.00	9,583.0 AF	0.0 AF	Out
Huntington Evaporation (outflow)	Week 39	167.7 AF	167.7	1,000.0 AF	0.0 AF	Out
		IN	96,258.90			
		OUT	96,258.90			

The highest priority is the physical processes and constraints (evaporation), followed by the minimum release: note that it is irrelevant whether this is a series of boating releases, a geomorphic release or a minimum instream flow. After this, the historic reservoir level is maintained and then water is allocated to the HPS Conduit and then to BC1.

Note that no water is left for either BC1 or the HPS conduit, in either week with this scenario, and so much water is required that the reservoir volumes are forced to drop in both weeks: note the reduction in water “In” on week 39.

Water Years

Baseline Water Years

HydroBasin uses "Baseline" water years to run scenarios against: these baselines are generated by using the CAWG-6 unimpaired data set to calculate inflows, USGS historic reservoir data is used to calibrate the reservoir volumes and power generation profiles are similar to historic based on USGS records. While the baselines have been built to closely match historic values, there are two significant differences:

- Diversions divert whenever possible
- Minimum Instream Flows are always exactly met, and never exceeded unless there is no other outlet for the water
- Since the Baselines are constructed using two different data sets, the baseline water years are not an exact match to USGS data

Implications:

This first two points result in slightly more water being diverted into the Big Creek and Shaver side of the network, while slightly less water is diverted into the Mammoth Pool side of the network.

Because Minimum Instream Flows are exactly met, the Baseline water years are modeled much closer to the limits of operation than Southern California Edison actually operates the Big Creek Network.

These differences from the actual operation allow us to more accurately model the question "is it possible to impose these constraints" since it results in a slightly larger margin for error than exactly replicating historic discharges. Because we are modeling changes from the baselines, the difference between SCE exactly making a 10 cfs release instead of exactly making a 5 cfs release actually understates the real costs, since SCE's historic operational patterns suggest a slight over-release to ensure compliance with existing constraints.

The final point, that the baselines are slightly different from historic data, appears to be of more significance than it really is. Since the HydroBasin model is being used to determine the feasibility of alternate flow regimes, it is almost guaranteed that the next "critically Dry" water year will differ from the "Baseline" critically dry scenario by significantly more than the "Baseline" Critically Dry water year differs from the historic year that it was based on.

Calculation of Local Inflows

Inflows to the diversions and major reservoirs were calculated using the unimpaired CAWG-6 data, and drainage basin areas. With this data, there were three ways to calculating local inflows:

- Data provided directly in the CAWG-6 Unimpaired data
- Inflows derived using CAWG-6 unimpaired data and the area ratio of basin drainage area
- Inflows derived by calculating the difference in flow between two points and allocating the resultant difference in flow to basins based on their relative drainage areas, and subtracting already derived inflows.

Pitman, Bear and Hooper Creeks were used as reference basins, and as such their inflows (above diversions) were readily available from the CAWG-6 data

A number of minor diversions were calculated based on a reference basin. As an example, the North and South Slide Creeks were allocated water based on the inflow to Hooper Creek, multiplied by the ratio of their drainage area to that of Pitman Creek.

Some Inflows were calculated by subtracting the inflow from other reaches. Florence Lake local inflow was calculated by subtracting the inflow from the Slide Creeks and Hooper from the reading for the South Fork San Joaquin River Below Hooper Creek. More complex inflow calculations included Mammoth Pool, which was the difference between the SJR above Shakeflat Creek, minus the value reported at the SFSJR below Hooper and all of the inflows for the minor tributaries above Mammoth Pool.

