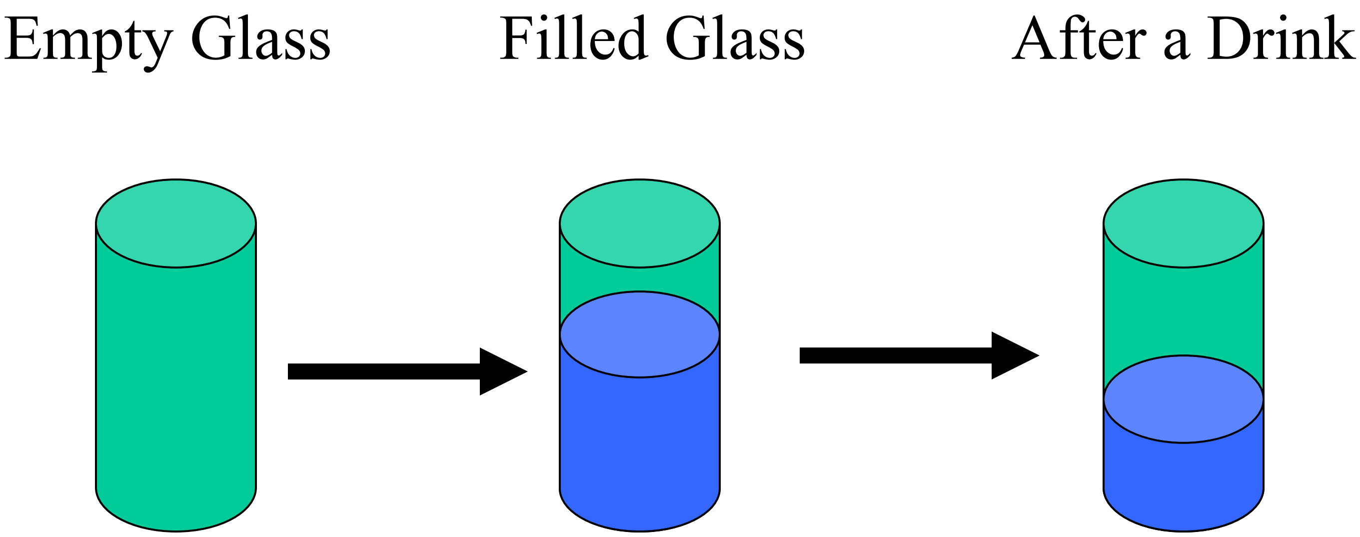
Conceptual Approach

Graph Theory

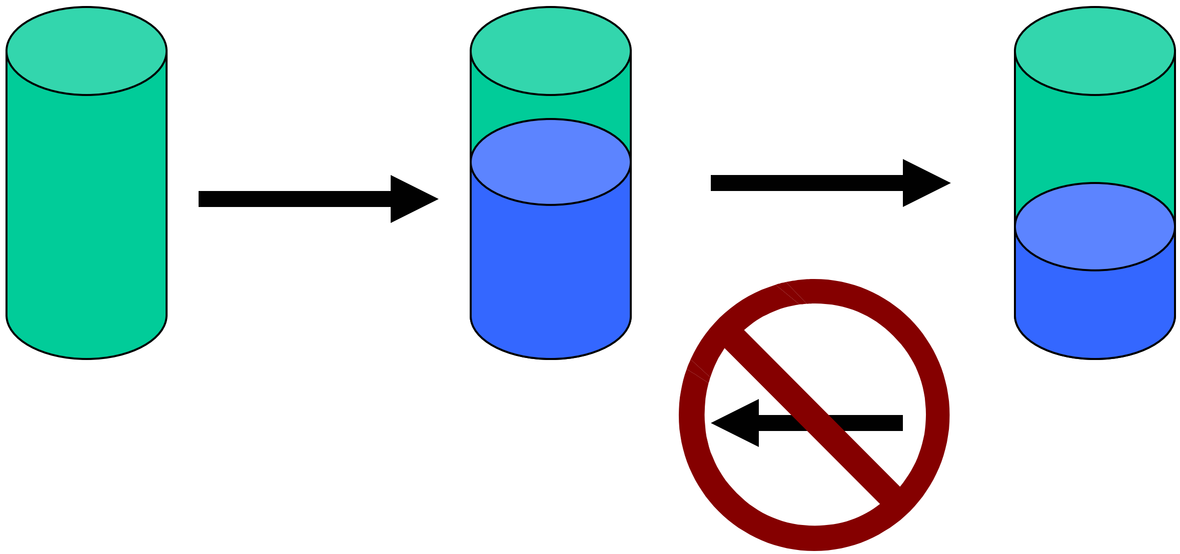
- What is a Node?
  - A node is a point where things connect
- What is an Edge?
  - An edge is the connection between two points
- How do you model reservoirs?
  - Reservoirs are both nodes and edges
  - “Temporal” storage edges

The Water Glass example



The Water Glass Example (2)

Empty Glass (Time = 0) | Filled Glass (Time = 1) | After a Drink (Time =2)



We cannot go back in time:
Water flows "Down Time" as well as downstream

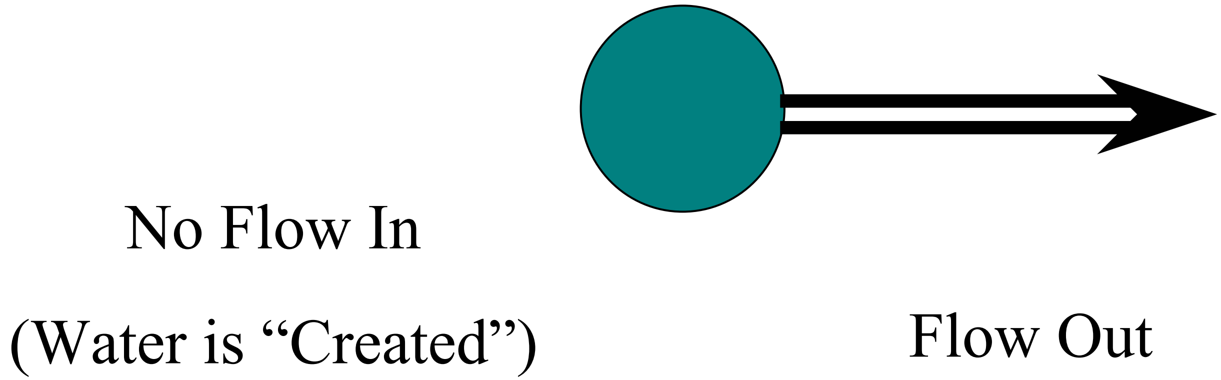
Node Types:

- Inflow
- Outflow
- Confluences
- Diversions and Reservoirs

Inflow:

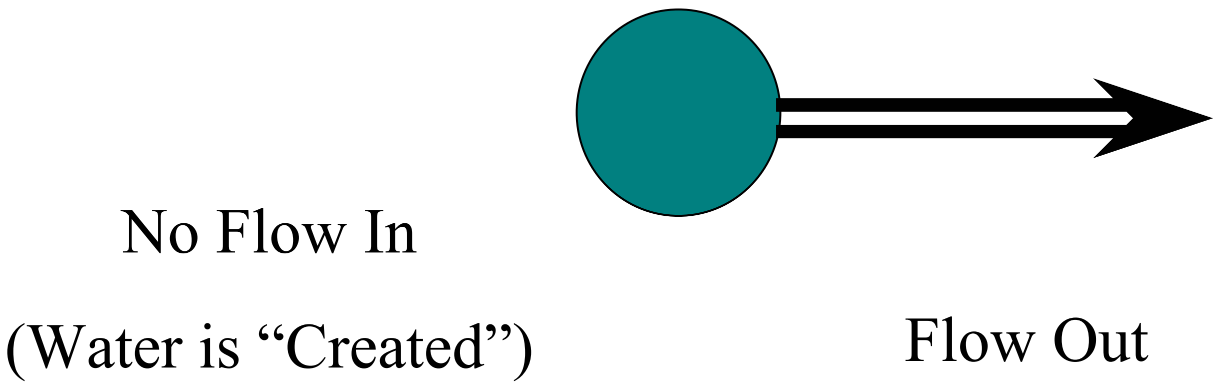
- We use an inflow node to put all water into the system. This node type can be treated like a gage measuring water entering the system.

Inflow Node Diagram



Inflow

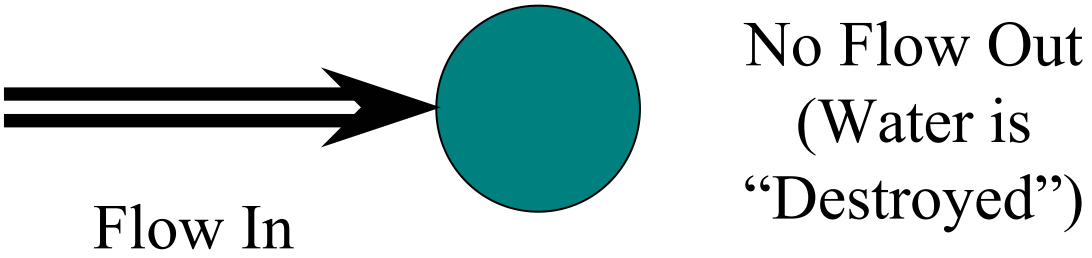
- All water from the “outside” of the system must start at an inflow node.
- Examples of these edges would include the South Fork San Joaquin River above Florence Lake (external Florence) or Bear Creek above the diversion dam (external Bear)



Outflow:

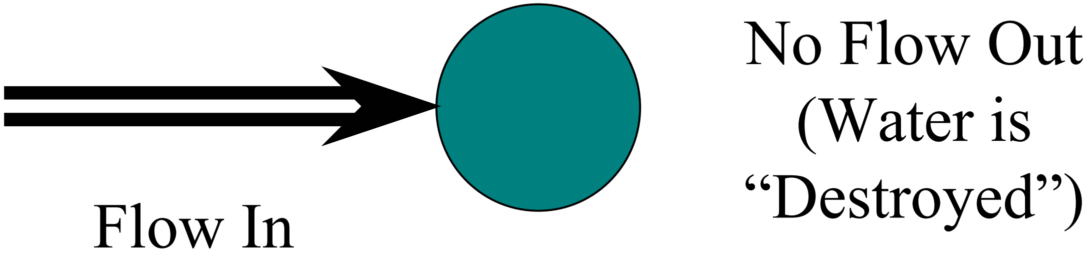
- We use an outflow node to remove any water from the system: This node type is used to ensure that we do not have water leave the system at any other nodes.

