USING RIVERWARE AS A REAL TIME RIVER SYSTEMS MANAGEMENT TOOL

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ABSTRACT

RiverWare has been used as a reservoir operation and river systems management tool by the Bureau of Reclamation, Tennessee Valley Authority and a number of other water resources management agencies and organizations for nearly 10 years. Development, maintenance and enhancement of RiverWare's capabilities is handled by the University of Colorado's Center for Advanced Decision Support for Water and Environmental Systems (CADSWES). Basins where RiverWare is presently utilized include the Colorado, Rio Grande, Truckee, Yakima and Tennessee Valley.

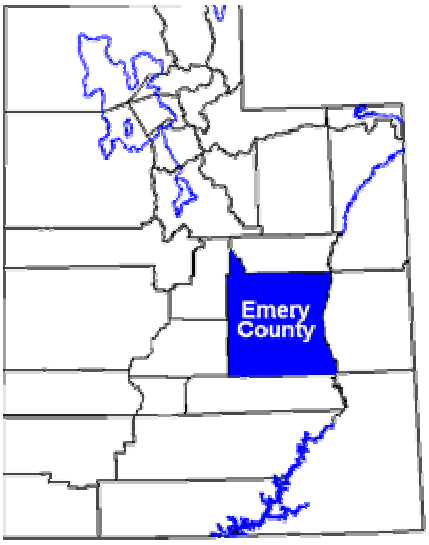

Figure 1. Location of Emery County, Utah.

RiverWare is currently being implemented on Cottonwood and Huntington Creek drainages located in Emery County in central Utah (see Figure 1). An effort is planned to operate a RiverWare model on a near real-time basis. The Emery

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County Project, a Federal water project operated by the Emery Water Conservancy District, includes a transbasin diversion from Cottonwood Creek to Huntington Creek. Recently, a non-Federal reservoir basin in the Huntington Creek watershed has started to leak, exporting water to drainage outside the county. This situation has put pressure on all the water users and threatens water rights. The implementation of RiverWare will hopefully help to determine the magnitude of the loss and provide a mechanism to improve river operations and ameliorate the situation.

INTRODUCTION TO RIVERWARE

RiverWare is a general purpose, object oriented modeling framework which can be used to develop multi-purpose simulation and optimization models of river and reservoir systems. Additional information about the general capabilities of RiverWare can be found in Zagona et al. (2001). RiverWare has been developed over the past ten years by the University of Colorado – CADSWES with substantial financial support from the Bureau of Reclamation, the Tennessee Valley Authority, the US Army Corps of Engineers and several other partners. Maintenance, technical improvements and distribution for RiverWare are handled by CADSWES.

RiverWare based models offer the capability to address short-term operations and scheduling, mid-term operational forecasting and planning, and long-term policy and planning issues. Computational time steps can range between one hour and one year, subject to the availability of data. Daily and monthly time steps are most commonly used.

A model constructed in RiverWare consists of a network of linked "objects" such as reservoirs, river reaches, canals and other diversions and water users. The objects hold data and algorithms that tailor it to the site in the river basin it represents. Information passes between objects by way of links e.g., the outflow of a reservoir is linked to the inflow of a downstream river reach. In this way, the modeler has flexibility to completely describe a river and reservoir system.

A key feature of RiverWare is a rulebased simulation solver, through which operating policy is introduced into the simulation by operating "rules" that determine operational decisions such as reservoir releases and diversions. These rules are prioritized, and conflicts are resolved by giving higher priority rules precedence. Another feature of RiverWare is the capability to do linear goal programming as a means of finding an optimal solution over the entire network and time interval. Another RiverWare capability allows the user to model the economics of hydropower through either simulation or optimization. More details of RiverWare's hydropower modeling capabilities, are found in Zagona and Magee (1999).

In many river basins in the western United States, it is necessary, not only to model water storage and deliveries, but also the ownership of that water. To address the issue of modeling water ownership and water type, RiverWare includes a Water Accounting module that represents the "paper water" as account objects that reside on the simulation objects. Legal accounts and "pass-through" accounts are two very useful features of RiverWare in addressing these issues.

