SIMULATING OPERATIONS IN THE TRUCKEE-CARSON RIVERWARE SYSTEM

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Abstract
A Truckee-Carson Basin RiverWare operations model has been developed by the Lahontan Basin Area Office of the United States Bureau of Reclamation. This model simulates operations within the Truckee and Carson basins according to all current basin policy including the 1935 Truckee River Agreement, the 1944 Orr Ditch Decree, the 1959 Tahoe Prosser Exchange Agreement, the 1994 Interim Storage Agreement, and 1997 OCAP. An overview of the model will be presented, and examples of specific operations within the system will be explored.

The model runs on a daily timestep from the current time through the end of the calendar year. The model was developed in RiverWare© and includes a physical model of the basin comprised of objects and links, as well as a ruleset that prescribes the operational policy and physical constraints on the system. RiverWare's simulation process will be described and its rule writing interface and language will be demonstrated. Several representative objects from the physical model will be highlighted, and sample rules will be reviewed.

Currently, the operations model is being substantially revamped to simulate the Truckee River Operating Agreement (TROA). TROA is an innovative, flexible operating agreement between the significant stakeholders in the Truckee-Carson Basin that allows for extensive exchanging and trading within the basin reservoirs. TROA presents many modeling challenges to the RiverWare modeling system as well as the LBAO modelers. A brief introduction to the fundamentals of TROA will be given, followed by a survey of the many modeling intricacies that TROA requires.

INTRODUCTION

Area of Study
While two separate river basins, the Truckee and Carson basins are often considered as a single river basin for the purposes of water management and modeling. The primary reason for this is due to the Truckee Canal, which brings Truckee River water to the Carson River basin. The Truckee River flows from the outlet of Lake Tahoe in the Sierra mountain range of California to its terminus at Pyramid Lake in the desert plains of Nevada. The river is approximately 105 miles long, and contains two distinct regions with differing physical characteristics. In the lower portion of the basin, the river slows progressing towards its terminus, passing through the metropolitan areas of Reno-Sparks before terminating in Pyramid Lake. The Carson River also originates in California, but as two main forks, an east fork and a west fork. The two forks are largely unregulated by reservoirs, but are regulated by irrigation diversions as flows reach Nevada. The two forks join in the Carson Valley of Nevada, where significant irrigation diversions regulate the flow of the Carson River. The river passes near Carson City before flowing into Lahontan Reservoir. Prior to the development of the Newlands project downstream of Lahontan Reservoir, the Carson River reached its terminus at Carson Lake. With the Newlands Project, the vast majority of the storage in Lahontan Reservoir is used to meet water rights for the project. The upper portions of the Truckee and Carson River basins are characterized by cold, rapid flowing water in mountainous valleys and canyons. These portions of the basin receive the majority of precipitation reaching the basin, and thus produce the majority of the runoff. A map of the Truckee-Carson Basin is shown in Figure 1.

There are seven significant storage reservoirs located in the upper reaches of the Truckee River in California. These reservoirs control approximately 70% of the flow in the Truckee River. Two are owned by private interests to provide water storage for the cities of Reno and Sparks and the Truckee-Carson Irrigation District for irrigation in the Newlands Project. One is a flood control reservoir owned by the US Army Corps of Engineers (COE). The remaining four are Bureau of Reclamation (BOR) facilities used to provide storage for agricultural irrigation, municipal use, industrial use, and endangered fish in Pyramid Lake. There are two large structures on the main stem of the river. These are Derby Diversion Dam and

Marble Bluff Dam. Derby Diversion Dam is located downstream of Reno, and provides irrigation water for the BOR's Newlands Project. Additionally, water taken from the Truckee at Derby Dam flows into Lahontan Reservoir on the Carson River, and is used to irrigate agricultural lands in the Carson basin as well as supply water to a wildlife refuge. Marble Bluff Dam was constructed to check the downcutting and erosion of the river channel upstream from Pyramid Lake (Rieker et al, 2005).

