MONITORING AND OPERATING A WATERSHED USING LOW-COST
AUTOMATION AND THE INTERNET:
THE SEVIER RIVER EXPERIENCE

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ABSTRACT
The Sevier River Water Users Association (WUA) and the U.S. Bureau of
Reclamation (Reclamation) are rapidly moving toward creating a virtual
watershed, an accurate real-time representation of the Sevier River watershed
displayed on the Internet. This, coupled with low-cost remote control on all major
water structures, makes for near instantaneous decision making. The ability to
react promptly to changing hydrologic and weather conditions has made for
consistent improvements in the way the river and canals are operated.

In 1997, the WUA teamed with Reclamation and StoneFly Technology to
establish a web site (water.gbasin.net) for the distribution of real-time data on
Sevier River streamflows, canal flows, reservoir levels and releases, and weather.
By the end of 1999, WUA will have automatic remote control on all major
reservoirs and diversion structures. Additionally, over 20 real-time river and
canal monitoring sites and two weather monitoring stations will provide hourly
updating on the water user’s web site. WUA’s Internet system also includes one
live still image of a major diversion structure and one live horizon image for the
National Weather Service.
Future enhancements to the system have many applications. Reclamation’s Denver office is currently developing software so irrigation companies can place water orders over the Internet. The National Weather Service and the Utah State Climatologist are using the WUA’s real-time communication system and web site to fill gaps in their weather monitoring network, allowing for a more comprehensive historic record and better forecasts. Further, a Utah State University (USU) team is working on a water rights model which updates daily. Plans are also underway to post dam safety information on the web site. To date, the water users have only scratched the surface of what is possible.

INTRODUCTION

This presentation is dedicated to the proposition that real-time technologies will revolutionize the way water projects and watersheds are managed. An important ingredient in this network are the links to the Internet. This connectivity allows sharing of real-time information among various water user groups and among such non-traditional customers as meteorologists and climatologists, kayakers and boaters, fishermen, researchers, dam safety specialists, and vacationers.

But first, a word of caution: There are critics who feel the Internet is being over promoted. Robert Hughes’ (1995) editorial in Digital Time about the information highway claims “We will look back on what is now claimed . . . and (wonder) how we ever psyched ourselves into believing all the bulldust about . . . fulfillment through interface and connectivity. But by then we will have some other fantasy to chase, its approaches equally lined with entrepreneurs and flacks, who will be the beneficiaries.”

SEVIER RIVER BASIN

The Sevier River Basin (Basin) in south-central Utah is one the state’s major drainages. A closed river basin, it encompasses 12.5 percent of the state’s total area. From the headwaters, 250 miles south of Salt Lake City, the river flows north and then west 225 river miles before reaching Sevier Lake. Since the turn of the century, irrigation has depleted the river and the only flows that reach the terminal lake are occasional floods, like those in 1983 and 1984, and some return flow.

The river is regulated by reservoirs and irrigation systems. The three largest storage facilities in the Sevier River Basin--Otter Creek, Piute, and Sevier Bridge--account for about 75 percent of the total water storage capacity. Information on the three storage reservoirs is shown on the following table.
Major Reservoirs in the Sevier River Basin

<table>
<thead>
<tr>
<th>RESERVOIR</th>
<th>SOURCE OF WATER</th>
<th>CAPACITY (acre-feet)</th>
<th>SURFACE (acres)</th>
<th>USE*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otter Creek</td>
<td>East Fork</td>
<td>52,660</td>
<td>2,520</td>
<td>IR,R</td>
</tr>
<tr>
<td>Piute</td>
<td>Sevier River</td>
<td>71,830</td>
<td>2,508</td>
<td>IR</td>
</tr>
<tr>
<td>Sevier Bridge</td>
<td>Sevier River</td>
<td>236,150</td>
<td>10,905</td>
<td>IR,I,R</td>
</tr>
</tbody>
</table>

*Primary use of stored water: IR=Irrigation, I=Industrial, R=Recreation.

Agricultural use accounts for the largest depletion of water (60 percent) in the Basin (see Figure 1). Municipal and industrial (M&I) use accounts for only 2 percent of the total depletion because of the lack of large population centers and major industries. Most of the M&I water use is by the Intermountain Power Project located just north of Delta, which is currently diverting approximately 20,000 acre-feet annually.

Water has been allocated by the courts to users through the application of a complex set of water-rights decrees. Water rights in the Basin consist of two types: (1) primary or streamflow rights and (2) storage rights. Storage rights are entitlements to water that is not usable for irrigation by direct diversion, i.e. winter runoff, flood flow, and return flow from primary rights. Most of the conflict over water in the Basin involves the distinction between surface and storage rights. In the past, disputes over water rights offered interesting reading from a historic perspective, but practically speaking drained off a lot of the Basin’s human energy.

