

RiverWare™ is a general river basin modeling tool that enables you to build and manage your own river basin models—and to modify those models as features, uses and policies change.

RiverWare's integrated functions allow seamless switching from one task to another. Its customization options make it flexible enough for any application.

With RiverWare, you may never need another river basin management software tool. RiverWare is designed to meet your river basin modeling and management needs now and in the future.

RiverWare™

River Basin Modeling for Today and Tomorrow

With RiverWare you can . . .

Model Any Basin

Select generic basin features from a palette, name the features, and link them together to create your basin topology.

Customize Your Model

Select the appropriate physical process equations for each basin feature. Choose units for entering and displaying data. Create and name data icons for holding special data for policies or user-defined functions. Configure plots and spreadsheet-like views of the data.

Express Operating Policy as Dynamic Data

Determine policy with maximum flexibility and ease of use thanks to RiverWare's ability to express operating policy as user-defined data. Because policy is not compiled into the code, it can be created and modified easily.

Simulate or Optimize

Switch easily between pure simulation, rulebased simulation and optimization modes. RiverWare's integration of these modeling approaches into one package makes this possible.

Schedule, Forecast and Plan

Manage daily scheduling, mid-term forecasting and long-range planning by using RiverWare's flexible and innovative utilities. Easily modify the model to apply to new design studies or the analysis of operating policies.

Use Your Model with Ease

Enjoy intuitive interaction and informative messaging to achieve better modeling results—faster and more efficiently, even for users with a wide range of experience and expertise.

Update Your Model to Meet Future Needs

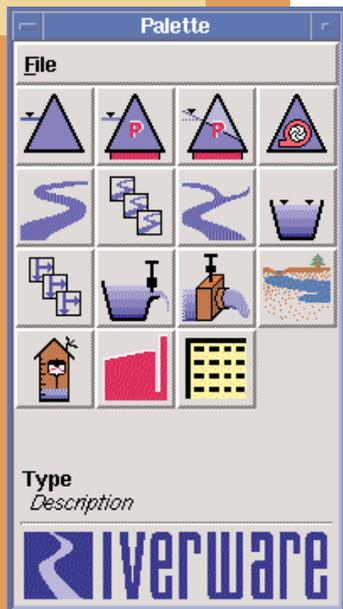
Use RiverWare's data-centered design to update any aspect of your model as needs change. To complement your changing needs, RiverWare developers provide updated, enhanced versions of the model, compatible with changing compilers and operating systems. In short, RiverWare makes obsolescence obsolete.

Create Your Model

RiverWare's graphical user interface (GUI) makes it easy to build a river basin model to your exact specifications.

Select the features of your river basin from the palette, and link them together to create the basin topography. Then, for each feature, enter or import data, and use the methods menu to select engineering algorithms you want to apply.

Because RiverWare offers several options for solving the system, the model only has to be built once. From this model, you can use pure simulation, rule-driven simulation or optimization. Also, you can handle the full range of tasks— scheduling, forecasting, planning, design and analysis studies.



Basin Features and Engineering Processes

As you build a model, select the appropriate methods for modeling physical processes on each feature. Changing the processes for a different application is as easy as selecting and de-selecting items on a menu. Some of RiverWare's generic features and their physical processes are:

Storage Reservoir: Calculates mass balance, including evaporation, precipitation and bank storage; releases; regulated and unregulated spill; and sediment accumulation.

Power Reservoir: Calculates storage reservoir processes plus turbine releases, hydropower and energy and tailwater elevation.

Slope Power Reservoir: Calculates storage and power reservoir processes plus wedge storage and reservoir routing.

Pump Storage Reservoir: Calculates power reservoir processes plus pumping power and energy.

Inline Pump/Generator: Calculates pumping/generating power and energy and turbine/pump flow.

River Reach: Routes flow and calculates gains and losses.

Confluence: Calculates mass balance at a river confluence.

River Gauge: Reflects measured or forecasted flows.

Water Users: Calculates depletion (consumption), groundwater and surface water return flow.

AggDiversions: Aggregates water users and models simple diversions.

Diversion: Models gravity or pumped diversion structure.

Aggregate Delivery Canal: Models off-line delivery canals.

Groundwater Storage: Models temporary aquifer storage for return flows.

Canal: Models bi-directional flow between reservoirs.

Thermal Object: Represents economics of hydropower in total hydro/thermal power systems.

Data Object: Evaluates user-defined expressions.