Outflow Node Diagram



Outflow

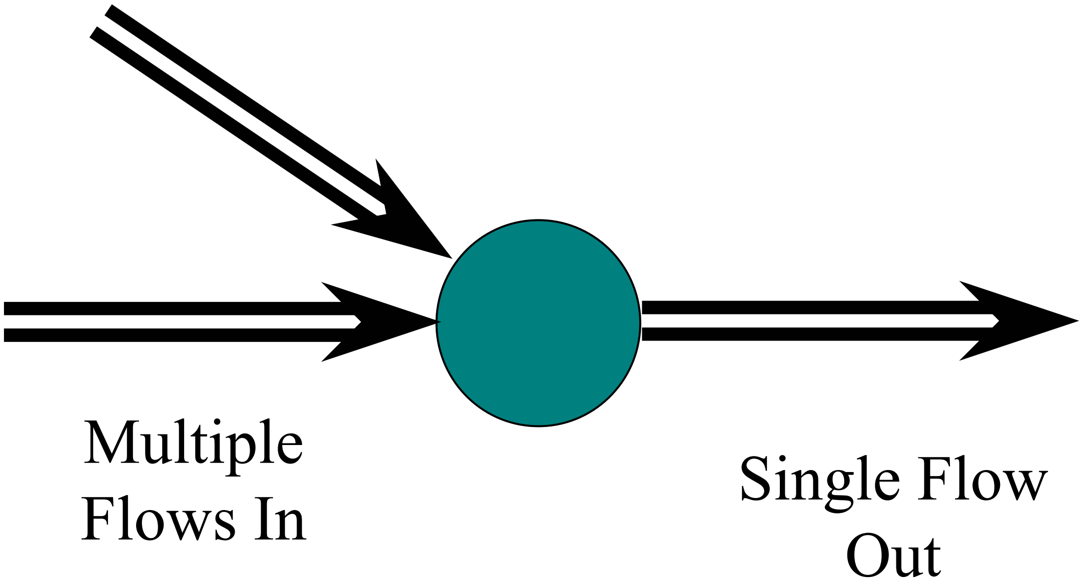
- All water that leaves the system must exit through an outflow node.
- An example of these edges is the San Joaquin River below PH4.



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 (this is not currently applied within the HydroBasin model).
- An example would be the Stevenson Confluence, where Stevenson Creek joins the San Joaquin River below Dam 6.

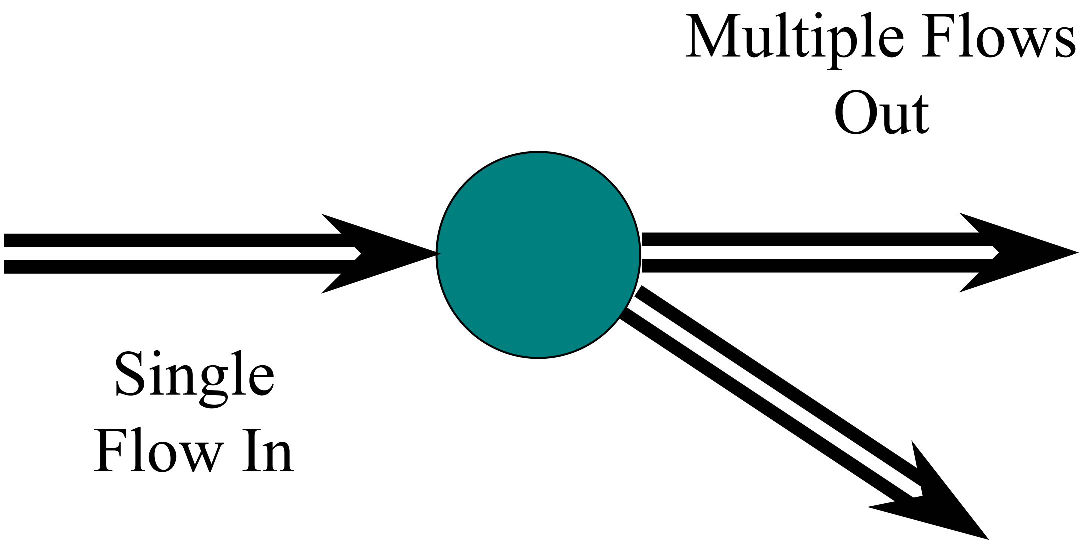
Confluence Node Diagram



Diversions

- This 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.
- An example of this type of node would be the Crater Creek diversion dam, where Crater creek inflow is split into the Crater conveyance and Crater creek.

Diversion Node Diagram



Reservoirs

- The six major reservoirs: Edison, Florence, Huntington, Shaver, Mammoth, and Redinger Lakes are represented in HydroBasin.
- Additionally, we model the Balsam Forebay, as a reservoir, since it can provide water to NF Stevenson Creek when it cannot be diverted from Huntington Lake through Tunnel 7.

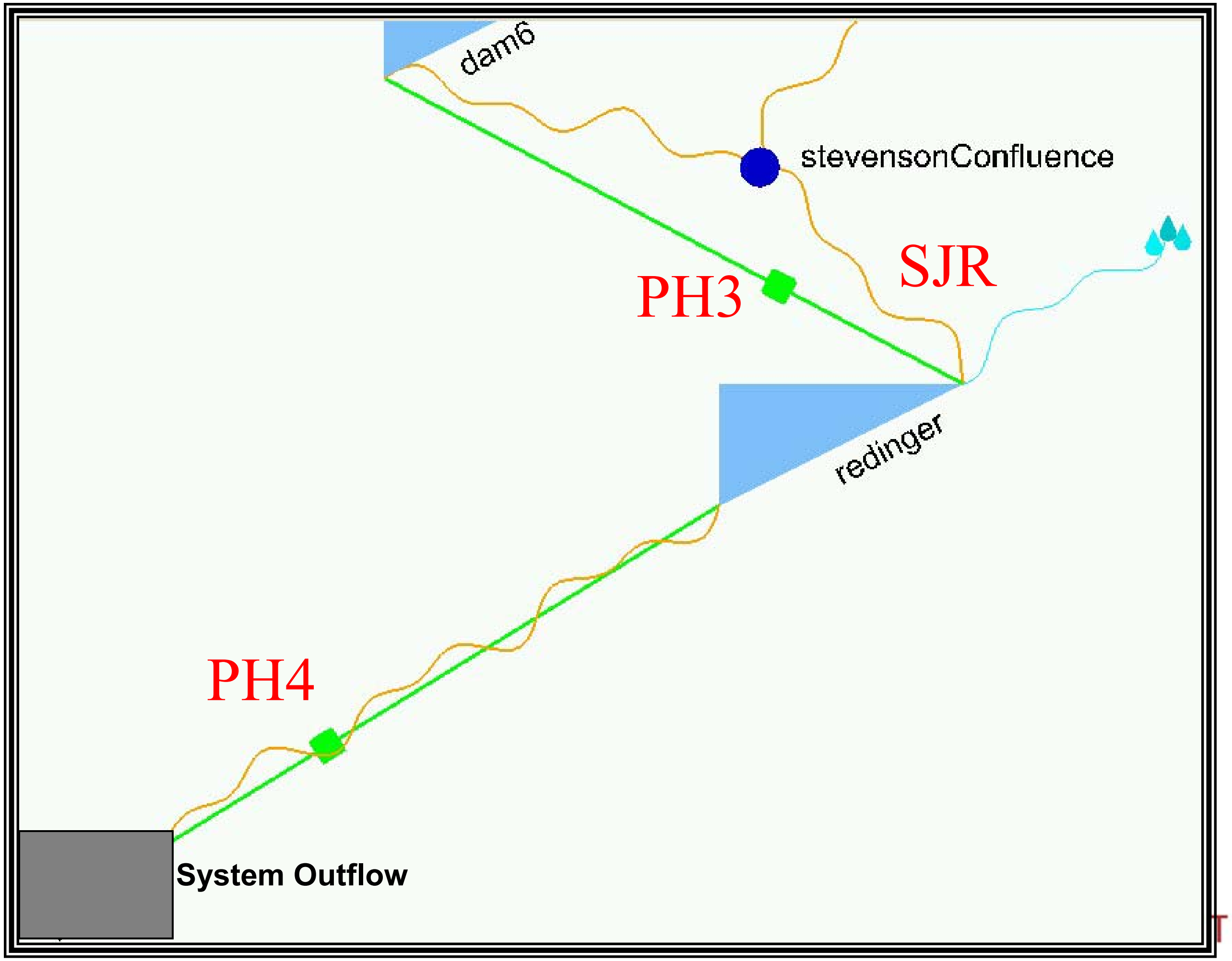
Why are Diversions and Reservoirs Different?

- While you could argue that all of the diversion dams have some storage capacity, most do not have the capacity to do more than detain flow for a short time.

Basic Reservoir Example

- A more complex example would be Redinger Lake, which has inflows from PH3, the San Joaquin River upstream of PH3.
- Outflows include PH4, and releases to the San Joaquin River below Redinger Lake.

Basic Reservoir Example



Physical Edges

An edge is the connection between two points

There are 6 Physical Edge Types:

- Inflow
- Outflow
- Streams
- Conveyances
- Powerhouses
- Storage

Inflow

- All water from the "outside" of the system must start at an inflow node.
- Examples of these edges would include the South Fork San Joaquin River above Florence Lake (external Florence) or Bear Creek above the diversion dam (external Bear)

Outflow

- All water that leaves the system must exit through an outflow node.
- An example of these edges is the San Joaquin River below PH4.

Streams

- The important thing about streams in a model is that they do not have a limit on how much water you can put into them.

- For example, during spill extremely large amounts of water may flow in the San Joaquin River.