Calculation of Reservoir Volumes

While Historic reservoir levels were available from USGS records, we would not use these directly. Using the end-of year starting storage as “Time 0” reservoir initialization for our first time step, and the local inflows calculated above, we attempted to match both historic reservoir levels as reported to USGS, as well as the historic patterns recorded for conveyances and powerhouses. The mass balance algorithm generated profiles for the 1991, 1995, 2000 and 2001 water years that were very similar to USGS reported values for both reservoir storage volumes as well as generation, so these baseline water years are being used as representative water years for the “Critically Dry”, “Wet”, Above Normal” and “Dry” water years respectively. There were no “Below Normal” water years in the 20 available years from 1983-2002, where unimpaired CAWG-6 data is available, so this water year type is not represented in the HydroBasin model

Constraints

HydroBasin is designed to mode the effects of imposing additional constraints on the Big Creek network. HydroBasin is configured to contain **all** of the existing License requirement constraints. If a new constraint is added to the system, there is an excellent chance that it will coincide with existing constraints. If there are multiple constraints on a given location at any given time, then the HydroBasin application is configured to choose the highest flow or storage constraint on each reach or reservoir (by total volume) for each day. If this constraint is met, then all lower constraints also are met

The HydroBasin application applies existing constraints to all user-generated scenarios, to ensure that all of the existing constraints are met. By automatically applying appropriate constraints, the HydroBasin model allows users to concentrate on the constraints that are important to their interests, instead of requiring them to memorize the existing constraints for various water year types and apply them to all of their scenarios. HydroBasin will automatically apply the most restrictive constraint. . It is important to note that if a user constraint is entered that is lower than the current constraint the user constraint will be ignored and replaced by the existing constraint: the user constraint will ***not*** be used instead of the existing constraint.

There are five constraint types used by the HydroBasin application.

- Mammoth Pool Operating Agreement (MPOA)
- Minimum Instream Flows
- Storage Constraints
- Boating Releases
- Geomorphic and Riparian Releases

MPOA

The Mammoth Pool Operating Agreement is a constraint on the total amount of water that must be present in the major reservoirs of the Big Creek network on September 30th of each year, as well as imposing maximum spring storage values. The MPOA as implemented by the model is more simplistic and simply ensures that the total aggregate reservoir storage is above a certain pre-set level for each water year type, as listed in the table below. The spring maximum levels are handled by ensuring that the baselines conform as closely to the historic data as possible, since the historic values were below the required volumes. The MPOA aggregate storage requirements are as follow:

Water Year Type	Aggregate Storage Requirement
Critically Dry	152,000 Acre Feet
Dry	202,500 Acre Feet
Below Normal	202,500 Acre Feet
Above Normal	325,000 Acre Feet
Wet	325,000 Acre Feet

Users are not allowed to modify the Mammoth Pool Operating Agreement

Minimum Instream Flows

Minimum instream flow constraints are requirements for minimum stream flows applied through given date ranges on specified reaches. There are a number of existing instream flow constraints, and these are applied at two levels, depending on the current water year type. One set of instream flow constraints is required for Dry and Critically Dry water year types, and a second is required for all other water year types. Minimum instream flows are calculated daily, with the release volume needed being equal to the flow requirement in cfs multiplied by 1.983 (the conversion factor for cubic feet per second to acre feet per day) and rounded to the nearest 0.1 acre foot.

A list of existing constraints can be found in Appendix 1, Existing Instream Flow Constraints.

Minimum Storage Volumes

Minimum Storage Volumes are constraints to keep reservoir volumes or levels at or above a given level. There are a number of existing Storage minima, which vary depending on the water year type. Note that many of the existing constraints are worded “as full as possible”: matching the historic reservoir profiles satisfies these constraints.

The existing Storage Constraints can be found in Appendix 2: Existing Storage Constraints.

Boating Releases

Boating releases are requests for flows to meet boating needs, and tend to take place over a period of hours or a few days. These flows are defined as the target flow for boating in cubic feet per second (cfs), an upper peak flow above which the reach would be unboatable, the period (start and end dates and times), for which this flow rate needs to be maintained. Daily flow volumes for this type of release are calculated by determining the maximum release volume for each hour, summing these up for each day and then rounding to the nearest 1/10 acre foot.