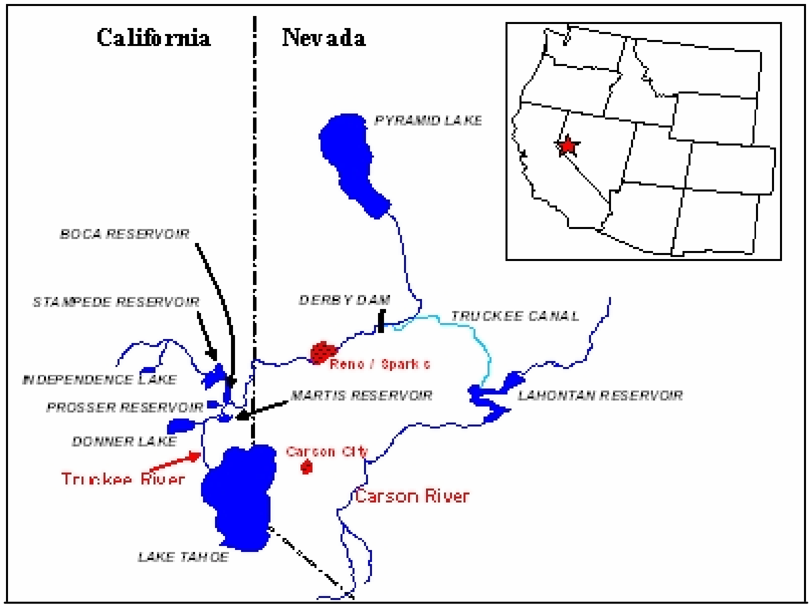


Figure 1. Map of Truckee-Carson Basin

RIVERWARE OPERATIONS MODEL

RiverWare Modeling Within Truckee-Carson Basin

RiverWare© is a comprehensive reservoir and basin modeling system that is ideal for modeling complex river and reservoir operations. RiverWare provides a generalized modeling environment for building basin-specific river and reservoir models (Zagona et al., 2001). RiverWare operations models have been applied to several river basin projects including Bureau of Reclamation (BOR) projects In the Colorado, Upper Rio Grande, and Yakima River basins. The Truckee-Carson RiverWare Modeling System is currently being developed by the BOR for water accounting, forecasting, operations/scheduling, and long-term planning for river and reservoir operations within the Truckee-Carson River System (Rieker, et al., 2005). The Truckee-Carson RiverWare Modeling System is made up of three separate RiverWare models: a water accounting model, a hydrologic forecasting model, and a river-reservoir operations model, as shown in Figure 2.

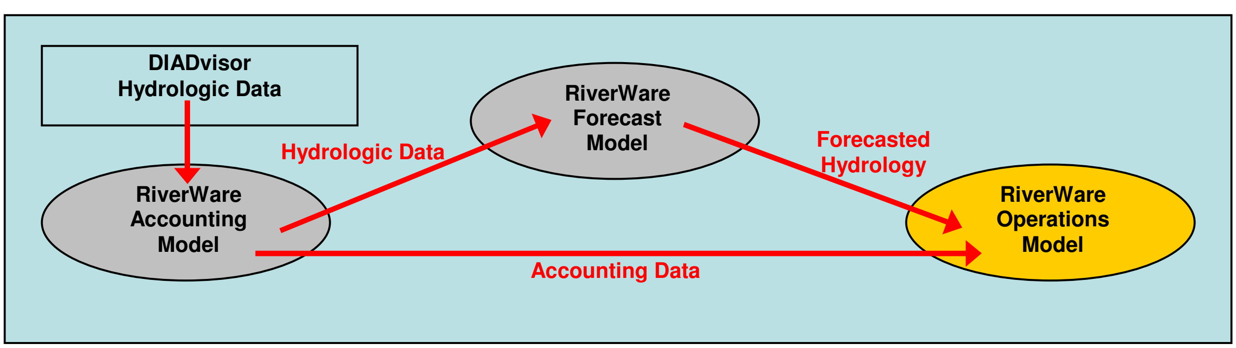


Figure 2. Schematic of Truckee-Carson RiverWare System

The three models, while separate, are linked together as a system for the purpose of water accounting, forecasting, scheduling, and long-term planning for Truckee-Carson Basin river and reservoir operations. The system is currently under development, and is intended to be used for implementation of the new basin operating policy, the Truckee River Operating Agreement (TROA). The current RiverWare system simulates current basin policy, and is being used for water-supply and operations forecasting. Development work is focusing on combining the accounting and operations models into a single accounting-operations model, as well as construction a TROA ruleset. The forecasting and accounting models are described in greater detail by related papers submitted to the 2006 Federal Interagency Hydrologic Modeling Conference (Mann, 2006; Boyer, 2006).