Conveyances

- These are generally pipes, tunnels, or canals through which water flows.
- In general, a conveyance has a physical maximum to its 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 the channel will overflow and spill water into another drainage basin.

Powerhouses

- These are conveyances with a generator attached to them.
- Powerhouses have a physical maximum flow capacity.
- Examples include PH1 or Mammoth Pool Powerhouse.
- Each powehouse is treated as one entity
- Power is calculated by multiplying generator efficiency (in kWh/Acre foot) by volume of water passed through the generator per unit time.

Storage

- Water than can be stored in a basin (reservoir).
- It is represented by water volumes moving from the reservoir at one time period to the reservoir at the next time period by means of a storage edge.
- All of the major reservoirs are examples of this type of edge

Virtual Edges

Water usage is determined by purpose as much as it is defined by physical structure.

- Virtual Edges model the usage of water
- Each Physical edge will have 1 or more virtual edges associated with it
- Many virtual edge types can only be associated with a single physical edge type

Virtual Types

The virtual types include:

- Evaporation
- Inflow
- Outflow
- Power
- Release
- Spill
- Storage
- Transport

Technical Approach

Virtual Edge Examples

Streams have at least 2 virtual edges

- Release
- Spill

Some streams have a third virtual edge type

- Conveyance

Reservoirs have at least 3 virtual edges

- Minimum Storage
- Historic Storage
- Maximum Storage

BREAK

Technical Approach

- As an overview, what we do is put water in the "top" of the network and let it flow down the system until it comes out the "Bottom" of the network

Modeling Water Flows

- Inflows
  - Starting reservoir storage levels
    - based on USGS historic record for WY type
  - Inflows based on unimpaired flow data for WY type

- Outflows
  - Outflow SJR below PH4
  - Evaporation ????
  - Year End storage

Water Flow Rules

- The simple rule for water allocation:
  - For each node:

Water In = Water Out

- The two exceptions:
  - Inflow nodes are allowed to create water
    - But no water is allowed to enter them
  - Outflow nodes are allowed to remove water
    - Flow out of an outflow node is removed from the model

Priorities

- Priorities are how we ensure that the water is used appropriately, based on mandatory requirements and user priorities.

Priority Order

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

Physical Requirements and Processes

Examples

- Reservoirs that cannot be drained past a certain level will not physically allow you to divert water once they reach a minimum elevation
- Evaporation will take place regardless of other constraints or priorities, so this is the highest priority in reservoirs

Instream Flow Requirements (Minimum Instream Flows)

- Minimum instream flows are a very high priority.
  - If available, based on structural constraints,
  - Minimum instream flows are the highest release priority.
  - Other constraints would come next.

Instream Flow Requirements

- Most of the flow constraints that you enter into the HydroBasin modeling program will be treated as mimimum instream flows.
- These include instream flows, boating releases, geomorphic, and riparian flows.
- The model will use the highest instream flow constraint on each reach in each time step
- If this instream flow constraint is met, all of the smaller constraints are also met

Reservoir Storage Constraints

- If water is available after evaporation and minimum instream flows are met then minimum reservoir levels are the next priority.

Reservoir Storage Constraints

- There are a number of "As full as possible" license requirements.
- These are modeled by attempting to match historic reservoir levels as closely as possible.

Power and Conveyances

Basic Operation

- Once all the previous constraints have been met, the next priority is to generate power.
- The model emulates the historic operations of the Big Creek system in moving water and generating power by water year type.
- This is subject to modification by the higher priority uses (constraints).

Power and Conveyances

- This historic generation profile will change when additional constraints are put on the system
- Since power is a lower priority than constraints, the net effect of adding constraints is to reduce the amount of power generated.
- If changes in water availability occur from historic amounts, changes will occur to power generation that differ from historic levels.

Shifts in Generation and Conveyance Patterns

- Example:
  - A higher instream flow requirement in the SFSJR would cause more water to arrive at Mammoth Pool
  - Water above that required to match historic reservoir levels and MIFs will be used to generate power to the limit of the physical max of the MPPH.
  - However, this would result in less generation in the Huntington or Shaver Chains and an overall decrease in generation.

Additional Reservoir Storage

- Water not used to meet constraints, historic storage levels, maximum power, or conveyance amounts is used to fill reservoirs.
- From the previous example:
  - If a large amount of water was released to the SFSJR
  - Once MIFS were met and the MPPH was at maximum capacity
  - Then Mammoth Pool Reservoir would start to fill above its historic level.

Spill

- Any water entering a reservoir that would result in more water than the storage capacity and releases for MIF and flow capacity of an associated PH must be spilled.

Spill

- Continuing the previous example:
  - If the release from Florence continued to be above the levels at which MPPH could handle,
  - Then Mammoth Pool would continue to fill until it reached its capacity
  - At that point it would spill, and put any additional water into the San Joaquin River Below Mammoth Pool.

Time to Decide.

Model Differences from the Real World

- All models are simplifications of reality
- Both structure and process are simpler, but the objective is to reproduce important processes and structures in a representative manner.

Simplifications in the HydroBasin Model

There are some significant differences between the HydroBasin model and the way water moves in reality

- MPOA
- Water Storage
- Diversions
- Time Steps
- No Pumpback at EPS
- Junction "Overflows"
- Data complexity

MPOA

- Approximated with a simplified rule set.
- We do not apply the MPOA spring maximum storage levels
- Required end of year storage is based entirely on water year type end-of-year aggregate volume, as follows:
  - Critically Dry: 152,000 af
  - Dry: 202,500 af
  - Below Normal: 202,500 af
  - Above Normal: 325,000 af
  - Wet: 325,000 af

Water Storage

- In the real world water can be "stacked" on top of a reservoir, so that several feet of water is spilling over the top, and the actual storage of the reservoir is greater than its "maximum" capacity

- HydroBasin models spill events by "leveling off" all water above a reservoir's rated maximum storage so that spill events tend to be more abrupt than they are in reality.

Diversions

- Diversions divert "Perfectly" so that MIFs are exactly met
- Diversions will divert whenever possible
- "Perfect" diversions results in more water being moved to the Shaver/Huntington side of the network than in actual history, which slightly distorts the spill, storage and generation profiles
- Some Diversions (Tombstone and the Slide Creeks for example) currently have conveyance that are out of service.
  - These are modeled by setting the conveyance maximum to "0"
  - It is possible to "reactivate" these conveyances for modeling if needed

Time Steps

- HydroBasin operates on a weekly time step, with constraints calculated on a daily basis.
- As a result the reported volumes must be viewed in the context of weekly averages of daily values.
- This combination was determined to be an optimal balance between usefulness and calculation performance.
- As an example, a 7-day geomorphic flow may cause other constraints to fail when it is applied in a single week, and not cause these constraints to fail when split across 2 weeks. A further discussion of how constraints interact will follow.

No Pumpback at EPS

- The HydroBasin application does not model Pumpback at EPS from Shaver Lake.
- The net effect of the pumpback operation is to reduce total power generation while increasing peak period power availability.

Junction “Overflows”

- The Big Creek network is configured so that the sum of inflows into a junction can be greater than the capacity of the conveyance below the junction.
- That is more flow reaches the mouth of a conveyance than it can handle.
- An example would be the Mammoth Tunnel, if full of water, reaching Rock and Ross Creeks Junction and additional water being present for diversion.

Junction "Overflows"

- In such cases, it is possible to allocate more water to the node than it can physically move down the conveyance.
- For these cases, we have an "administrative" stream that "spills" water from the junction to the most appropriate stream node, to simulate the inability of the diversion dam to put the water into the conveyance in the first place
- In the previous example, flow that does not "fit" into the Mammoth Tunnel would spill to the SJR at the location of the junction.

BREAK

Data

- The HydroBasin Model uses data derived from several sources including:
  - Gaged flow data
  - Unimpaired estimates
  - Operations information
- We generate inflow data to many of the smaller diversions by allocating water based on relative drainage areas

Data

- Since all scenarios are processed using the same data, the differences between scenarios will be due to changes in the rules or constraints.
- Therefore, the results should indicate differences between baselines and test cases similar to the differences between actual scenarios in the real world.

Data

- Inflow data is derived from unimpaired estimates
- Storage levels are derived from USGS records
- We then generate a "Baseline" data set that is as close as possible to the historic reservoir profiles and spills
- We modify the inflows as necessary to achieve mass balance for each baseline water year

BREAK

Time to Decide.

Constraints

HydroBasin is designed to model the effects of applying new constraints to the Big Creek System.

This section will discuss:

- Which constraints are chosen
- How constraints are rolled up on a weekly time-step
- Implications of weekly constraint roll-up

Which Constraints are Chosen

- HydroBasin is configured to contain **all** of the existing License requirement constraints
- If you create a new constraint set there is an excellent chance that some of the user constraints chosen will coincide (in time) with existing constraints.
- In this case, the highest flow or storage constraint on each reach or reservoir (by total volume) for each day is selected.
- If this constraint is met, then all lower constraints also are met.