Water Quality

Model water quality along with water quantity processes:

- Model temperature, total dissolved solids and dissolved oxygen in reservoirs and reaches.
- Select from a simple, well-mixed reservoir or a two-layered reservoir model.
- Choose from several water quality routing methods, with or without dispersion.

User-Selectable Engineering Algorithms

Physical processes in your basin are modeled according to specific algorithms or methods you select, based on timestep size, data availability, desired resolution or an institutional need to use a particular method. Some examples of categories of physical processes and their methods are:

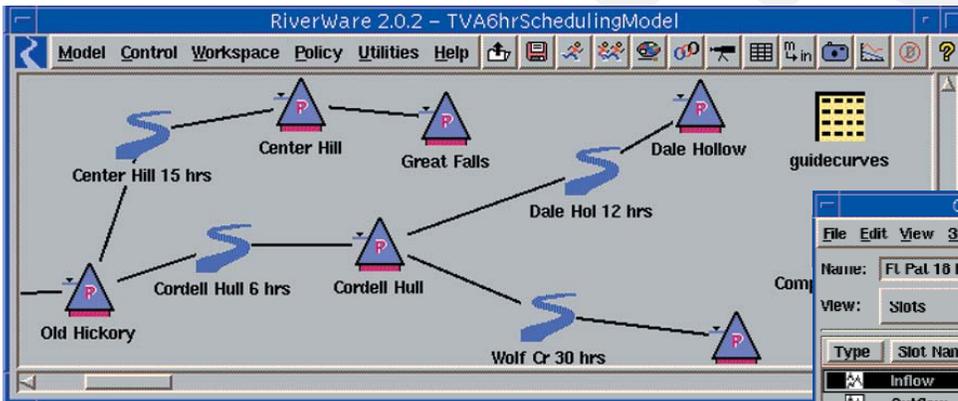
- Power Generation: Plant Power Method, Unit Generator Power Method, Peak Base Power Method and Empirical Power Plant Method.
- Tailwater (TW) Calculation: TW Base Value Only, TW Base Value Plus Lookup Table and TW Stage Flow Lookup Table.
- Reach Routing Methods: Time Lag, Impulse Response, Muskingum, Muskingum-Cunge, Kinematic Wave and Storage Routing.

View Your Model

When it comes to viewing a river basin model, RiverWare's combination of object-based topology and customized spreadsheet views gives users the best of all possible worlds.



view



Type	Slot Name	Value	Units	Status
<input checked="" type="checkbox"/>	Inflow	2.29	1000 cfs	<input type="checkbox"/>
<input type="checkbox"/>	Outflow	2.29	1000 cfs	<input type="checkbox"/>
<input type="checkbox"/>	LogTime			
<input type="checkbox"/>	GainLoss Coefficient			
<input type="checkbox"/>	Constant GainLoss			

Open Object

Each basin feature, or object, is opened by double-clicking its icon on the workspace to reveal a list of the data variables (slots) associated with the feature and a list of the user-selected methods. Each slot can be opened to show time series or table data. The user can enter or import data, customize display format and data units, and change the input/output status of the data.

Spreadsheet View

RiverWare's Spreadsheet Control Table (SCT) gives users a customized spreadsheet-formatted view of all the time series data in the model. Think of it as opening a window into data on all features in the basin at once. What's more, you can configure multiple SCTs to get different views of the model, and easily switch from one view to another with the click of a mouse.

Value:	Clear Output
2.00	
	Inflw 1000cfs
Nov 26 1995 06:00	O 1.78
Nov 26 1995 12:00	O 1.01
Nov 26 1995 18:00	I 2.00
Nov 26 1995 24:00	I 2.00
Nov 27 1995 06:00	O 1.79
Nov 27 1995 12:00	O 1.03

From the SCT you can:

- View any time series data in the model, in any order.
- Change the input/output status of values.
- View the data in time-aggregated form.
- Change data values.
- Set special operating flags.
- Execute model runs.

	11/28 24:00	11/29 6:00	11/29 12:00	11/29 18:00	11/29 24:00	11/30 6:00	11/30 12:00	11/30 18:00
Watauga Storage	225.46	225.65	225.36	225.46	225.30	225.42	225.06	225.09
Watauga Pool Elev	1938.79	1938.86	1938.76	1938.79	1938.74	1938.78	1938.65	1938.6
Watauga Turbine Rel		0.24	2.12	0.47	1.41	0.24	2.12	0.47
Watauga Power Coeff	510	510	510	510	510	510	510	510
Watauga Energy		30	270	60	180	30	270	60
Watauga Spill		0.00	0.00	0.00	30.00	0.00	0.00	0.00
Watauga Outflow	1.17	0.24	2.12	0.47	1.41	0.24	2.12	0.47
Watauga Tailwater Elev		1651.00	1651.00	1651.00	1651.00	1651.00	1651.00	1651.0
Wilbur Inflow	1.17	0.24	2.12	0.47	1.41	0.24	2.12	0.47
Wilbur Local Inflow	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04



Photo courtesy of NCWCD



Pure Simulation

RiverWare's simulation algorithm solves upstream, downstream, or any well-determined combination of these in a single run. Input/output data combinations are flexible, allowing various combinations of, for example, storage, pool elevation, releases, energy and inflows as inputs to drive the simulation.