There are currently no Boating constraints on the Big Creek system

Geomorphic and Riparian Releases

Geomorphic or Riparian Releases are Instream flow requirements for streambed or habitat maintenance, and these flows tend to take place over days or weeks. As with boating releases, a target flow rate is specified, but this rate may be exceeded. Ramp up and ramp down rates are also specified, along with start and end dates and times. Daily flow volumes for this type of release are calculated by determining the maximum release volume for each hour, summing these up for each day and then rounding to the nearest 1/10 acre foot.

There are currently no existing Riparian or Geomorphic constraints on the Big Creek system.

Determining the constraint to use

Instream Flows use the largest required flow (in acre feet per day) on each reach for each day. Minimum storage volumes use the largest required volume (in acre feet) on each reservoir each day.

Time Step

HydroBasin operates on a weekly time step, with constraints calculated on a daily basis. This combination was determined to be an optimal balance between usefulness and calculation performance. Another significant factor that was considered was that with a weekly time step the raw data would not need to undergo any data smoothing or transformations, since the weekly averaging would have this effect, and still be readily understandable.

The reported volumes resultant from The HydroBasin application must be viewed in the context of weekly averages of daily values, some of the implications of which follow.

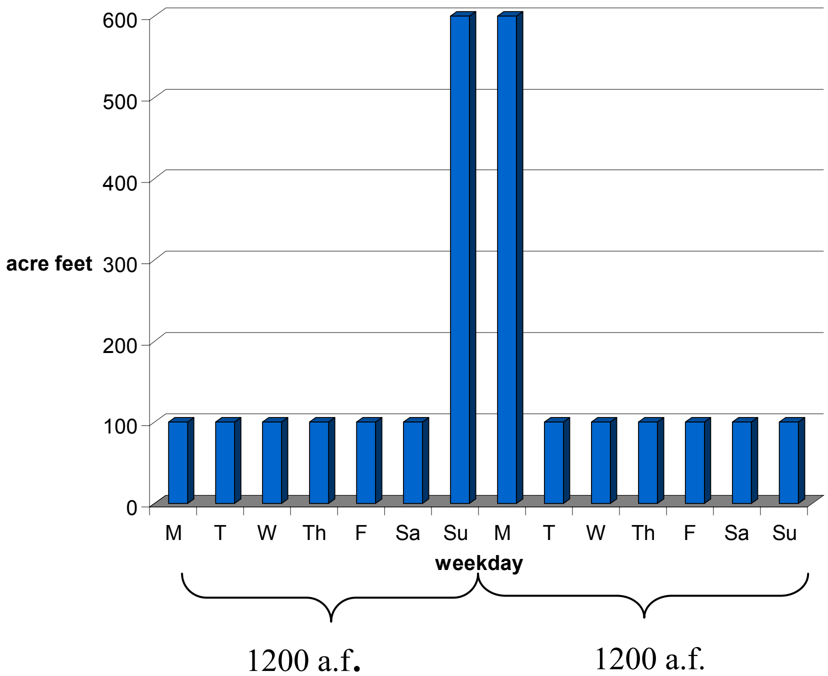
Reservoir Storage Volumes

Reservoir Storage Volumes are reported at the end of each week. Since reservoir constraints can be applied to any part of a week, we felt that it would introduce unnecessary effort to force the users to determine when all of the week breaks were so that they could apply “correct” storage constraints on a weekly basis. As a result, reservoir storage volumes are handled by having the largest single reservoir storage target taking place in each week assigned as the week end storage target. This has the added benefit of ensuring that any storage constraint less than a week is guaranteed to be applied to at least one week.