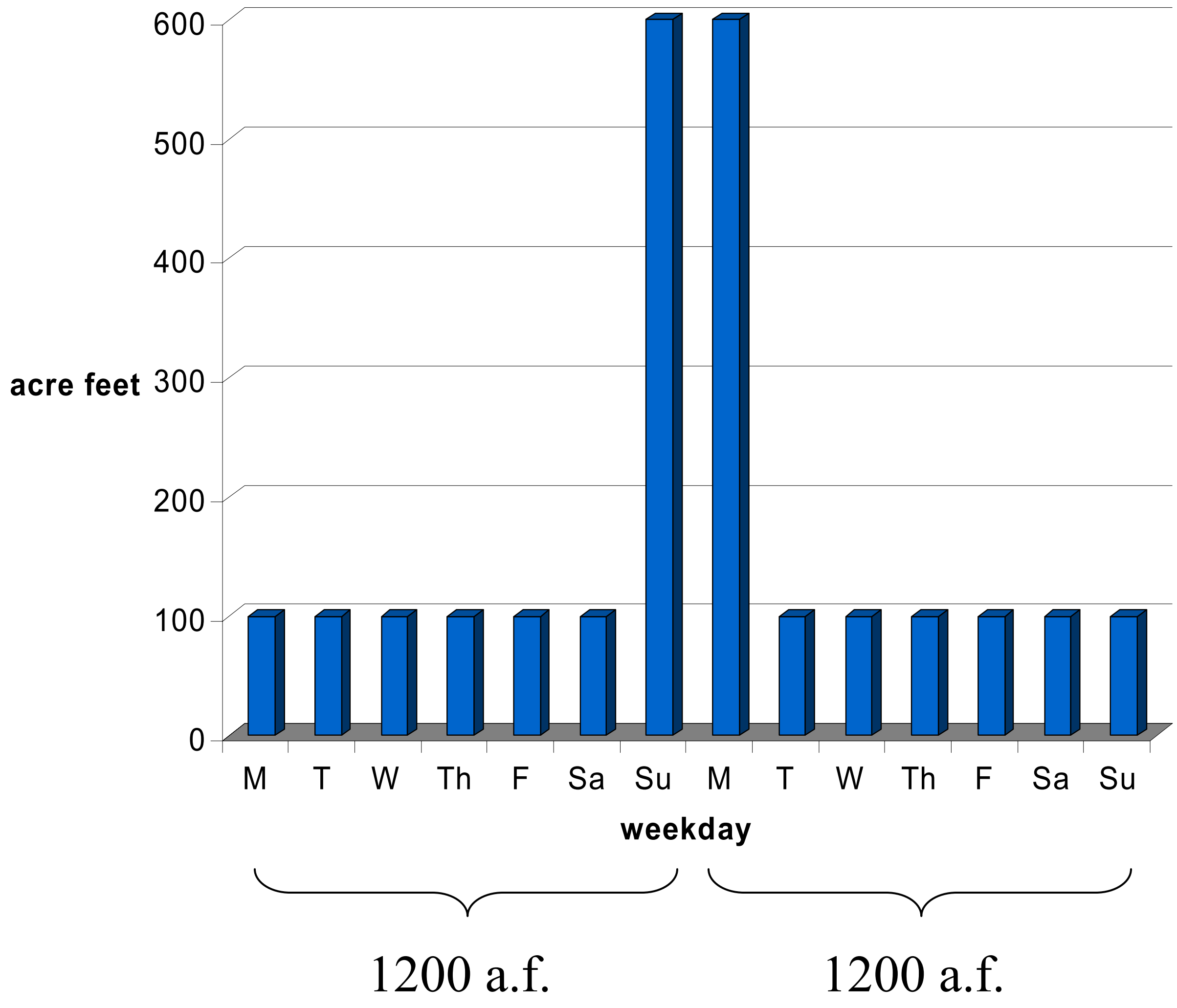
How Constraints are Rolled up to a Weekly Time Step

- HydroBasin is configured to use a weekly time step, and constraints are chosen on a daily time step, it is important to understand how they are rolled up to weekly constraints.
- Reservoirs use the largest constraint volume from the week
- Instream flows take the largest volume per day, and sum the total constraint volumes as the required weekly flow

Implications of Weekly Constraint Roll-Up

Example: Since instream constraints are rolled up to a weekly time step, the following slides indicate potential consequences

Example 1



600
500
400
300
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100
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acre feet
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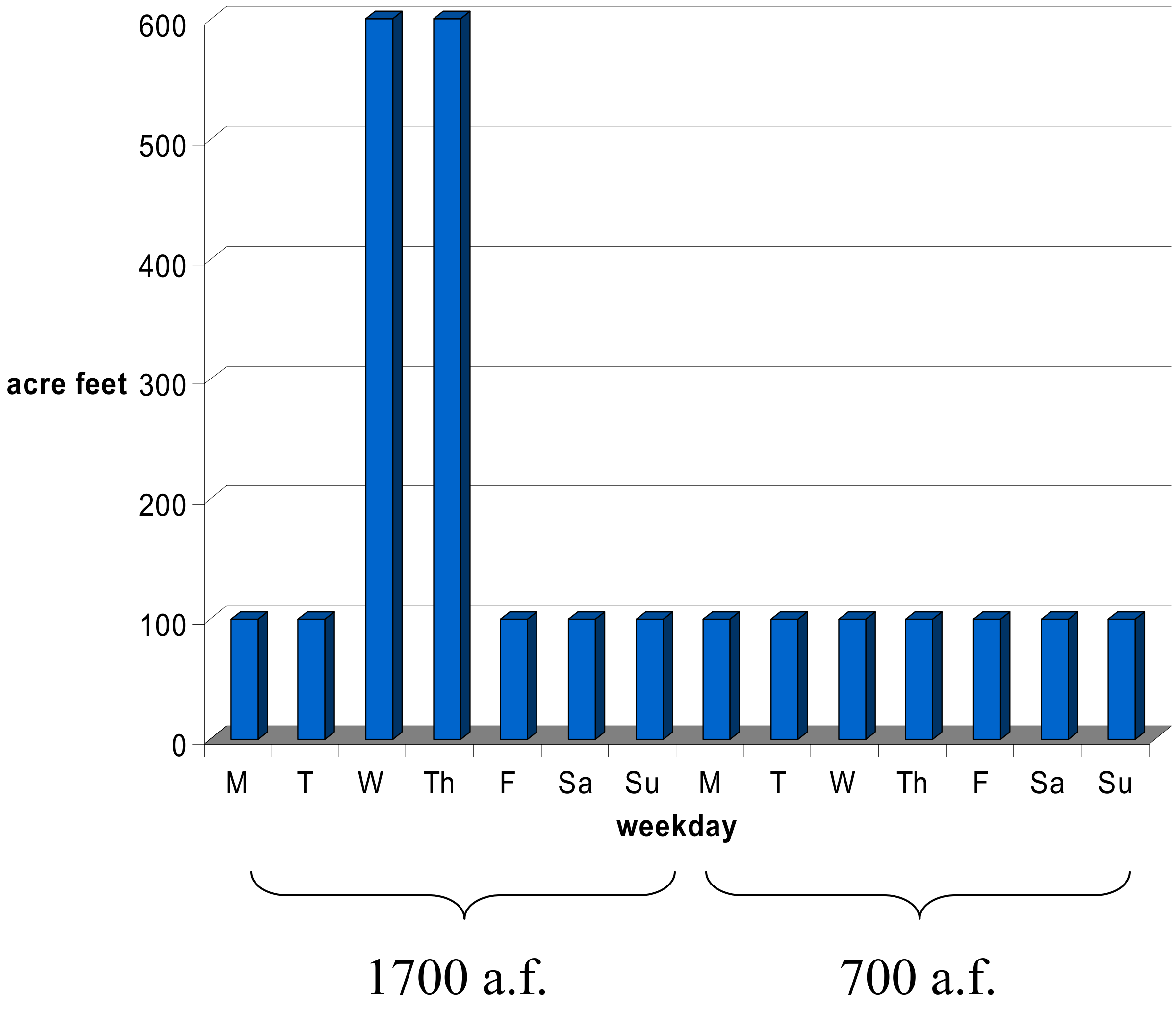
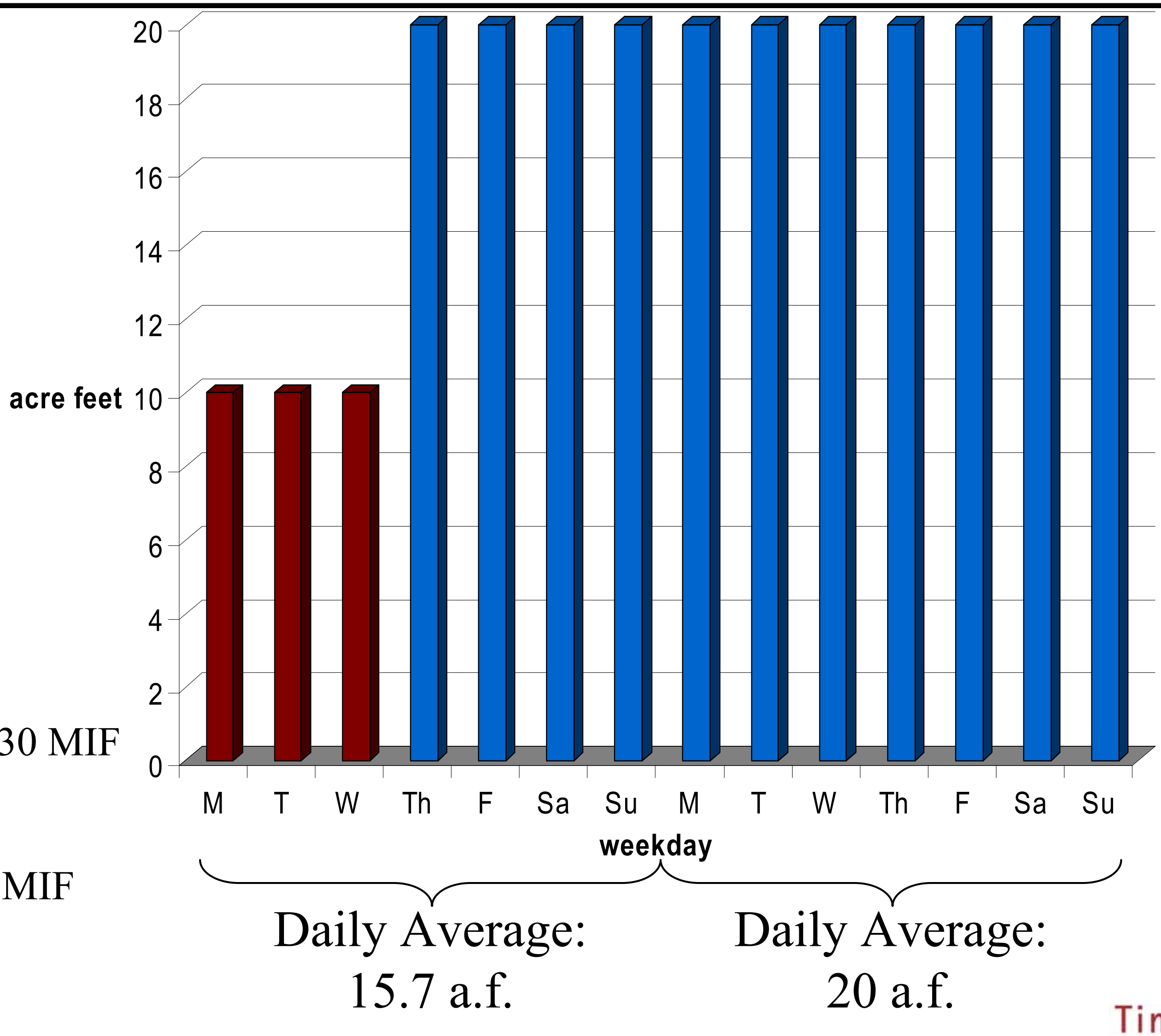
weekday
1200 a.f.
1200 a.f.