Model Workspace

Within the RiverWare modeling environment, the basin is physically represented and flows are simulated within the model workspace. Figure 3 shows a section of the Operations Model workspace.

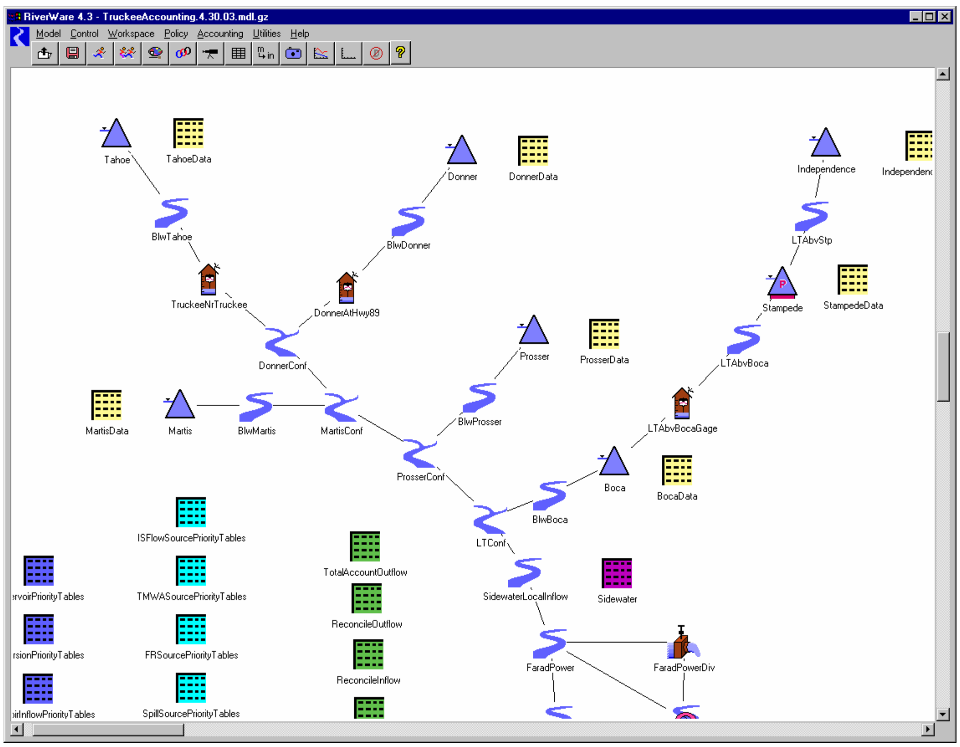


Figure 3. Portion of RiverWare Operations Model Workspace

Objects on the workspace represent reservoirs, reaches, confluences, diversions, power generating facilities, water users, and store all physical and accounting data. The objects are linked and the simulation process involves simulating the flow of the Truckee and Carson Rivers from upstream to downstream. Each object has engineering methods that govern how the water is simulated to flow across the object. Conveyance loss methods, lateral inflows, seepage methods, and accounting methods are specified for each of the objects. The objects can be arranged on the workspace to visually mimic the actual layout of the basin. This provides for a very intuitive and flexible representation of the modeled Truckee-Carson Basin.

Ruleset

The Truckee-Carson Basin RiverWare Operations model also consists of a ruleset. This ruleset characterizes the basin policy that governs the operations within the basin. Decrees, agreements, physical constraints, and other operational criteria are represented in the model's ruleset. Figure 4 shows a portion of the Operations Model ruleset.

