Simulation of Selected Reservoir Operations in the Upper Truckee River Basin, California

U.S. Department of the Interior—U.S. Geological Survey

Truckee–Carson Program

After decades of litigation and negotiation, the Truckee–Carson–Pyramid Lake Water Rights Settlement Act was passed in 1990. The law provides a foundation for developing operating criteria for interstate allocation of water to meet demands for municipal, irrigation, fisheries and wildlife, and recreational uses, as well as to meet water-quality standards, in the approximately 7,000-square-mile Truckee River and Carson River Basins of western Nevada and eastern California (fig. 1). The Truckee–Carson Program of the U.S. Geological Survey (USGS) is assisting the U.S. Department of the Interior in implementing the act. The program has the following objectives:

- Consolidate streamflow and water-quality data from several agencies into a single data base;
- Establish new streamflow and water-quality gaging stations for more complete water-resources information and more-consistent support of river operations; and
- Build, calibrate, test, and apply interbasin hydrologic computer models to support efficient water-resources planning, management, and allocation.

Figure 1. Geographic and hydrologic features of the Truckee River and Carson River Basins.

Hydrological Simulation Program–Fortran

A computer model simulating storage, flow, and quality of the water in the Truckee River and Carson River Basins and in the Truckee Canal is being developed to help meet the third objective of the Truckee–Carson Program. The model, based on the Hydrological Simulation Program–Fortran (HSPF: see Bicknell and others, 1993), simulates reservoir and diversion operations to analyze alternative water-management scenarios.

This fact sheet summarizes some of the capabilities that were added to HSPF to simulate complex reservoir operations in the upper Truckee River Basin in eastern California. Examples of such operations include releases based on water-storage and flood-control criteria; releases to meet agricultural, municipal and industrial, and hydropower demands; and exchanges of water categories[1] between reservoirs. In this summary, simplified or isolated examples are used to illustrate specific reservoir operations that can be represented by HSPF. Actual day-to-day system management or simulation is more complex. It requires consideration of present and forecast flow conditions and of reservoir stages and volumes at various locations in the river basin as well as compliance with numerous legal agreements, legal decrees, and demands.

The HSPF program uses water-quantity and water-quality information to simulate hydrologic processes on pervious and impervious land surfaces, in the soil profile, in drainage networks, and in well-mixed lakes and reservoirs. The model simulations described in this fact sheet use only those parts of HSPF involved in routing streamflow and in operating reservoirs.

HSPF was chosen to simulate Truckee River operations primarily because it can (1) simulate continuously over time, including periods of storm runoff and low flows, (2) simulate at a variety of time steps, including daily and hourly, (3) simulate the hydraulics of complex natural and manmade drainage networks, (4) produce simulation results for many locations along the river and its tributaries, and (5) compute a detailed water budget that accounts for inflows and diversions as well as different categories of water in the river and associated reservoirs.

HSPF uses conditional logic to simulate reservoir operations (Tom Jobes, Aqua Terra Consultants, written commun., 1995). Accordingly, if certain conditions are met, then certain actions are taken. Conditions that are evaluated during simulations include the time of year; reservoir stage, reservoir storage, or volume of a given water category in a reservoir; streamflow magnitude, temperature, or water quality at a given location; and fulfillment of water demands. Thus, for example, release from the Lake Tahoe category "pooled water" could be programmed to occur if the date is during the period from April 1 through October 31 of a given year, if the elevation of Lake Tahoe is within the range 6,223.0 to 6,225.5 feet, and if the demand for additional water at the Farad gaging station (fig. 1) has not been met.

[1]A category of water is any block of water that is individually accounted for in an observed or simulated water budget. A single river, reservoir, lake, or diversion ditch may contain several categories. Water within a category may have specific ownership, such as "privately owned stored water," or have a designated use, such as "pooled water" (used to meet a minimum-flow requirement known as Floriston rates).