Example 2



Time to Decide.

Example 3



March 1 - April 30 MIF (5 cfs)

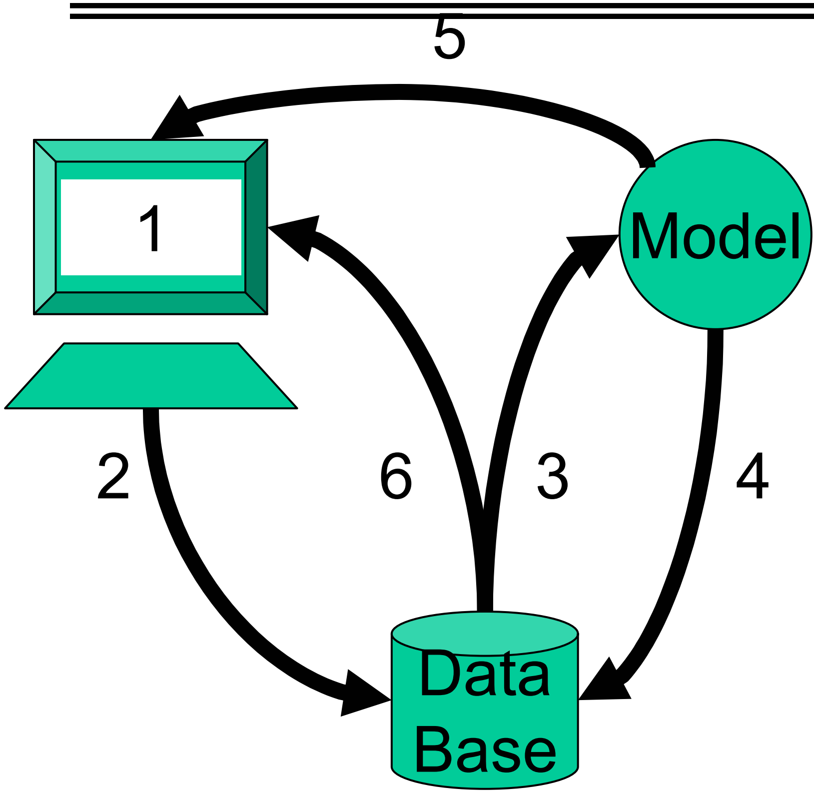
May 1 - Sept 30 MIF (10 cfs)

Time to Decide.

BREAK

HydroBasin Website

Website/Model Interaction



- Define constraints using Website
- Constraints are saved in a database
- Model runs using the constraints
- Model posts results in the database
- Model sends e-mail to confirming run
- View results using Website

HydroBasin Website

Set constraints/targets:

- Minimum Instream Flows
- Reservoir Constraints
- Boating Releases
- Geomorphic & Riparian Flows

Review results:

- Review Sample Scenarios

HydroBasin Mass Balance

Remember:

- Allocates water according to priorities
- Quits allocating when it runs out of water
- Makes sure “water in” = “water out”

HydroBasin Results

- Instream constraints missed
- Reservoir storage targets missed
- Instream constraints at full natural flow
- MPOA pass/fail
- Reservoir level profiles
- Power generation

Water Years

- Four representative water year types may be simulated
- These include*:
  - Wet
  - Above Normal
  - Dry
  - Critically Dry

* No Below Normal WY occurred in the 1983-2002 period used

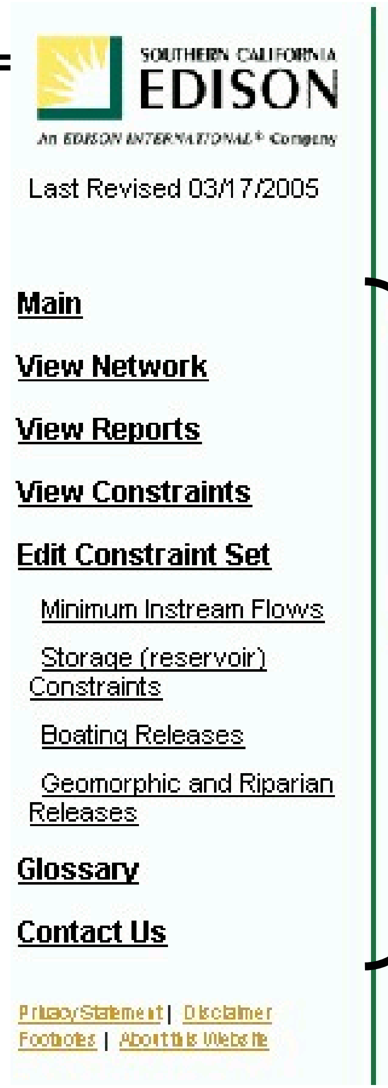
BREAK

Web Site Preview for Stakeholders

HydroBasin

- Web access requires MS Internet Explorer 6
- Has high speed connections to the internet
- Only available to registered users with passwords

Website Navigation



Navigation

Network Viewer

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Last Revised 03/17/2005

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  - Boating Releases
  - Geomorphic and Riparian Releases
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HydroBasin Network Viewer