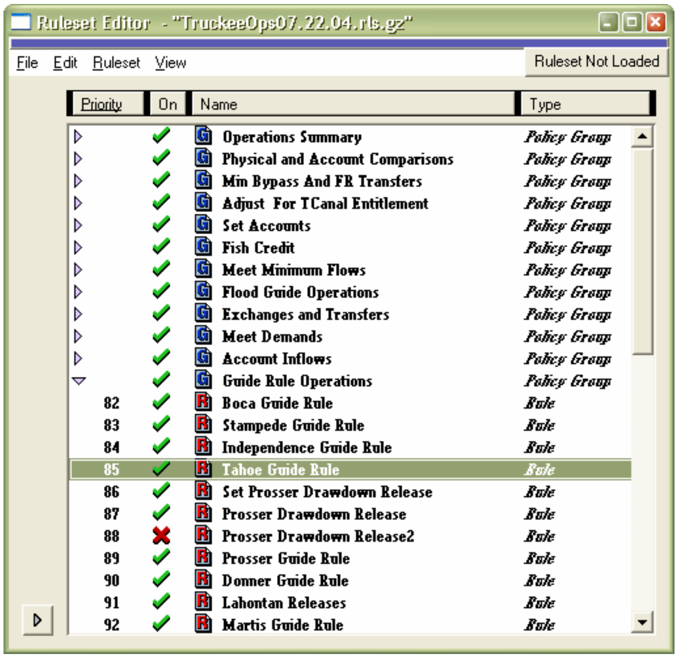


Figure 4. Portion of RiverWare Operations Model Ruleset

Rules are written in the RiverWare scripting language. The rules are arranged in priority order such that the highest priority rules are at the top of the rule set and the lowest priority rules are at the bottom. During each timestep of the simulation, the model starts at the bottom of the ruleset and "fires" the rules, one at a time from bottom to top. Because each successive rule the model processes as it works its way up the ruleset is of higher priority than those previously processed, it will overwrite any values previously set for that day. For instance, the release from a reservoir may initially be set according to a guide rule that prescribes a desired elevation value for a given date. Another, higher priority rule may be encountered later (higher up in the ruleset) that prescribes a higher release in order to meet a downstream demand. Finally a still higher priority rule may require a reduction in the release value in order to accomplish an exchange or in lieu of release with another reservoir. In this way, the higher priority rules have the last opportunities to change releases and other operations in the system. One timestep consists of firing each rule in the ruleset and then simulating the resulting flows within the linked physical model. Rules not only control the physical operations in the model; the accounting that is done in each timestep after the physical flows are set is accomplished with rules as well. Figure 5 shows an example of a rule written in the RiverWare Policy Language (RPL).

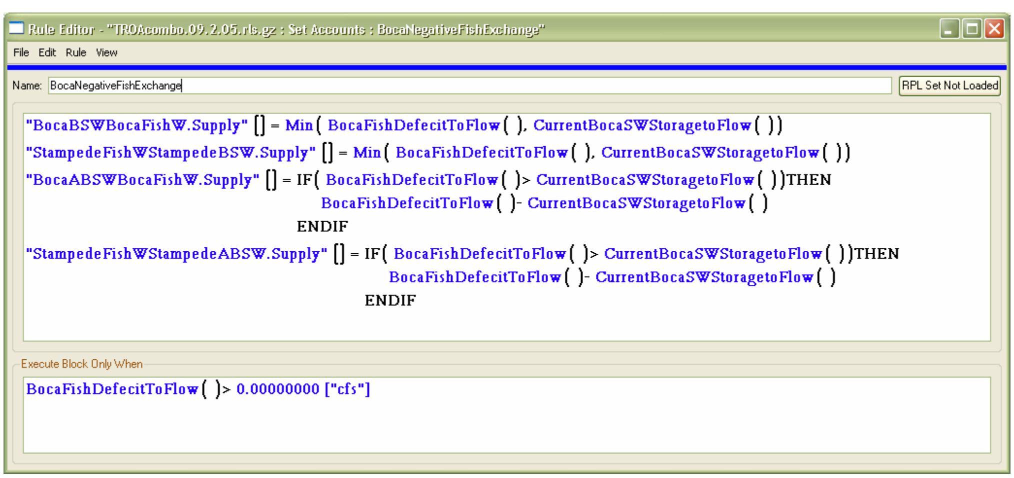


Figure 5. Example RiverWare Rule

Basin Operations

Operating policy within the Truckee-Carson Basin is a complex matrix of decrees, court orders, federal rules, and even informal agreements among the major basin water users. The major pieces of policy that govern the operations within the basin and a brief summary of their contents are as follows:

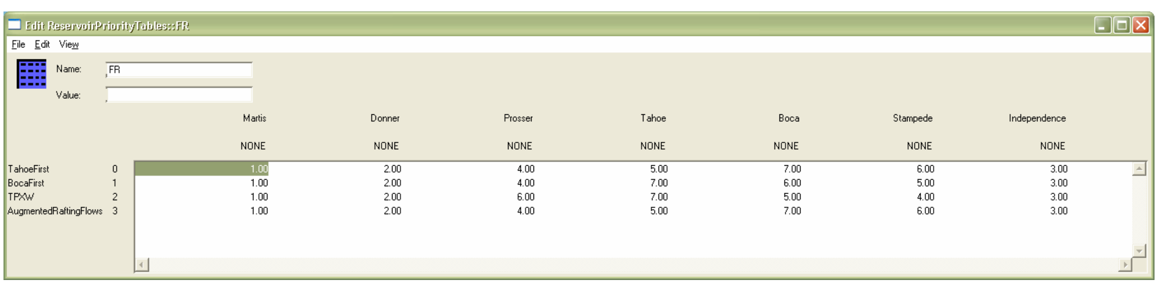
1. 1935 Truckee River Agreement – Defined the Floriston Rate in its current form and how it is to be met.
2. 1944 Orr Ditch Decrree – Adjudication of all Truckee-Carson water rights. Assigned priority dates to water rights.
3. 1943 Donner Lake Agreement – Divided Donner Lake storage rights between the Truckee-Carson Irrigation District (TCID), and Sierra Pacific Power Company (now TMWA).
4. 1959 Tahoe Prosser Exchange – Lake Tahoe minimum releases not needed to meet Floriston Rates are stored or exchanged for storage in Prosser Reservoir.
5. 1994 Interim Storage Agreement – Sierra Pacific (TMWA) allowed to store private water in Federal Reservoirs (Boca and Stampede).
6. 1997 Adjusted OCAP – Governs diversions from the Truckee River to the Newlands project along the Truckee canal. Minimizes use of Truckee River to meet Carson Division water rights.

Each of these pieces of policy and their entire contents are represented in the ruleset.

Floriston Rate Example

There are several major demands which in conjunction with the natural unregulated flow in the basin dictate the flows in the river. These demands are met according to a strict priority system among the sources of water. Some of the demands include endangered species flows, Truckee Canal entitlement, and Orr Ditch water rights. Each of the seven upstream storage reservoirs has a designated purpose (or project water) that defines the demands for which it can store and release water. As a result, the RiverWare model simulates operations using a generalized priority based algorithm for meeting demands. This procedure is summarized below.

The fundamental piece of policy driving operations within the system is maintenance of the Floriston Rate. The Floriston Rate is a minimum rate of flow within the Truckee River at the California / Nevada state line. During the times of the year when unregulated flows in the California portion of the Truckee basin are not sufficient to maintain Floriston Rates, releases from the seven upstream storage reservoirs must make up the difference, subject to numerous restrictions and sub-policies. In order to model this process, a priority system to meet this demand is invoked. In RiverWare, each of the seven storage reservoirs is placed in a priority table and assigned a priority according to policy. With regards to the Floriston Rate demand, there are several different scenarios, each of which has a different set of priorities based on the time of year of the current timestep and the current storage within Lake Tahoe (see Figure 6).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Value:

		Martis	Donner	Prosser	Tahoe	Boca	Stampede	Independence
		NONE	NONE	NONE	NONE	NONE	NONE	NONE
TahoeFirst	0	1.00	2.00	4.00	5.00	7.00	6.00	3.00
BocaFirst	1	1.00	2.00	4.00	7.00	6.00	5.00	3.00
TPXW	2	1.00	2.00	6.00	7.00	5.00	4.00	3.00
AugmentedRaftingFlows	3	1.00	2.00	4.00	5.00	7.00	6.00	3.00

Figure 6. Floriston Rate Demand Priority Table

The model first calculates the difference between the Floriston Rate and the natural unregulated flow at the state line. It then takes this difference and goes to the priority table in order to meet the demand fully. There are two reservoirs which can store adverse to the Floriston Rate, Independence (first 3000 acre-ft), and Donner. When the model gets to these in priority, it just takes what is already being released for drawdown or minimum flows and counts these flows toward meeting the defecit. The rest of the reservoirs in the basin must pass their inflows (ie they cannot store any water) to meet the rate, so the model will go through these in the order prescribed in the table and meet any remaining Floriston Rate deficit. Finally when this does not result in enough flow to meet the demand, the model releases storage from Tahoe and Boca. The Truckee River Agreement of 1935 authorized the construction of Boca reservoir as a supplement to Tahoe for meeting the Floriston Rate. It also mandated that when Tahoe pool elevation is below 6225.5', Tahoe storage is used first for meeting the Floriston Rate and when the Tahoe pool elevation is above 6225.5', Boca is used first. This is reflected in the priority table as different rows with headings TahoeFirst, and BocaFirst. The model goes through the same basic process in meeting each of the demands on the system. This priority system is primary mechanism at work within the Operations model. It provides a framework that is most compatible with the policy that governs the operation of the Truckee River. Figure 7 shows the flows at the state line for 2005. The blue plot represents the Floriston Rate target while the gray line is the actual flow in the river.