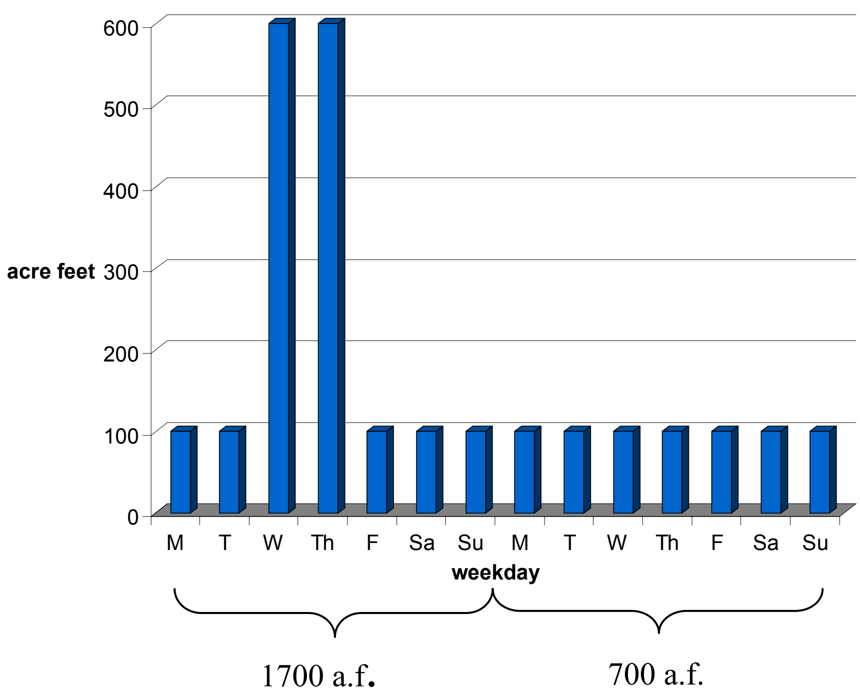
Minimum Instream Flows

Minimum instream flows use the highest flow volume (in acre feet per day) for each day on each reach. While this ensures that all of the constraints will be made (if the highest constraint is made each day, then all of the lower constraints will also be made) this does cause some reporting issues which need to be identified. The primary concern is that short periods of high flows intermixed with lower flows will give different results based on what time of the week they occur in. two examples follow, each of which is a two-day boating release: in example 1, the boating release happens to occur across a week break, while in example two it does not.

Example 1: Two Boating releases falling on a week break



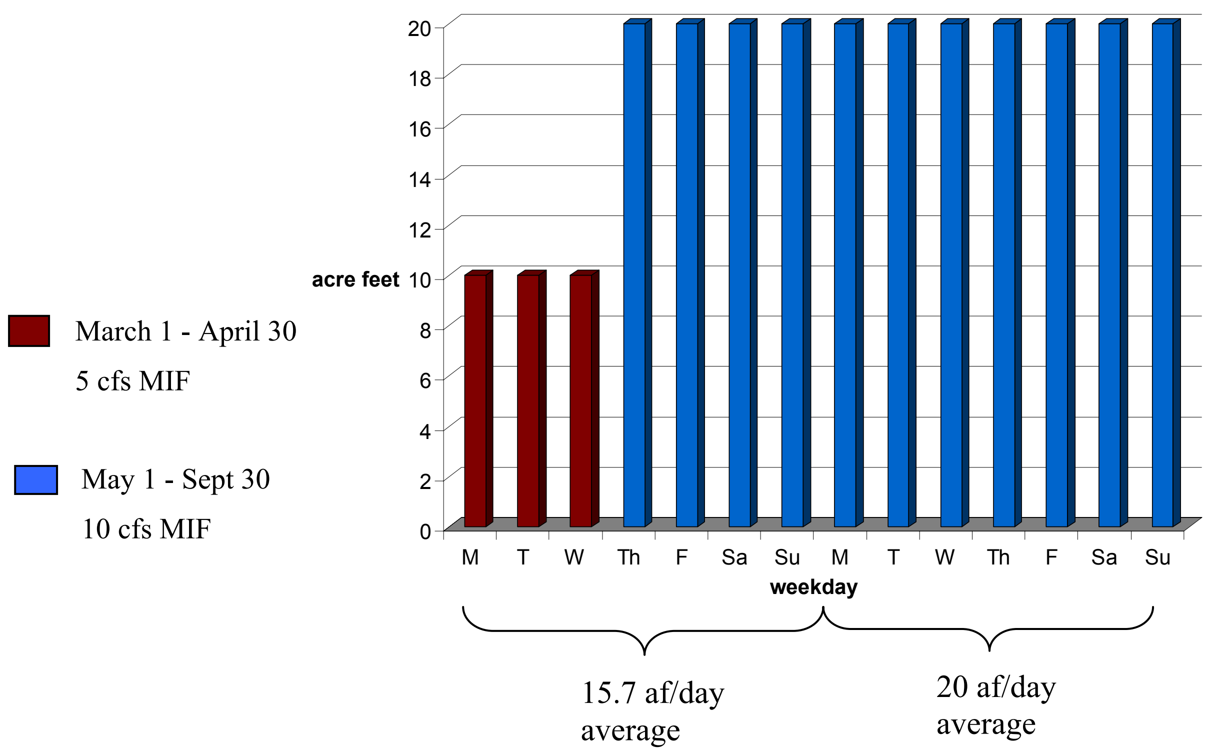
Example 2: Two boating releases falling in the middle of a week