Click on an element in the network diagram below to learn about it

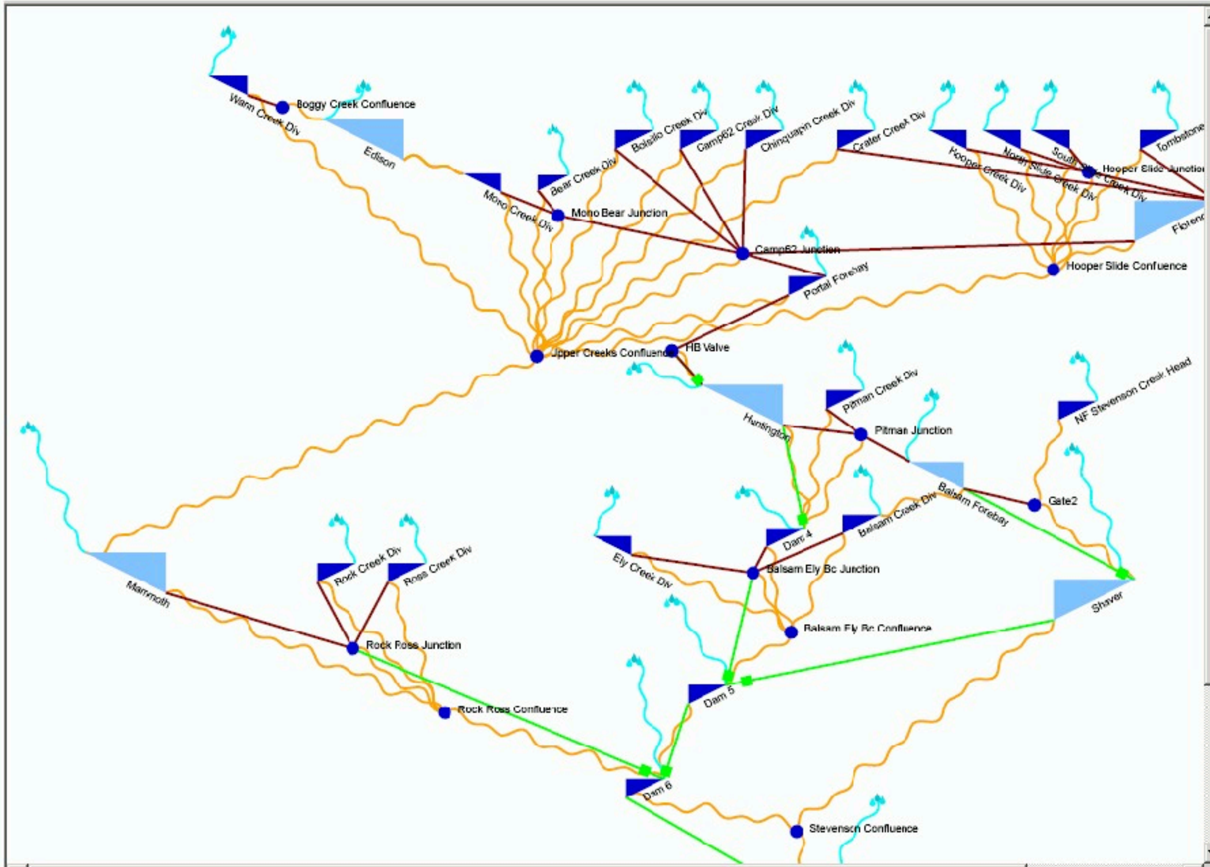
Click for more information

Ctrl-Left Click to Zoom In

Shift-Ctrl-Left Click to Zoom Out

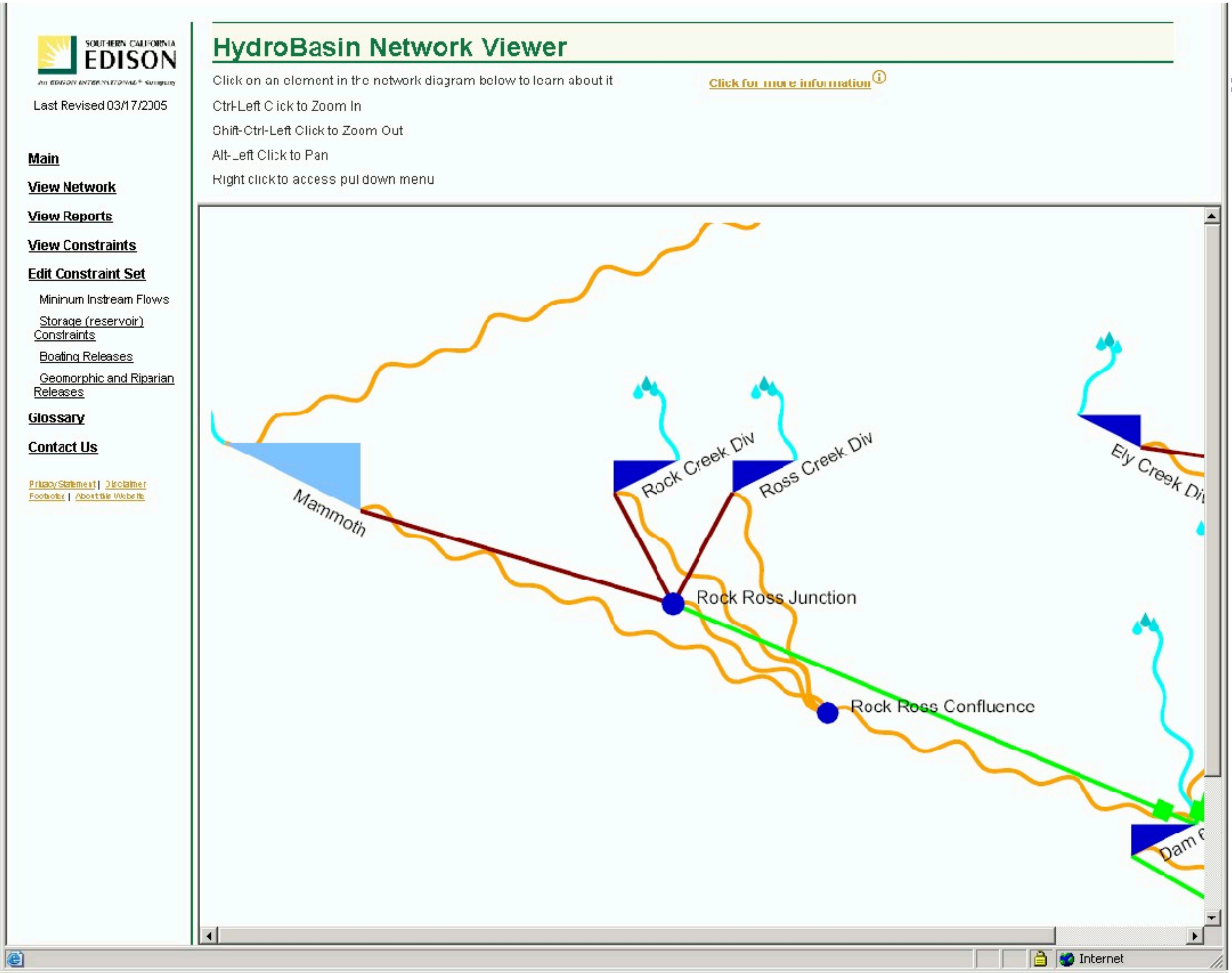
Alt-Left Click to Pan

Right click to access pull down menu



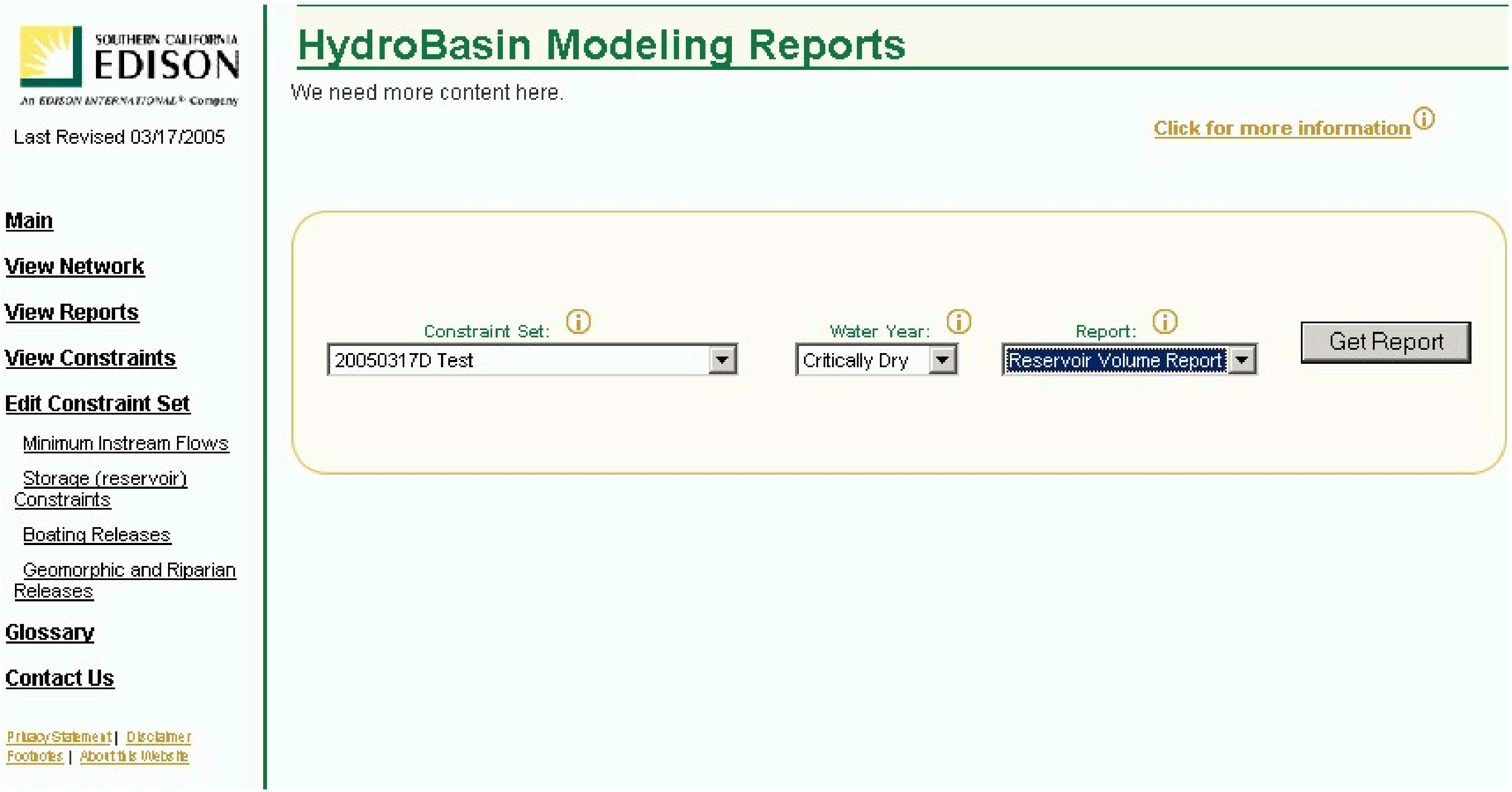
Time to Decide.

Network Viewer Zoom



Time to Decide.

Accessing Reports



Example Report (Reservoir Volume)

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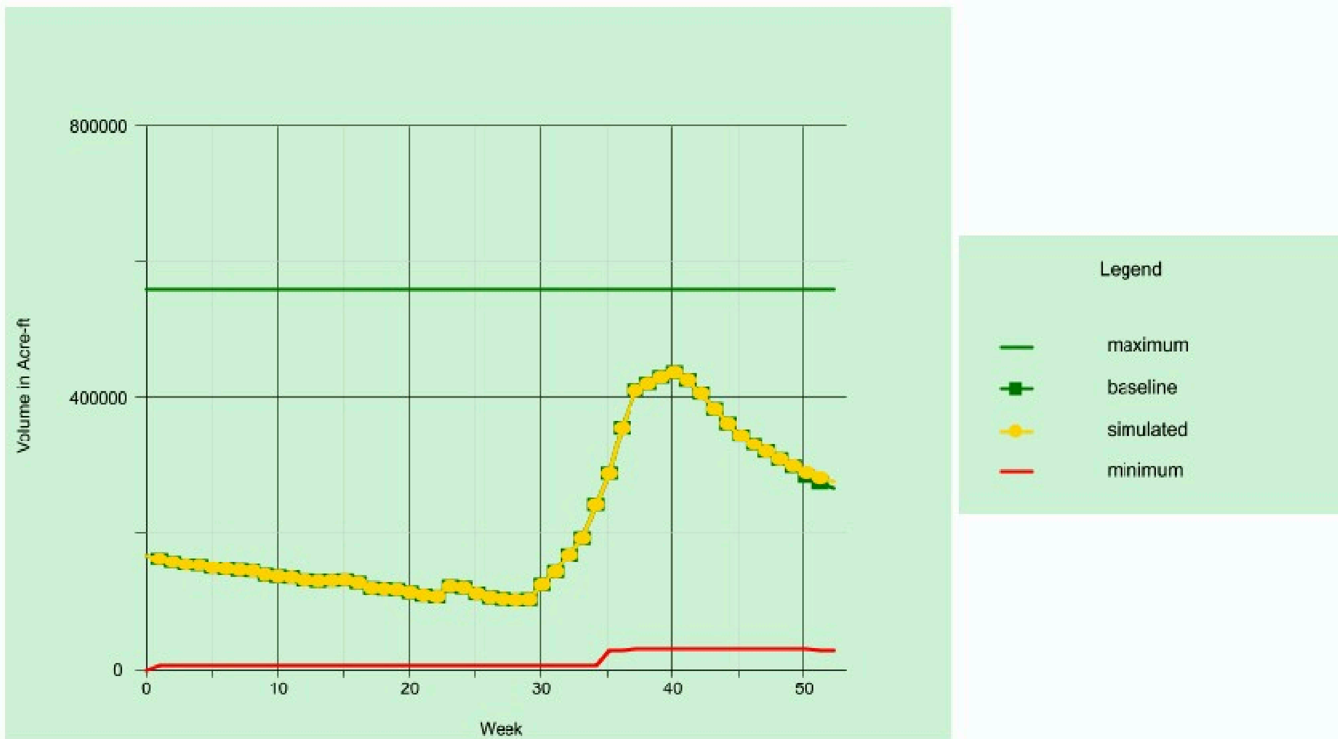
HydroBasin Modeling Reports

Select Another Report

Note that these charts are for USGS water years, and run from October 1 to September 30

All Reservoir Volumes



Edison Volume

Selecting & Viewing Constraint Sets

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Select and View Constraint Sets

We need some text here to introduce visitors to the constraints.