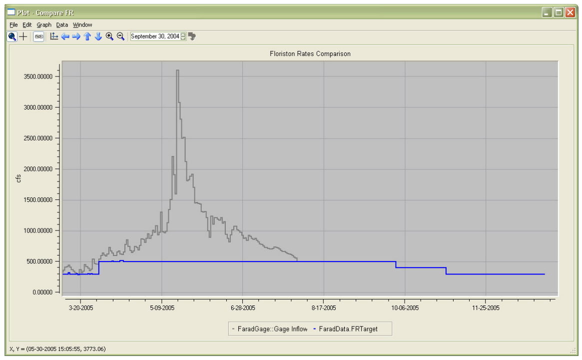

Figure 7. Floriston Rate target and actual flow at CA/NV state line in 2005

<u>Current Development</u>

The Lahontan Basin Area office technical staff is continuing to develop the suite of RiverWare models. The Truckee River Operating Agreement (TROA) is nearing completion and adoption as the operative agreement within the basin. A RiverWare model of TROA will be used by the TROA administrator to implement this agreement.

Combo-Model

The RiverWare modeling suite as described in the introduction has a significant amount of data being passed from model to model via a database. It was determined that much of the overhead associated with data transfer and maintenance of three separate models could be reduced by merging the Accounting and Operations model. The new system includes a combination Acocunting/Operations model which invokes the RiverWare Forecast Model mid-run. The schematic of the new modeling system is shown in Figure 8.

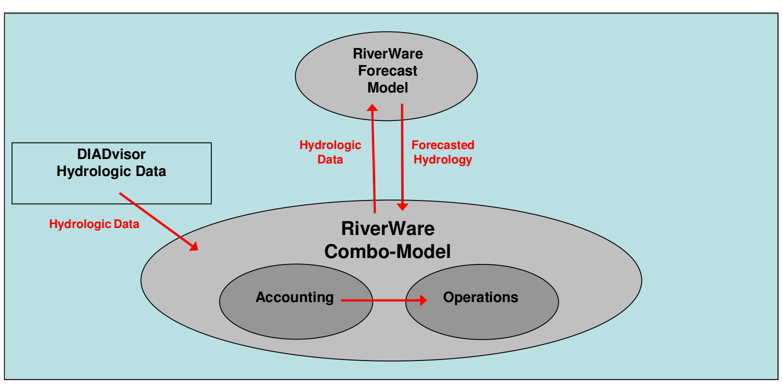

Figure 8. Combo-model schematic

The Combo-model begins the simulation at the start of the water year and proceeds in accounting mode up to the current time, the time at which gage flow and reservoir storage data ends. At this point it sends out all hydrologic data to the RiverWare forecast model which generates daily inflow forecasts for all of the headwaters and sideflows in the model. The forecasted hydrology is sent back to the Combo-model which then enters an operations mode and, based on the forecasted hydrology, operates the system according to basin policy and does accounting through to the end of the following calendar year. This streamlining of the modeling process reduces the amount of data that is being moved in and out of models, and provides a better foundation for the continued development of the TROA ruleset.

HDB

The LBAO technical staff and the TROA implementation coordination office have recently completed the deployment of a new data base to support the TROA modeling effort. The previous suite of models employed three separate DSS databases using the US Army Corps of Engineers' HEC_DSS format. However with the transition to TROA imminent, it was determined that a new database would be needed to implement TROA and to serve as the "database of record" in the Truckee-Carson basin. The new database is an implementation of the Hydrologic Database (HDB). HDB was developed by Bureau of Reclamation water managers in conjunction with the center for Advanced Decision Support for Water and Environmental Systems (CADSWES), and is currently being used within the Upper Colorado and Lower Colorado Regions in their management of the Colorado River. HDB is an Oracle-based database that provides all of the functionality that the administration of TROA requires.