HUNTINGTON AND COTTONWOOD CREEK DRAINAGES

Huntington and Cottonwood Creeks are tributaries of the San Rafael River, which drains a portion of the eastern slope of the Wasatch Plateau. The San Rafael is a tributary to the Green/Colorado River basin system. Stream flows in the San Rafael system are dominated by snowmelt runoff – with occasional runoff from spring and summer rainfall events.

The Emery Water Conservancy District (District) is the overarching water institution in Emery County and is interested in using real-time technologies and decision-support tools to improve river system operations. The flow of Huntington Creek is partially controlled by four non-Federal high mountain reservoirs which have a combined capacity of 17,400 acre-feet. Electric Lake, constructed by a regional electric utility to serve one of its coal-fired power plants, is located on a tributary of Huntington Creek (see Table 1).

Table 1. Statistics for Major Water Storage Reservoir.

Reservoir	Creek	Capacity (AF)	Elevation (ft above S.L.)	Surface (acres)	Max. Depth (feet)
Electric Lake	Huntington	32,000	8,575	425	217
Huntington North	Huntington (off stream)	5,690	5,839	225	56
Joe's Valley	Cottonwood	62,450	6,990	1,183	169

Huntington North Reservoir is an off-stream Federal reservoir located fairly low in the river basin. Joes Valley Reservoir is a Federal reservoir on Cottonwood Creek.

Most water rights in the District's service area are held by the Cottonwood Creek Consolidated Irrigation Company (CCCIC), Huntington Creek Irrigation Company (HCIC), PacifiCorp (the regional power company), and the Federal government. However, several other entities and water rights also exist. The water rights consist of direct flow rights (non-storage water) and storage rights of Federal and non-Federal entities. The Emery County Project provides water from Joes Valley reservoir to CCCIC and HCIC canals and Huntington North

Reservoir via a transbasin diversion. Exchanges can also occur whereby water is used in a location without being physically moved from another location.

In 1993, the District and Reclamation designed and installed the first step in a comprehensive real-time hydrologic and weather monitoring system. This real-time network was designed to improve the responsiveness of the county's water delivery systems. Data from the field sites was telemetered back to District's office by line-of-sight radio. In this initial effort, 17 water and 3 weather monitoring sites were upgraded by adding telemetry equipment.

This initial effort was expanded in subsequent years. The District's now has a monitoring system covering all of western Emery County that includes over 100 field sites, 5 repeaters, and a base station. The system also includes 10 control sites, an early warning system on Joes Valley Dam and Reservoir, and 3 fully automated cloud-seeding sites. The real-time and historic data (for the water year) is displayed on the District's website (www.ewcd.org), which is updated hourly.

Since 1993, the base station for the District's automated data collection system has evolved. It started out with a PC running DOS and the RTU (remote terminal unit) vendor's software, and has over time become far more complex. The current base station includes: (1) a router/firewall which secures the real-time network; (2) a switch which routes network communications; (3) an ADSL modem which connects to the upstream Internet provider; (4) a data collection server running Windows 2000 Professional, which polls the RTUs and stores the real-time data to disk; (5) dual web servers running Redhat 7.3 Linux which provide web/e-mail/DNS hosting for www.ewcd.org; (6) a mirror system residing in an adjacent building; (7) a healthy UPS with web-based management; and (8) a diesel-powered emergency generator.

IMPLEMENTATION OF RIVERWARE

Recently, Electric Lake started to leak and the end result is that water is being unintentionally exported to an adjacent drainage. This has put pressure on all the water users and threatened the water rights associated with the Emery County Project and others. Plans are to make RiverWare operate on a near real time basis on Huntington Creek. Before that can be done, however, a water rights and accounting analysis using historical data must be completed. Although the basin is not hydrologically complex, the water rights, transbasin diversions, and exchanges make the water accounting problem complex.

Using a combination of mass-balance, water accounting features, and rules, the District's RiverWare model will enable after the fact detailed water accounting of the basins. The implementation of RiverWare will hopefully help to quantify the magnitude of the loss, account for all real and paper water, and enhance

operations. Researchers believe that the Huntington Creek implementation will pave the way for additional real time applications of RiverWare by local government entities and stakeholder organizations in Utah as well as other locations.

REFERENCES

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Zagona, E., T. Fulp, T. Magee and H.Goranflo (2001) "RiverWare: A Generalized Tool for Complex Reservoir Systems Modeling", Journal of the American Water Resources Association, Volume 37, Number 4, pages 913-929.