Click for more information

Constraint Set: Rollout Baseline (No Constraints)

Get Constraint Set | Copy and Edit Constraints

Minimum Instream Flow Constraints

There are no minimum instream constraints in the current selection.

Minimum Reservoir Storage Constraints

There are no minimum reservoir volume constraints in the current selection.

Rafting Release Constraints

There are no rafting flow constraints in the current selection.

Flushing Flow Constraints

There are no flushing flow constraints in the current selection.

Viewing Constraint Sets

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Select and View Constraint Sets

We need some text here to introduce visitors to the constraints.

Click for more information

Constraint Set: 20050317C Test

Get Constraint Set | Copy and Edit Constraints

end-to-end test of website

Minimum Instream Flow Constraints

Constraint Name	Location	Start Date	End Date	Flow (cfs)
MIF Test	Big Creek Below Dam 4	Oct 01	Sep 30	10

Minimum Reservoir Storage Constraints

Constraint Name	Location	Start Date	End Date	Volume (acre-ft.)
Test Storage	Florence	Jun 01	Sep 30	22000

Rafting Release Constraints

Constraint Name	Location	Start Date	Release Length (hours)	Target Rate (cfs)	Max. Peak Rate (cfs)	Ramp Up Rate (cfs/hour)	Ramp Down Rate (cfs/hour)
Test Boating	San Joaquin River Below Mammoth Pool	Oct 01, Midnight	5	800	1000	100	150

Flushing Flow Constraints

There are no flushing flow constraints in the current selection.

to Decide.

Submitting Constraints for Processing

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Edit Constraints and Submit for Processing

Click for more information

Name for new constraint set: 20050317C Test copy

Description of new constraint set: Copied by smartin from Published by smartin:20050317C Test

Submit Constraint Set

Minimum Instream Flow Constraints Edit

Constraint Name	Location	Start Date	End Date	Flow (cfs)
MIF Test	Big Creek Below Dam 4	Oct 01	Sep 30	10

Minimum Reservoir Storage Constraints Edit

Constraint Name	Location	Start Date	End Date	Volume (acre-ft.)
Test Storage	Florence	Jun 01	Sep 30	22000

Rafting Release Constraints Edit

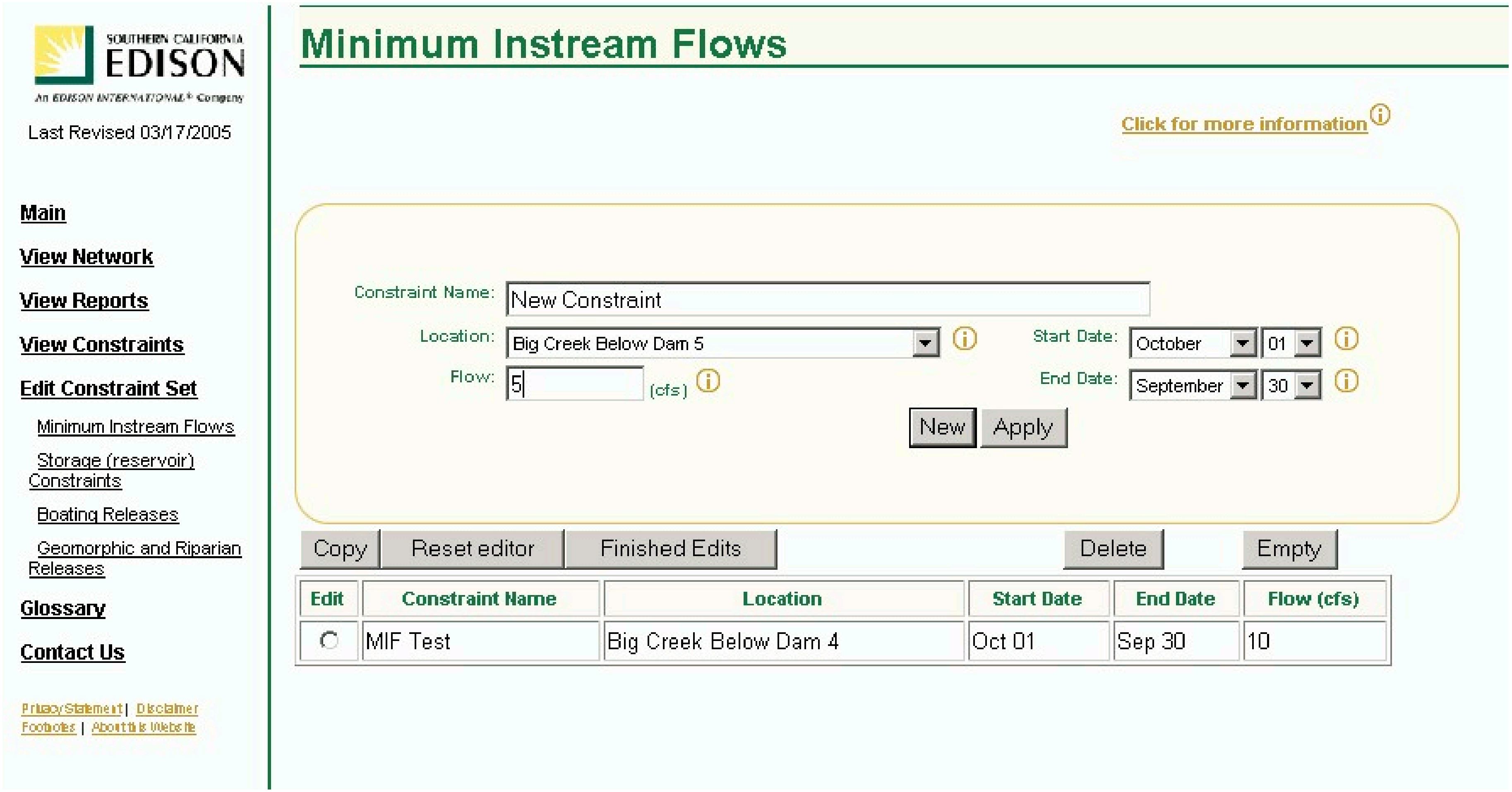
Constraint Name	Location	Start Date	Release Length (hours)	Target Rate (cfs)	Max. Peak Rate (cfs)	Ramp Up Rate (cfs/hour)	Ramp Down Rate (cfs/hour)
Test Boating	San Joaquin River Below Mammoth Pool	Oct 01, Midnight	5	800	1000	100	150

Flushing Flow Constraints Edit

There are no flushing flow constraints in the current selection.

to Decide.