For the administration of water rights, the basin is divided into 2 major divisions: the Upper and Lower Sevier Basins. The dividing point is Vermillion Dam located just east of the city of Richfield (see Figure 2).
The institutional structure for operating the river is relatively straightforward. There are no large Federal water projects and no conventional water conservancy districts. Operation of the river is overseen by a River Board (an executive committee of the Sevier River Water Users Association) that meets annually to deal with current issues and to make assessments to offset the costs of operating the river. Water rights are administered by two river commissioners (state employees under the Utah Division of Water Rights), one for the Upper Basin and one for the Lower. Other than the two commissioners, there is only one full-time, water-related employee (the office manager for the canals and reservoirs in the Lower Basin; he also serves as secretary/treasurer for the River Board). Most canal companies are operated out of the homes of their managers, and employees (i.e. ditchriders, watermasters) are seasonal.

**CANAL AND RESERVOIR AUTOMATION HISTORY**

**GOES Real-time Monitoring System**

In the late 1980s, GOES (Geosynchronous Operational Environmental Satellite) technology was used on river and canal monitoring stations along the Sevier River. These stations, which provided data on an hourly basis, demonstrated the usefulness of real-time information for improving management of the river. The problems with the initial system were two-fold: (1) the communication system was one way and thus not suitable for most control applications, and (2) the system for distributing the data was primitive, each river commissioner had his own satellite downlink station, and thus the data was not widely distributed.
Delta Area Canal Automation

In 1991, the Delta Canal and Melville Irrigation Companies in the Lower Basin asked USU and Reclamation to develop and install a system to control the flow of water through Canal A, which supplies water to the two companies. The system was developed and installed by engineers through USU’s Biological and Irrigation Engineering Department (Walker, 1993). The canal automation system included: (1) a radio-telemetry network that transmits data and commands; (2) a datalogger/controller that collects data about gate positions and water levels, and raises and lowers gates; and (3) a microcomputer that controls the system.

The aim of the Canal A automation project was to reduce losses while maintaining a high degree of on-demand flexibility in the canal’s operation. The system was designed to improve regulation through easier and more timely changes in gate openings, better flow measurement as a result of more stable outflows, and automatic regulation during periods when the canal was unattended. The project proved successful, producing a water savings of 3,000 acre-feet in 1993, its first full year of operation.

Richfield Area Canal and Reservoir Automation

After viewing the success of the Delta project, irrigators in the Richfield area opted to try components of a selective automation system. During 1993, in a joint effort with Reclamation, the Richfield Irrigation Company installed a radio-telemetry monitoring station on the Parshall flume at the head of their canal. The station allowed the water manager to observe conditions and improve canal operations. After a year of monitoring canal flows, the company decided to upgrade to real-time control.

During the early Spring of 1994, the telemetry equipment and controller were moved 200 feet from the flume to the diversion structure. Subsequently, the gates on the diversion structure were motorized with solar-powered DC motors, and the datalogger/controller was reprogrammed for manual remote control (see Figure 8). This enabled the water manager to make gate changes from his residence. Richfield’s new system proved to be a useful water conservation tool (Pugh and Hansen, 1995).

During 1995, the Richfield diversion structure was equipped with automatic remote control. This was accomplished by installing enhanced software at the field site. Now instead of moving the gates by remote control, the water manager could set a canal flow target remotely and the gates automatically move to maintain the require flow. The canal manager estimates that the system has helped the company conserve approximately 12 percent of its water supply.
After the success of the Richfield Canal automation project, Reclamation assisted seven other canal companies in the Richfield area to automate their structures. Both major reservoirs, Piute and Otter Creek serving the area were also automated. In addition, there are 15 real-time river and canal flow monitoring sites. All data communications in the area are by a combination of VHF radio and telephone equipment (Hansen and Pugh, 1997).

WEB SITE HISTORY

The various monitoring and automation systems in the Sevier River Basin generate substantial amounts of data, but it was unavailable to all but a few water managers. This was a constant source of frustration to a number of water managers who needed the data to improve their operations.

Meanwhile, the rapid rise in the development and use of the Internet meant that many of the water managers were either getting “on-line” or considering it. It became apparent that getting the real-time data onto the Internet might become a good way to distribute the data to a wide audience without requiring the water users to purchase specialized equipment.

In 1997, StoneFly Technology approached the water users in the Upper Basin with a proposal to connect their real-time database to the Internet. This proposal was accepted and Reclamation agreed to assist with the project. That fall, a preliminary web site was tested and well received. The site was enhanced for the 1999 irrigation season and the graphic displays were expanded.