HSPF Simulations of Truckee River Operations

In the upper Truckee River Basin, seven dams are operated upstream from the Farad gaging station, a USGS site on the Truckee River, to augment water supply and to minimize flood hazards. These dams control water releases from Lake Tahoe, Donner Lake, Martis Creek Lake, Prosser Creek Reservoir, Independence Lake, Stampede Reservoir, and Boca Reservoir. These lakes and reservoirs are operated according to complex regulations and legal decrees that specify conditions for the storage and release of water. HSPF models the reservoir operations by evaluating the same conditions and simulating the designated action.

The following examples show results from preliminary HSPF simulations of Truckee River operations based on selected existing legal decrees and regulations. These examples are intended to illustrate only how HSPF can simulate operations rather than to convey citable or quantitative model results.

Reservoir Operations Based on Flood-Control Criteria and Storage Priorities

Reservoir operations use flood-control criteria and storage priorities. Flood-control criteria are rules used to determine when and how much water must be released from reservoirs to maintain reservoir flood-control space to minimize potential downstream flood damages. Once reservoir flood criteria have been met, a complex set of rules derived from the Truckee River Agreement of 1935 and other legal decrees govern the priority for storage of water of a particular water category within each reservoir. Storage priorities dictate when and how much water a reservoir may impound. Conditional-logic capabilities within HSPF allow the user to simulate reservoir releases made to satisfy both flood-control criteria and storage priorities.

Daily reservoir elevations simulated by HSPF on the basis of Prosser Creek Reservoir flood-control criteria are shown in figure 2. The period from August 7 to November 1 includes the precautionary drawdown period, during which the reservoir elevation is lowered to 5,703.7 feet to allow storage room for winter and spring inflows. This elevation is maintained from November 1 to April 10 by releasing all reservoir inflows. From April 10 to May 20, water storage is based on rules governing maximum daily storage. From May 21 to August 6, the reservoir typically is operated more to meet downstream water demands than to maintain flood-control space.

A simplified graph of daily water storage simulated for Donner Lake and Prosser Creek Reservoir by HSPF on the basis of legally decreed storage priorities is shown in figure 3. Donner Lake has an earlier storage priority than that for Prosser Creek Reservoir and thus can begin storing water sooner. From April 3 to 14, water storage remains constant at the winter-capacity storage: 2,500 acre-feet at Donner Lake and 9,800 acre-feet at Prosser Creek Reservoir. On April 15, Donner Lake storage begins to increase while Prosser Creek Reservoir storage remains constant. Because of a later storage priority, Prosser Creek Reservoir storage does not begin until April 20.

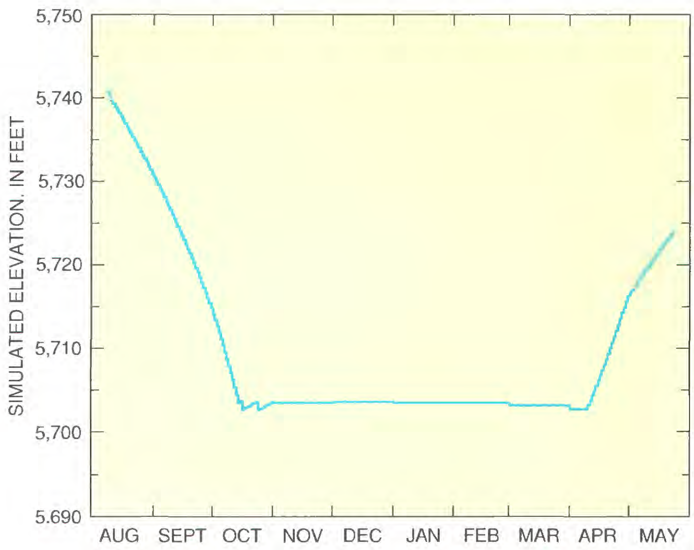

Figure 2. Prosser Creek Reservoir elevations simulated on the basis of flood-control criteria.