Value-Added Features

- The solution can progress forward or backward in time, as the data requires. This allows for meeting future storage targets or solving for upstream releases to meet downstream future demands.
- The object-oriented modeling approach makes it easy to find where your model may be over- or underdetermined.
- Advanced diagnostic utilities provide detailed information about the progress of the solution at each timestep, making it easy to analyze runs.

Rulebased Simulation

Rulebased simulation allows the specification of prioritized "if-then" operating policy statements to drive the simulation instead of input data values. The rules are easily written by the user in a language provided through the syntax-directed editor. Complex policy can be represented clearly and concisely by using a library of pre-defined or user-customized functions. The rules are interpreted and executed when the simulation needs additional data. The most valuable benefit of RiverWare's rulebased simulation is that the rules represent policies as dynamic data, which can be viewed and modified outside the compiled code.

Value-Added Features

- Customized libraries of functions simplify rule writing.
- Automated testing of rules for correct syntax before making a run.
- Graphical rule editor permits easy switching of rule priorities and toggling ON/OFF individual rules or sets of rules.
- Comments and diagnostic messages added by the user to the rules facilitate analysis of model runs.

Water Accounting

Create storage, flow and diversion accounts, and track the legal ownership of water through a basin.

Value-Added Features

- Account information is viewed and configured globally or on each feature.
- Separation of "physical" and "paper" water; the user defines reconciliation of paper accounts with modeled water quantities.
- Representation of water rights, accruals, carryovers and exchanges.
- Accounts can be solved "after the fact" or account data can be assessed to use in the operating rules to drive the simulation.

Run Your Model

RiverWare offers users the ultimate package of integrated solutions for river basin management. Using the same model, RiverWare provides both prescriptive and descriptive solutions. Choose from pure simulation, rulebased simulation or optimization. Easily change the start and end times of the run, or the timestep size, on the graphical run control panel.





Optimization

The realities of water resource management demand that system operators balance multiple—often conflicting—objectives and operations. RiverWare's preemptive goal programming optimization mode provides a valuable tool for trading off multiple objectives. Both experts and nonexperts can employ this sophisticated optimization technique.

Manage Multiple System Objectives

- Water supply
- Flood control
- Navigation
- Recreation
- Fish and wildlife habitat
- Hydropower production

RiverWare's Optimization Works—Automatically

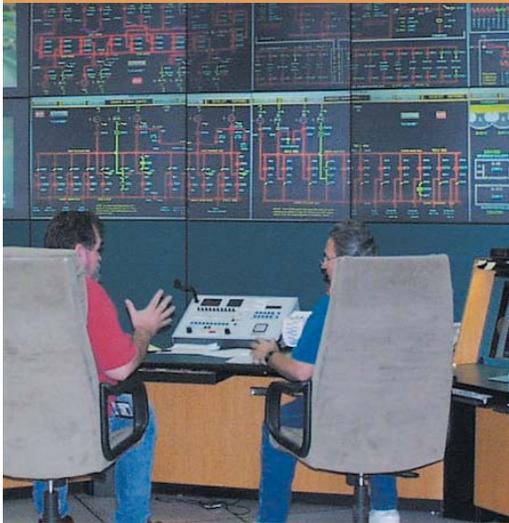
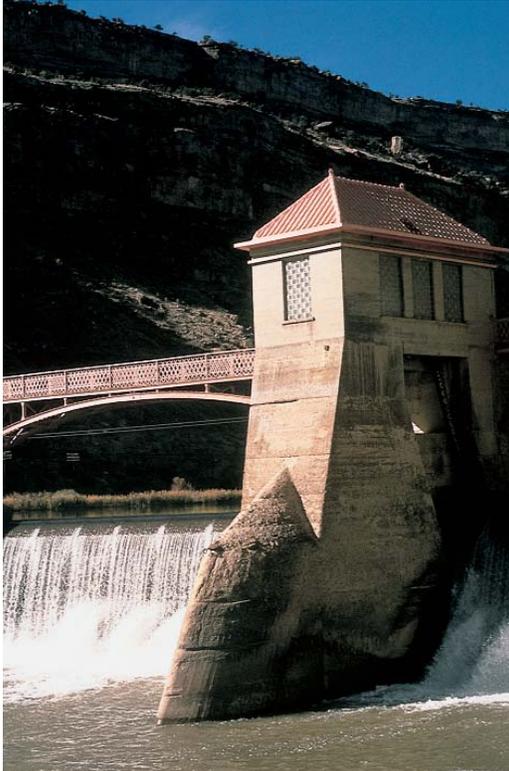
When an optimization run is made, RiverWare automatically generates the physical constraints—such as mass balance, topological connections and upper/lower bounds—from the constructed model. Enter prioritized policy objectives and constraints through a graphical constraint editor, and they are automatically linearized. The linear program (LP) is generated for each goal and sent to a powerful, fast commercial solver. Objectives are met in order of priority, and the solution is returned to the objects.