During 1998, the web site came to the attention of the National Weather Service (NWS). Their meteorologists expressed an interest in using the water users’ communications system and web site to fill gaps in Utah Mesonet, a real-time weather monitoring web site operated by the University of Utah. Reclamation and WUA, in a joint effort with the Utah State Climatologist, agreed to add two weather stations immediately and other stations in the future, when feasible.

At their annual meeting in January 1999, the Sevier River Board enthusiastically endorsed a proposal to expand the web site to include the entire Sevier River Basin. By the end of 1999, the web site will present an accurate real-time representation of conditions throughout the Basin. Any water manager or interested individual will be able to sit down at a computer and survey hydrologic and weather conditions throughout the Basin.
WEB SITE: water.gbasin.net

The web site created by StoneFly Technology is designed to serve a variety of users with a variety of displays. The log-in page gives the user several options (see Figure 3). Current river and canal flow information is displayed in spatial diagrams (see Figure 4).

Figure 3. The log-on page; all real-time options are listed on the left.

Figure 4. Spatial diagram displaying real-time information for a stretch of the upper Sevier River.
A variety of time-series information is available. One popular display is of hourly flow data for the previous 7 days (see Figure 5). For troubleshooting the automation system, a display showing battery voltage is critical (see Figure 6). Since most of the field sites are solar powered, this is an important diagnostic tool.

![Hourly Average Flow at Clear Creek]

Figure 5. This time-series plot displays hourly flows at one of the stream gaging sites for the previous 7 days.

![Hourly Average Battery_Voltage at Clear Creek]

Figure 6. Another time-series display shows battery voltage.

In addition to real-time displays, there is also descriptive information posted on the web site (see the bottom of the log-in page). This information includes: (1) a description of the Sevier River Basin and (2) a history of water development in the Basin. (The latter is important because the water users feel strongly that their history has been misrepresented in past studies, like Arrington’s 1951 treatise.)
Another important component of the descriptive information is detailed descriptions of the real-time (automation) equipment and a comprehensive list of manufacturers and vendors. This information is important for troubleshooting and making repairs.

Web site usage is also monitored (see Figure 7). A comprehensive log is maintained, which allows web site designers to assess the utility of the various tables and displays.

![Usage Statistics for water.gbasin.net](image)

**Figure 7.** This bar chart provides statistics on web site usage over the previous 12 months.

### INTERNET CAMERA SYSTEM

During the summer of 1998, StoneFly Technology under contract to the Sevier River WUA designed and installed a prototype Internet camera system at the head of the Richfield Canal in the Upper Basin. This camera takes high-quality color images of the headgates every 10 minutes and makes them immediately available worldwide via the Internet at `water.gbasin.net` (See Figure 8).

The real-time images have several benefits. The canal company manager is now able to visually verify the gate settings on the automation system. (The camera
serves as a redundant gate position sensor.) The image is also used to check for the trash build-up on the river side of the gates, and for deterring vandalism.

Figure 8. Real-time image of the fully automated gates on the Richfield Canal diversion structure.

In March 1999, a second camera was added to the system. This camera takes an image of the northern sky every 10 minutes. These horizon images are fed to the National Weather Service and Utah Mesonet and used to verify weather conditions.

To allow water users and meteorologists to see changes that have occurred over the previous 24 hours, the still images are automatically assembled, once an hour, into a time-lapse movie.

The real-time camera system is composed of three subsystems: the camera platform, the communication link, and web server. The camera platform consists of a consumer-grade digital camera; a single-board, PC compatible computer with a 4MB flash memory based hard disk, and a datalogger/controller. The single-board computer runs a special distribution of the Linux operating system.

The communications link makes the camera platform a fully functional host on the Internet. It communicates with the web server at the Internet service provider (ISP) via spread-spectrum radio. At the ISP site, every 10 minutes a program
automatically transfers a copy of the latest image file from the camera platform to the web server.

FULL-TIME INTERNET CONNECTIONS

Two of the key players in the management of the Upper Sevier River have a need for frequent access to the real-time hydrologic data now available on the Internet. Both had Internet accounts with a local dial-up provider but were often unable to connect during periods of peak Internet use, commonly in the late afternoon and early evening. To solve this problem, equipment was installed to give each user a wireless full-time Internet connection.

The radio links which connect the water users to the Internet use license–free 900 MHz spread-spectrum radio modems. These radio systems have a range of up to 50 miles. One end of the radio link terminates at a Richfield ISP, the other at the water managers home. A custom-built router was installed at each home. The router allows the manager to connect his home computer, using an inexpensive network card and cable, to the Internet. The routers accommodate multiple computers. The speed of the Internet data link is between 57 kbps (bits per second) and 115 kbps.