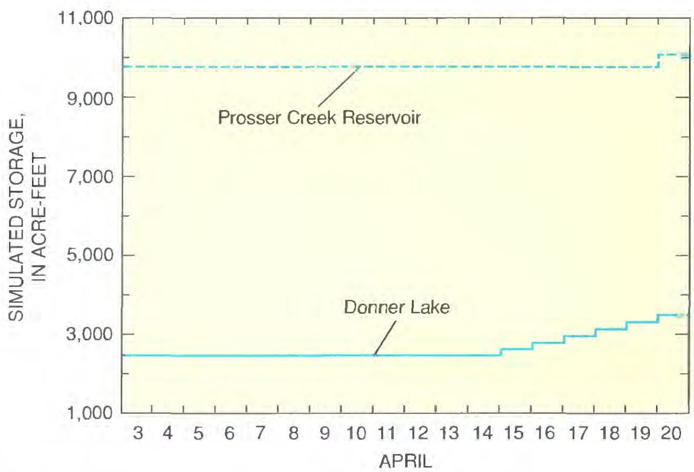

Figure 3. Donner Lake and Prosser Creek Reservoir water storage based on April storage criteria.

Reservoir Releases to Meet Demands

Using conditional logic, HSPF adjusts simulated releases from reservoirs to meet downstream demands, such as Floriston rates. Originally established by a Federal District Court decree in 1915 and revised in 1935, Floriston rates are minimum-flow criteria for the Truckee River at the California–Nevada boundary and constitute the chief operational objective for the river. When flow rates (currently measured at the Farad gaging station, which is just upstream from the State line) meet Floriston rates, all downstream agricultural, municipal and industrial, and hydropower water rights are satisfied. According to the Truckee River Agreement of 1935, when these rates are not met by the natural flow of the river, water stored in Lake Tahoe and in Boca and Prosser Creek Reservoirs may be released to compensate.

An example of an HSPF simulation that illustrates how water stored in Lake Tahoe and in Boca and Prosser Creek Reservoirs can be released to attain Floriston rates for the period August through October is shown in figure 4. Simulated reservoir releases from pooled water compensate for and react to the variability of natural inflow to the Truckee River to approximate Floriston rates at the Farad gaging station (fig. 4*A*). The simulated flow at the Farad gaging station consists of the reservoir releases (fig. 4*B*) plus the natural, unregulated inflow to the Truckee River, routed downstream to the Farad gaging station.

Natural, unregulated flow into the Truckee River can be augmented by four categories of pooled water stored within the two reservoirs and Lake Tahoe to maintain Floriston rates. These categories are Lake Tahoe pooled water (hereafter abbreviated "Tahoe_pooled"), Lake Tahoe exchange water stored in Prosser Creek Reservoir ("Prosser_exchange"), and two categories of Boca Reservoir water called adverse-to-canal ("Boca_adverse") and nonadverse-to-canal ("Boca_nonadverse"). Under a complicated set of provisions within the Truckee River Agreement of 1935 and other legal decrees, orders of release to maintain Floriston rates are assigned to these water categories for different conditions and time periods of a given year (fig. 4). If the rates cannot be achieved by natural, unregulated flow, Tahoe_ pooled is the first choice for release. However, hydraulic properties of the outlet may limit release rates from Lake Tahoe. Therefore, in this example, releases from Boca and Prosser Creek Reservoirs must augment Tahoe_pooled releases to maintain Floriston rates. Water from the category Prosser_exchange may be released to augment releases from Lake Tahoe. Although not formally addressed in legal decrees or regulations, the U.S. District Court Water Master attempts to maximize recreational use of Prosser Creek Reservoir from April 1 through Labor Day. Therefore, Prosser_exchange releases are made, if possible, only from nonrecreational storage in the reservoir to attain Floriston rates in the HSPF simulation. Nonrecreational storage in the reservoir is that volume of water above 19,000 acre-feet that is less important for recreational activities (such as fishing, boating, and swimming). HSPF simulates this condition for the recreation season by the release of nonrecreational Prosser_exchange, which has been assigned the second highest order of release to maintain Floriston rates.

The third water category in line for release to maintain Floriston rates is Boca_adverse water. Boca_adverse water is the first 25,000 acre-feet of pooled water stored in Boca Reservoir. The category name comes from the fact that it has a higher storage priority than water diverted to the Carson River Basin via the Truckee Canal. Therefore, as storage of nonrecreational Prosser_exchange water becomes depleted (mid-August in this example), Boca_adverse water is released.