Setting Minimum Instream Flows



Setting Minimum Instream Flows

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Minimum Instream Flows

Click for more information

Constraint Name: New Constraint

Location: Big Creek Below Dam 5 | Start Date: October 01

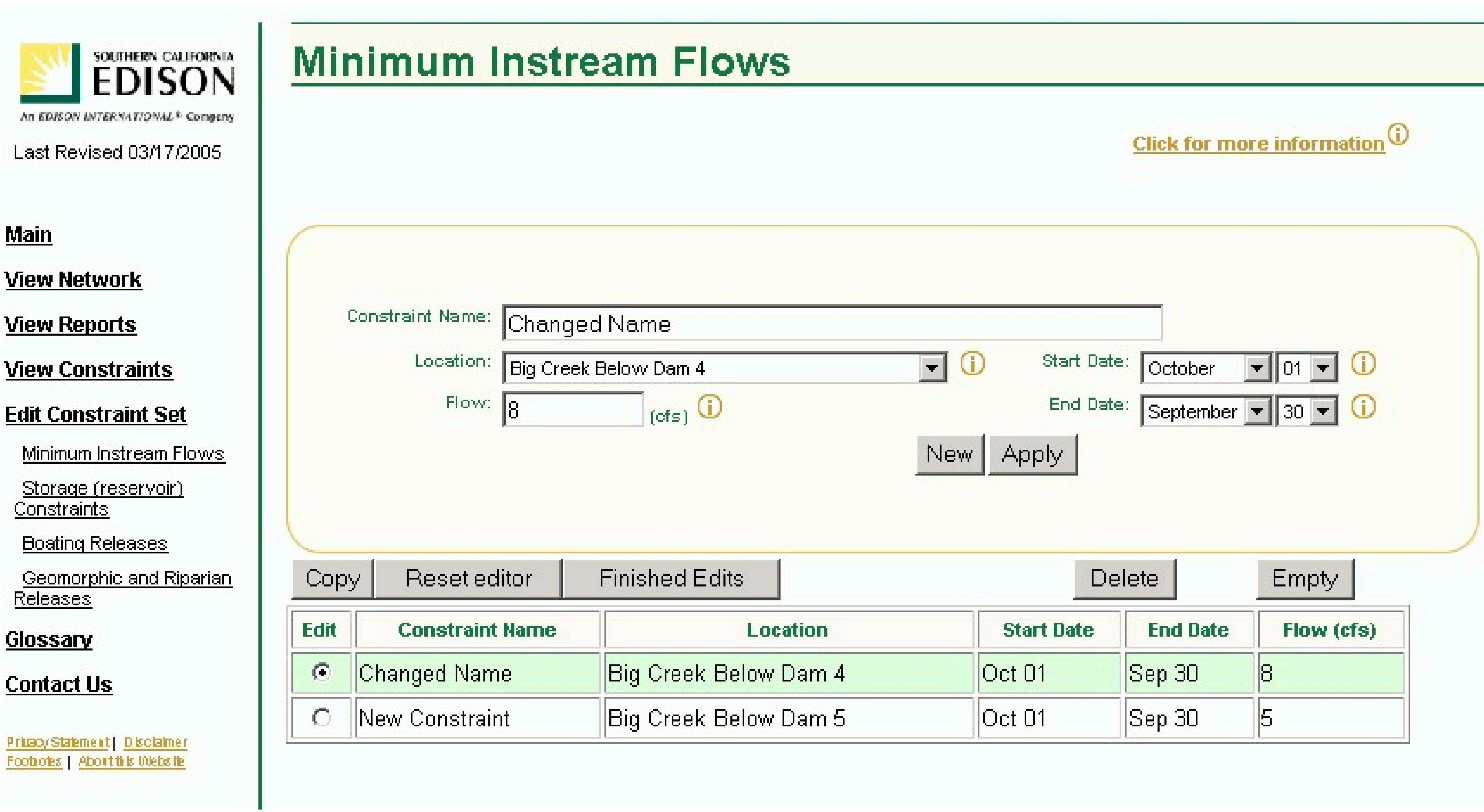
Flow: 5 (cfs) | End Date: September 30

New | Apply

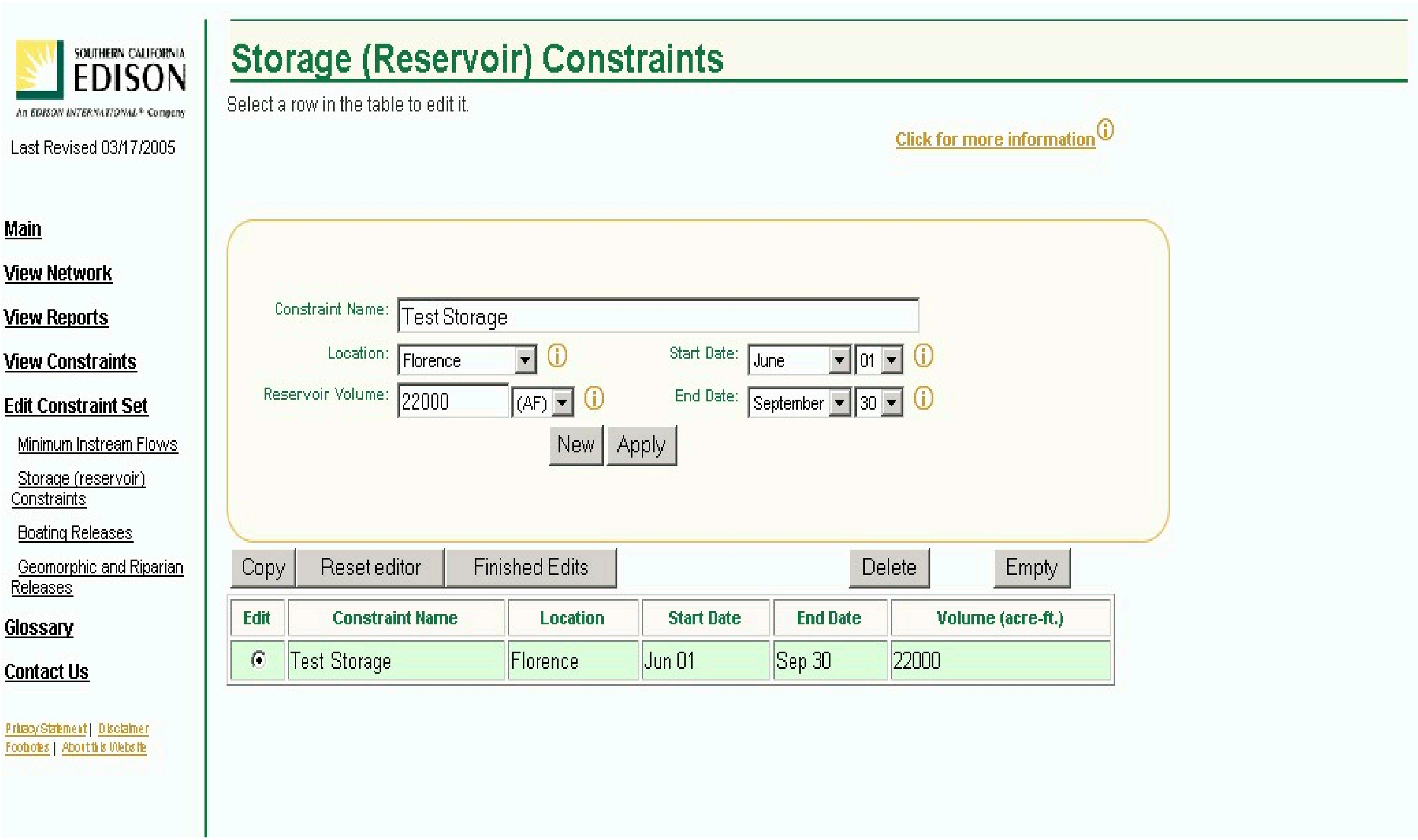
Copy | Reset editor | Finished Edits | Delete | Empty

Edit	Constraint Name	Location	Start Date	End Date	Flow (cfs)
○	MIF Test	Big Creek Below Dam 4	Oct 01	Sep 30	10
◉	New Constraint	Big Creek Below Dam 5	Oct 01	Sep 30	5

Editing Minimum Instream Flows



Storage (Reservoir) Constraints



Time to Decide.

Boating Releases

Southern California EDISON
An EDISON INTERNATIONAL® Company

Last Revised 03/17/2005

Boating Releases

Click for more information

Constraint Name: Test Boating

Location: San Joaquin River Below Mammoth Pool

Date: October 01 Midnight

Release Length: 5 (hours)

Ramp Up: 100 (cfs/hr.)

Target Flow Rate: 800 (cfs)

Ramp Down: 150 (cfs/hr.)

Maximum Flow Rate: 1000 (cfs)

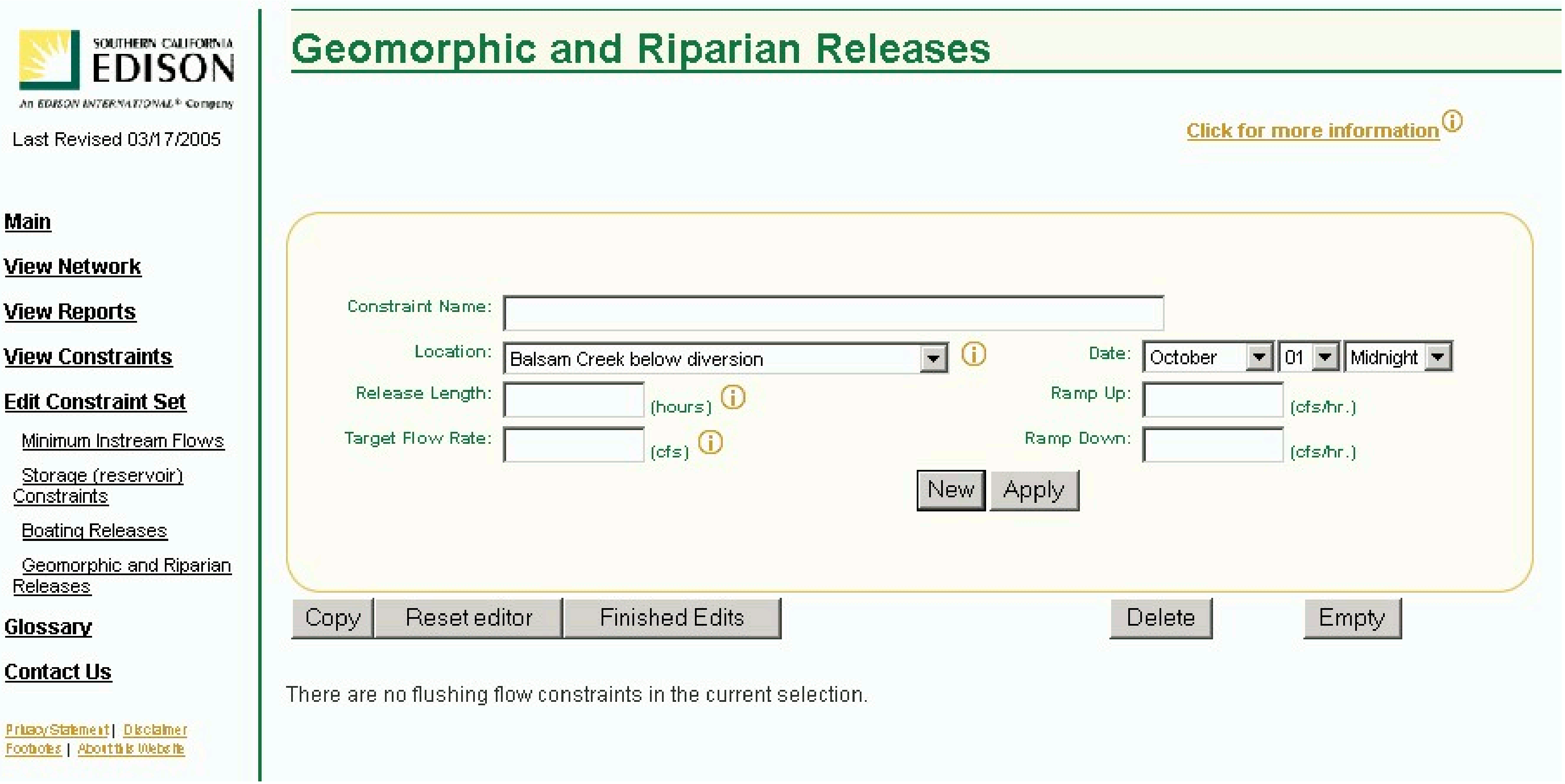
New | Apply

Copy | Reset editor | Finished Edits | Delete | Empty

Edit	Constraint Name	Location	Start Date	Release Length (hours)	Target Rate (cfs)	Max. Peak Rate (cfs)	Ramp Up Rate (cfs/hour)	Ramp Down Rate (cfs/hour)
⦿	Test Boating	San Joaquin River Below Mammoth Pool	Oct 01, Midnight	5	800	1000	100	150

Time to Decide.

Geomorphic & Riparian Releases



Time to Decide.

Website Demo/Training

- Web site training is scheduled for the week of April 11th
- Provide user names and passwords to Kearns & West