Since the installation of the full time radio modem links, both water managers are frequent users of the water.gbasin.net web site. Web site log files and personal conversations with them show them connecting to the site as often as 10 or more times per day. Since their Internet connection is always “on”, there is no set up time involved with looking at the web site. Both managers leave their computers on full time and their web browsers loaded. This means the latest water data is only a mouse click away.

FUTURE OF THE SYSTEM

The automation/Internet system of the Sevier River WUA continues as a work in progress. Ongoing or planned projects for 1999 include the following:

Expanding the System to the Entire Basin

The automation/Internet system is currently concentrated in the Richfield area (Upper Basin). By the end of 1999, it will be expanded to include the entire Sevier River Basin.

Limited Control via the Internet
At the Richfield Canal diversion structure, a halogen floodlight for night-time illumination a gate actuator on the sluice gate have been connected to the Internet host. When the software is completed, an authorized individual will be able to use his web browser to either turn on and off the floodlight or raise and lower the sluice gate.

**Water Orders over the Internet**

For the Richfield area, software is being developed to allow canal company managers to place water orders over the Internet. This, coupled with better streamflow forecasts, will allow the River Commissioner to fine-tune his reservoir releases and provide more operational flexibility to his canal company customers.

**Daily Water Rights Updates**

To keep water users apprised of the status of their water rights, the appropriate real-time data will be linked to an existing water rights allocation model developed by Dr. Wynn Walker at USU, and daily updates will be distributed over the Internet.

**Real-time River Model**

To date, each automated canal head gate is being operated individually. A real-time river model is being developed to further coordinate reservoir, river, and canal operations.

**SYSTEM EVOLUTION**

The nature of this technological intervention needs discussion. Reclamation’s projects in the past have had beginnings and ends. For example, in the past, the agency constructed a dam and then turned it over to the water users to pay for and operate. In the case of automation and Internet technologies, there is a continually evolving product. The technologies get more sophisticated and less costly with each passing day. And as the technologies get more complex, so do the needs of the water users. With real-time technologies we are promoting a process more than a specific product.

How this process might work is described in Eric S. Raymond’s seminal monograph: “The Cathedral and the Bazaar.” Raymond likens a traditional approach to product development to constructing a cathedral, an edifice carefully crafted by artisans working in inspirational isolation, with no beta released before its time. The process he envisions (the bazaar), however, is more promiscuous. No quiet, reverent cathedral building here, rather a noisy bazaar of differing
agendas and approaches out of which a coherent and stately system emerges. The mantra becomes “Release Early, Release Often.” It is this “bazaar” process that we have tried to emulate on the Sevier River automation/Internet project.

Traditionally, Reclamation had a fairly rigid product development process (cathedral). This approach was taken in the development and installation of large SCADA (Supervisory Control and Data Acquisition) systems. The problems with the cathedral process for small-scale automation systems are numerous: (1) it is too costly; (2) it takes too long; (3) hardware and software are frequently proprietary; (4) the customer does not always get what he needs; and (5) it is difficult for the product to evolve.

With the everybody-get-involved, bazaar-style development, the product evolves rapidly over time in concert with technological change and maturing water user needs. Prototypes (both hardware and software) are rushed to the field; feedback is critical. It becomes necessary for everybody involved in the project to interact, something the Internet facilitates.

SUSTAINABILITY

Is small-scale automation sustainable? We think so, but only time will tell. Right now, in the Sevier River Basin, the Federal Government is handling the research and development and WUA (and its members) are shouldering the costs for equipment. The latter is also installing more and more of the equipment themselves. The private sector is assisting with development, and these costs are currently being shared by Reclamation and the water users.

Important keys to the survivability of the innovations include: (1) active participation by WUA staff with design, installation, and maintenance and (2) WUA providing a consistent level of funding. (WUA is currently providing base-level funding but it is not yet at a high enough level to assure sustainability.) It is critical that WUA staff remain involved at all levels. This will necessitate redefining jobs. For example, a river commissioner will need to evolve from a gate turner/strip-chart reader to a telecommunications/computer expert. This transition will not always be easy.

CONCLUSION

The WUA river, reservoir, and canal automation system, with its links to the Internet, has served the water users well, providing a complete real-time picture of what is happening throughout the Sevier River watershed. This has led to
substantially improved, more timely water management than previously dreamed possible.

May we take the liberty of stating our own perception of the information highway. We will look back on negative perceptions of the Internet and realize with stunning clarity the degree to which we underestimated this amazing technology tool and the good it has brought mankind the world over, through efficient water management alone (for further reading refer to Davis and Meyer, 1998). Reclamation, the Sevier River WUA, and StoneFly Technology are committed to exploring future possibilities.

REFERENCES


Davis, Stan and Christopher Meyer, 1998. BLUR: The Speed of Change in the Connected Economy, Addison-Wesley, Reading, MA.