In the model, Labor Day triggers a change in the choice for release from Boca_adverse water to recreational Prosser_exchange water (fig. 4). Boca_adverse water releases are reduced to zero while recreational Prosser_exchange water releases are increased to help achieve Floriston rates. As storage of recreational Prosser_exchange water becomes depleted, Boca_adverse water is released again. Finally, as Boca_adverse water becomes depleted, pooled water in excess of the first 25,000 acre-feet, that is, Boca_nonadverse water, is released.

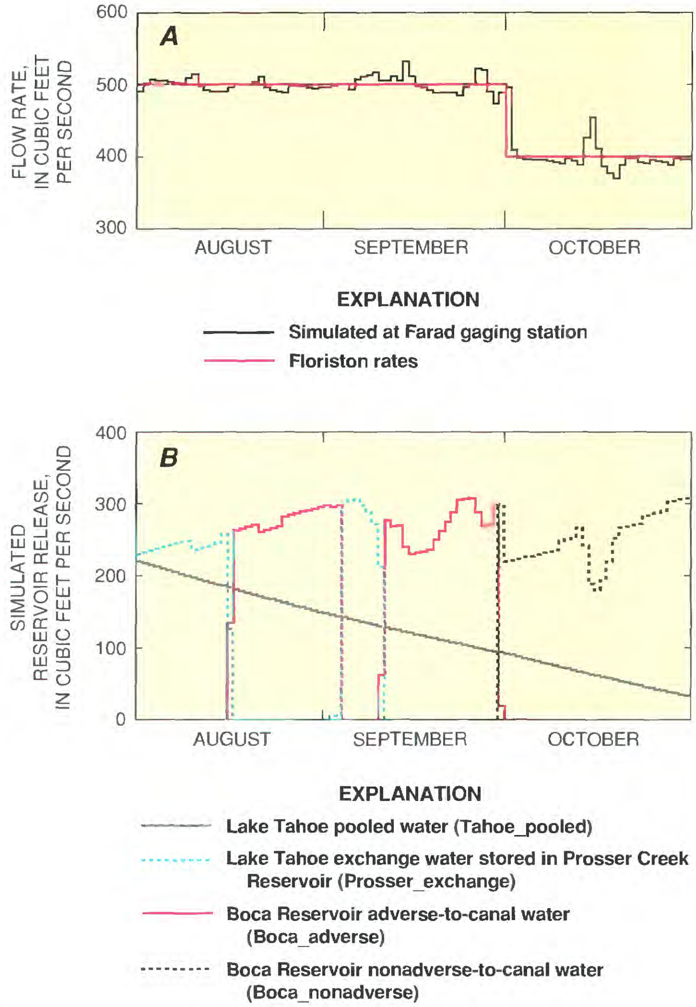

Figure 4. Lake and reservoir releases simulated to maintain Floriston rates at the Farad gaging station. *A*, Simulated total flow at the Farad gaging station compared to Floriston rates. *B*, Lake and reservoir releases necessary to augment natural Truckee River inflow.

Reservoir Operations Using Water Exchange

A commonly used operating method known as water exchange allows reservoir operators to meet multiple-use goals by transferring stored water from one reservoir to another. In this procedure, water is released from one reservoir in exchange for storage of an equal amount of water in another reservoir. In effect, the water is moved between the two reservoirs, even though the reservoirs may not be connected physically.

The Tahoe–Prosser Exchange Agreement of 1959 specifies the operation of Lake Tahoe and Prosser Creek Reservoir in order to meet multiple uses. This agreement requires releases from Lake Tahoe to maintain a minimum instream flow during periods when water would otherwise be stored and accumulated for later release. In exchange, the agreement requires that an equivalent volume of water be stored concurrently in Prosser Creek Reservoir in order to compensate for the release from Lake Tahoe. The water stored in Prosser Creek Reservoir through this exchange then is used as though it were Lake Tahoe storage and accounted for as a distinct water category called Prosser_exchange water.