The LP solver treats each successive constraint as an objective, finding the best solution and setting that solution as a constraint while meeting lower-priority objectives. The result: the best solution given the prioritized goals. The optimal values of the decision variables are then displayed in the slots. A post-optimization simulation run is automatically set up, the results of which provide an exact prediction of the basin's operation with the optimal reservoir releases.

Value-Added Features

- A multi-objective system can be solved without requiring “penalty matrices” or “objective weights” of conventional multi-objective optimization.
- The satisfaction of each objective is automatically distributed evenly over all reservoirs and all timesteps to avoid unacceptable solutions.
- The preferred linearization method for each variable can be selected, and the approximation points (e.g., for piecewise linearization) can be specified by the user.
- Objectives (goals) can be turned on and off or the priorities rearranged, through the graphical constraint editor.

Additional Features



Data Management Interface

RiverWare's Data Management Interface (DMI) utility provides the ultimate flexibility to share data with other applications and analysis tools, other agencies, and other system users. It allows you to customize and automate loading and exporting data and setting up runs for specific applications. The DMI provides maximum convenience and flexibility by executing tailored external programs invoked through RiverWare's graphical user interface. The DMI also allows you to:

- Load inputs from any external sources—including real-time or relational databases, outputs from other models and ASCII files.
- Export data to spreadsheets, analysis tools, databases, official schedules, other models, e-mails, and more.
- Extend or redefine start and end run times.
- Automatically load initial conditions, hydrologic forecasts, and special operating constraints in a single menu selection from RiverWare's DMI graphical user interface—enabling near-real-time operation.

Multiple Run Management

Set up many model runs at concurrent or consecutive time horizons and change data inputs or policies (rule sets or constraint sets). The index sequential option automatically permutes historical inflow data for planning studies.

Advanced Diagnostics

Improve analysis of model runs by printing optional informational messages on specified objects, slots, timesteps, methods and controllers. These messages are integrated with RiverWare's warning and error messages to provide exact problem diagnosis.

Subbasins

Define and name arbitrary groupings of features in a model as subbasins, which can be used in expression slots, policies and DMIs. Use this feature with DMIs to allow several operators to schedule different subbasins and to bring the results together into one model.

Expression Slots

Want to know the total power generation in a basin? The average inflows over the run? Create algebraic expressions on a data object, using RiverWare's slots and subbasins as variables. Build the expressions in RiverWare's graphical expression editor.

Snapshot Manager

RiverWare's snapshot manager automatically saves input/output values of selected slots for each model run. Change the scenario, make another run, and retain selected results for comparison. Data are kept on snapshot data objects and are created and modified through the snapshot manager interface.

Output Options

The plotting manager allows plotting of variables from successive model runs—with no limit to the number of plots. View and print the plots or export data in ASCII files or spreadsheet-readable files.

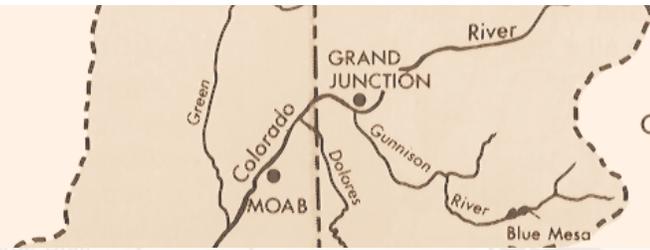
Batch Mode

Need to call in on the weekend to run a model via modem? RiverWare's batch mode utility lets you make a run, enter data, and look at the results in batch mode through its RiverWare Command Language (RCL).