If the inflow into a the upstream reservoir controlling this release was 100 cfs (approximately 1400 acre feet per week) there would be no effect on the reservoir levels in the first case (since the minimum instream flow requirement for the week is 1200 cfs per week, an average of approximately 86 cfs) while in the second example the reservoir level would be reduced by 300 acre feet (1400 AF inflow – 1700 AF outflow = -300AF of reservoir storage) even after all other outflows are reduced to zero, as seen with our earlier example of mass balancing Huntington.

A similar effect will be seen when an instream flow changes mid-week, as shown in example 3 (below) but this effect is a bit more intuitive: the week when the instream flow changes will average some intermediate value between the two flow constraints.

Example 3: Instream Flow Change Mid-Week



Technical Manual Appendices

Appendices

Appendix 1: Existing Instream Flow Requirements

Minimum Instream Flows used for Dry and Critically Dry Water Year Types

Dry Year Minimum Instream Flow Release Requirements
(in CFS)

Station #	Station Name	***WY Type	Oct	Nov 15/16	Dec	Jan	Feb	Mar	Apr 15/16	May	Jun
99	North Fork Stevenson Creek	Dry	3	3	3	3	3	3	4	4	4
100	Balsam Creek below Forebay	All	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
104	Big Creek below Huntington	All	2	2	2/0	0	0	0	0/2	2	2
105	Big Creek near Mouth	Dry	2	2/1	1	1	1	1	2	2	2
114	*Hooper Creek below Diversion	All	2	2	2	2	2	2	2	2	2
117	Bolsillo Creek below Diversion	All	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
119	Mono Creek below Edison	All	10	10	10	10	10	10	10	10	10
121	Pitman Cr. Near Tamarack Mt.	All	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
124	SJR below Dam 6	All	3	3	3	3	3	3	3	3	3
125	**SJR above Willow Ck (below Dam 7)	All	15	15	15	15	15	15	15	15	15
129	*So. Fk. SJR below Hooper Cr.	Dry	13	11	11	11	11	11	11	20	20
131	Stevenson Cr. Below Shaver	All	3	3/2	2	2	2	2	3	3	3
152	Warm Creek below Diversion	All	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
157	SJR above Shakeflat Creek	Dry	12.5	10	10	10	10	10	10/12.5	12.5	12.5
175	Bear Creek below Diversion	Dry	1	1	1	1	1	1	1	2	2
176	Mono Creek below Diversion	Dry	6	5	5	5	5	5	5	9	9
180	Camp 62 Creek below Diversion	All	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
181	Chinquapin Creek below Diversion	All	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1
192	**SJR below Willow Creek	All	20	20	20	20	20	20	20	20	20

* No more than 4 cfs from Hooper Creek may be included in South Fork San Joaquin River below Hooper Creeks minimum flow.
** Combined flow of Willow Creek and the release from Dam 7 must be a minimum of 20 cfs
*** Implementation of release year runs from May 1st - Apr 30th for all station except SJR above Shakeflat Creek which runs from Apr 16th - Apr 15th. At No. Fk. Stevenson Creek if during a designated dry year, the Feb. 1 or Mar. 1 CDWR forecast indicates that dry year conditions no longer prevail (Apr-Jul runoff forecast of the SJR at Friant is above 900.000 AF), normal year flow releases shall resume within 7 days of the CDWR forecast.