How HSPF simulates the linked operation of Lake Tahoe and Prosser Creek Reservoir is shown in figure 5. The agreement requires a minimum instream flow below Lake Tahoe of 50 cubic feet per second between October 1 and March 31 and a flow of 70 cubic feet per second for the remainder of the year. In this simplified example, HSPF simulated the release of water from Lake Tahoe to maintain Floriston rates until May 24 and thus met the instream-flow requirement specified in the agreement. Therefore, the storage of Prosser_exchange water remained constant through May 24. After May 24, most of the water released from Lake Tahoe was no longer required for Floriston rates, so Lake Tahoe outflows could have been reduced to zero on certain days. Instead, the release from Lake Tahoe was maintained at 70 cubic feet per second. Storage of Prosser_exchange water increased after May 24 at rates corresponding to that fraction of Lake Tahoe releases made solely to meet the instream-flow requirement.

To model this exchange of water, HSPF determines the minimum-flow requirement for a given date, the present rate of release from Lake Tahoe, and the availability of releasable storage in Lake Tahoe and of storable water in Prosser Creek Reservoir. If the conditional logic specified for the model determines that an exchange should and can be made, then Lake Tahoe releases for minimum instream flows are exchanged for Prosser Creek Reservoir water and designated as Prosser_exchange water. The model must track the accumulation and later release of this Lake Tahoe exchange water (stored in Prosser Creek Reservoir) through time.

Other Models Under Development

In addition to the HSPF simulations of selected reservoir operations already described, other types of simulations, using complex priority rules, currently are being tested for inclusion in the HSPF operations model. These include simulations of minimum-flow requirements for fisheries; of water allocations for agricultural, urban, and wildlife demands; and of other operations described in legal decrees. The HSPF operations model is just one modular component in a comprehensive computer-modeling system being developed by the USGS Truckee–Carson Program. The modeling system integrates data management and analysis (Bohman and others, 1995) with the basin-operations model and physically based hydrologic models that simulate flow, stream temperature, precipitation-runoff relations, and selected water-quality characteristics. The modeling system, when calibrated and tested, will provide the tools necessary for modelers and those officials responsible for water-related policy to examine many interrelated hydrologic and resources-management issues for the two river basins. The ability to simulate alternative management scenarios and compare the simulation results will help users understand the effects of changes in river/reservoir operations, land use, water-rights transfers, and irrigation practices on water quantity and quality throughout the system.

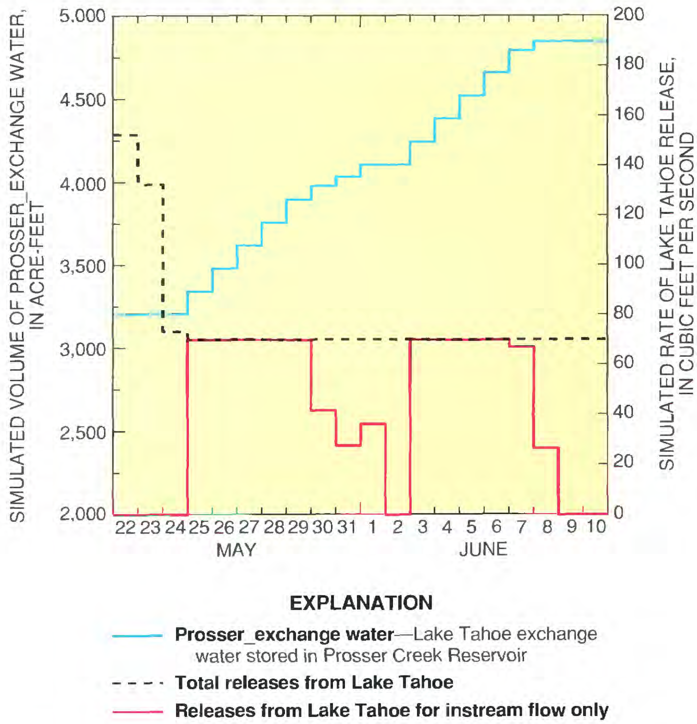

Figure 5. Prosser_exchange water category in Prosser Creek Reservoir and Lake Tahoe release simulated on the basis of criteria in the Tahoe_Prosser Exchange Agreement of 1959.

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