RiverWare Applications

UTAH

COLORADO



Tennessee Valley

The Tennessee Valley Authority uses RiverWare in simulation and optimization modes for daily scheduling of more than 40 reservoirs and hydroplants at a six-hour timestep. Their operating considerations include controlling floods, maintaining navigable depths, protecting aquatic communities, providing suitable levels and releases for recreation, and achieving economical hydropower generation schedules.

Colorado River

The U.S. Bureau of Reclamation has replaced both its long-term policy and planning model (Colorado River Simulation System) and its mid-term operations model (24-Month Study) for the Colorado River with RiverWare rulebased simulation models. These models are used for policy negotiations, to estimate future salinity mitigation needs, as well as to set the monthly target operations for the entire river basin.

Upper Rio Grande

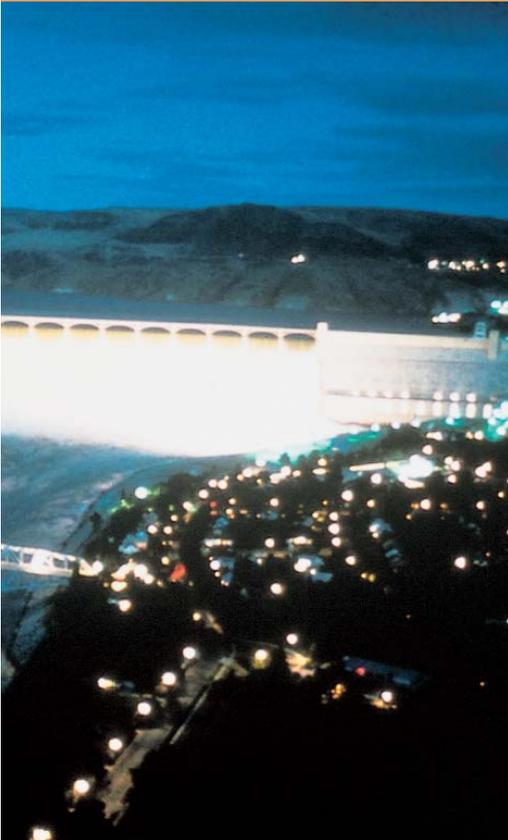
An interagency team including the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the U.S. Geological Survey has applied RiverWare's rulebased simulation and water accounting to a daily timestep Upper Rio Grande Water Operations Model (URGWOM). The model tracks native water and San Juan-Chama transbasin diversion water to fulfill compact deliveries, international treaty obligations, Indian water rights, and private rights and contracts.

San Juan Basin

An operations model of the San Juan River Basin in Arizona, Colorado, and New Mexico has been developed in a joint Bureau of Reclamation and USGS effort. The model is driven by operating policies to meet water supply demands, flood control, target storages, and filling criteria in its reservoirs as well as improved habitat for the endangered humpback chub and Colorado squawfish.



A Design for the Future



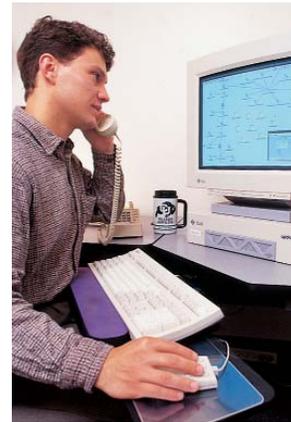
The quality of our future depends on improved management of our water resources, and RiverWare is a tool for achieving that improved management. If your organization is involved in one or more of these activities, RiverWare could deliver better and faster results:

- Short-term operational scheduling of flows, levels and hydropower
- Mid-term operational forecasting
- Long-term planning and analysis
- Design of new system components or new operating policies
- Multi-objective decision making for operations, policy or design of new structures
- FERC relicensing studies
- Research and teaching in the area of water resources planning and management

A Supported Software Product

RiverWare is supported, maintained and continually enhanced by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado at Boulder.

CADSWES is dedicated to providing the best tools for modeling and managing river basins and hydropower systems. Professional software standards are applied to maintain a reliable, robust, version-controlled software product. User support by phone or Internet, training classes and documentation are available to licensees of RiverWare.



Staff Qualifications

The CADSWES team—comprised of environmental and water resources engineers, software engineers, operations research analysts, geographers, and management information systems scientists, among others—works together to offer state-of-the-art river basin modeling tools, allowing users to explore and visualize a universe of planning and operations scenarios.

Licensing

RiverWare is licensed by the University Technology Corporation, 3101 Iris Avenue, Suite 250, Boulder, Colorado 80301.

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