Minimum Instream Flows used for Below Normal, Above Normal and Wet Water Year Types

Normal Year Minimum Instream Flow Release Requirements
(in CFS)

Station #	Station Name	***WY Type	Oct	Nov 15/16	Dec	Jan	Feb	Mar	Apr 15/16	May	Jun
99	North Fork Stevenson Creek	Normal	4	4	4	3.5	3.5	3.5	5	5	5
100	Balsam Creek below Forebay	Normal	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
104	Big Creek below Huntington	Normal	2	2	2/0	0	0	0	0/2	2	2
105	Big Creek near Mouth	Normal	3	3/2	2	2	2	2	3	3	3
114	*Hooper Creek below Diversion	Normal	2	2	2	2	2	2	2	2	2
117	Bolsillo Creek below Diversion	Normal	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
119	Mono Creek below Edison	Normal	10	10	10	10	10	10	10	10	10
121	Pitman Cr. Near Tamarack Mt.	Normal	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
124	SJR below Dam 6	Normal	3	3	3	3	3	3	3	3	3
125	**SJR above Willow Ck (below Dam 7)	Normal	15	15	15	15	15	15	15	15	15
129	*So. Fk. SJR below Hooper Cr.	Normal	17	15	15	15	15	15	15	27	27
131	Stevenson Cr. Below Shaver	Normal	3	3/2	2	2	2	2	3	3	3
152	Warm Creek below Diversion	Normal	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
157	SJR above Shakeflat Creek	Normal	25	10	10	10	10	10	10/25	25	25
175	Bear Creek below Diversion	Normal	2	2	2	2	2	2	2	3	3
176	Mono Creek below Diversion	Normal	9	7.5	7.5	7.5	7.5	7.5	7.5	13	13
180	Camp 62 Creek below Diversion	Normal	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
181	Chinquapin Creek below Diversion	Normal	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1
192	**SJR below Willow Creek	Normal	20	20	20	20	20	20	20	20	20

* No more than 4 cfs from Hooper Creek may be included in South Fork San Joaquin River below Hooper Creeks minimum flow.
** Combined flow of Willow Creek and the release from Dam 7 must be a minimum of 20 cfs
*** Implementation of release year runs from May 1st - Apr 30th for all station except SJR above Shakeflat Creek which runs from Apr 16th - Apr 15th. At No. Fk. Stevenson Creek if during a designated dry year, the Feb. 1 or Mar. 1 CDWR forecast indicates that dry year conditions no longer prevail (Apr-Jul runoff forecast of the SJR at Friant is above 900.000 AF), normal year flow releases shall resume within 7 days of the CDWR forecast.

Appendix 2: Existing Storage Constraints

Dry and Critically Dry Water year Types

Reservoir	Date Range	Minimum Volume
Edison Lake	October 1 to September 30	6,000 Acre Feet
Florence Lake	October 1 to September 30	1,000 Acre Feet
Florence Lake	July 1 – August 31	21,000 Acre Feet
Shaver Lake	June 15 – September 15	4,000 Acre Feet

Below Normal, Above Normal and Wet Water Year Types

Reservoir	Date Range	Minimum Volume
Edison Lake	October 1 to September 30	6,000 Acre Feet
Florence Lake	October 1 to September 30	1,000 Acre Feet
Florence Lake	July 1 – August 31	21,000 Acre Feet
Shaver Lake	June 15 – September 15	4,000 Acre Feet