TROA

Currently the LBAO technical staff is developing the TROA model and ruleset. TROA is a very innovative, flexible operating agreement that requires a highly sophisticated model of the basin and the policy to implement. It provides for the establishment of credit water within the basin and allows for its flexible management by the owners of the credit water. TROA will greatly increase the complexity of the physical operation of the system as well as the accounting. The number of accounts in the system grows from seven to around twenty. Each reservoir goes from storing one or two types of water to being able to store all types of credit water and several project waters. Additionally, trades, exchanges, and in-lieu of releases are provided for throughout the basin. All of this contributes to a substantial increase in the number and complexity of the modeled processes within the basin.

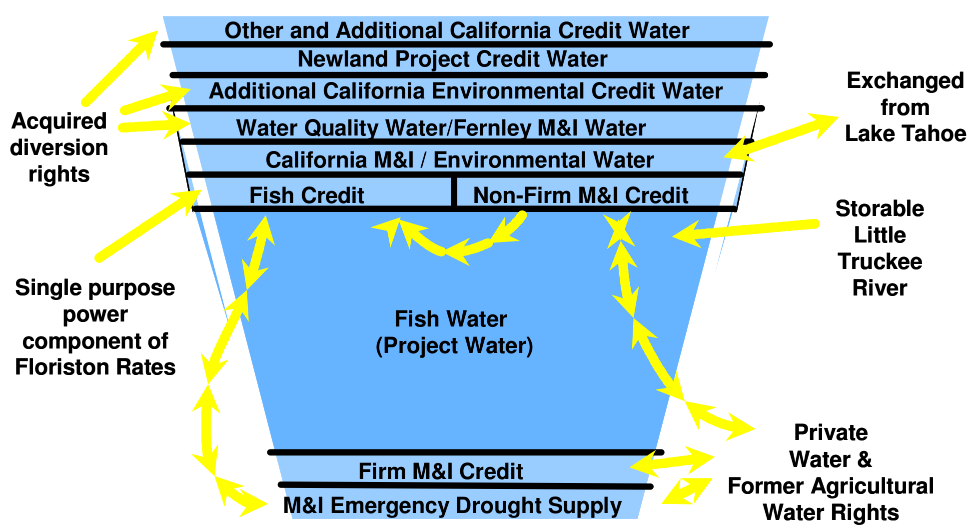

Figure 9. Schematic of Storage Accounts in Stampede Reservoir under TROA

The benefits of TROA are significant. It provides for improved drought protection for the Truckee Meadows (Reno and Sparks), Upper Truckee basin (California), and Fernley, NV. Capacity to meet the needs of the threatened and endangered fish in Pyramid Lake and the Lower Truckee is enhanced.

Recreation interests are better served. Water quality, especially in the low-flow periods of the year will be improved. Newlands Project diversions will be more precise. No new facilities are necessary to accomplish any of this and all storage fees will be used for wetlands and fish restoration.

In practice, TROA is administered by a federally appointed administrator; however each of the parties in the basin with credit water has the responsibility to manage the storage and release of their credit water. It is being described as "operation by committee". Consequently, the model is being designed to facilitate easy interaction among the parties in the basin with the model. This is a requirement that makes TROA and the TROA RiverWare model unique within the water resource management community.

SUMMARY

A RiverWare Operations Model for the Truckee-Carson Basin has been developed by the technical staff of the Lahontan Basin Area Office of the Bureau of Reclamation. The model consists of a workspace with linked objects and a ruleset which captures the operating constraints and basin policy. This model is part of a larger modeling system which includes an Accounting Model, a Forecasting Model, a realtime data collection system, and a set of databases. The modeling system is used to provide annual operational forecasts to Truckee basin stakeholders. The Operations model takes the updated accounting data from the Accounting Model and a distributed hydrologic forecast from the Forecasting Model and then simulates the operations of the Truckee-Carson system through to the end of the year. The primary mechanism at work in the Operations Model is a priority based system according to established basin policy for meeting the major demands in the basin. The modeling suite for the existing conditions is complete and functioning. In development is a suite of RiverWare models to model TROA, a new operating agreement. To this end, the Accounting Model and Operations Models have been combined into a single model and a new ruleset is being developed for the new TROA policy. The new modeling system will be used to administer TROA and will facilitate the collective operation of the system by basin stakeholders.

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