# www-BASED MONITORING AND CONTROL FOR OVER-STRESSED RIVER BASINS

Roger D. Hansen[1]
Bret Berger[2]
Arlen Hilton[3]

## ABSTRACT

The Bureau of Reclamation (Reclamation), StoneFly Technology (StoneFly), Utah State University (USU), and several Utah water user groups are working to create "virtual" river basins on the Internet. Websites with accurate real-time representations of the Sevier, San Rafael, and Duchesne river basins are being developed. These river basin websites, coupled with low-cost automatic remote-control on all major structures, allow for nearly instantaneous decisionmaking. The ability to see what is happening throughout a river basin and to react promptly to changing hydrologic and weather conditions is dramatically improving the way rivers and irrigation canals are operated. Additionally, these websites are important elements in building trust and encouraging collaboration between the various stakeholders.

## INTRODUCTION

In the 19th Century, most irrigation systems in the Western United States were run-of-the-river, and they frequently ran short of water in the late summer and fall as the natural flow of the river declined. In the 20th Century, significant man-made water storage became an important ingredient in water resource development projects, and there was a concerted effort to match water supply and demand. When new water storage and distribution systems were constructed, the complex interactions and impacts associated with modifying the natural behavior of river systems and the challenge of sustaining water resources, in an environment of increasing demands for water, were not always foreseen or understood. But in the 21st Century, the American public is clamoring for intense operation of river basins to deliver the right amount of water at the right time.

What is therefore needed is a coordinated effort to operate existing facilities with a basin-wide perspective in an optimal fashion that balances diverse objectives: (1) meeting increasing municipal and industrial (M&I) water needs;

1 Team Leader, U.S. Bureau of Reclamation, Provo Area Office, 302 East 1860 South, Provo, UT 84606-7313, rhansen@uc.usbr.gov
2 Engineer, StoneFly Technology, 1071 East 100 South, Suite D2, St. George, UT 84770, bret@stoneflytech.com
3 Technologist, U.S. Bureau of Reclamation, Provo Area Office, 302 East 1860 South, Provo UT 84606-7313, ahilton@uc.usbr.gov

(2) maximizing power generation; (3) improving water quality; (4) meeting in-stream flow and other biological requirements; (5) protecting endangered species; (6) enhancing recreational opportunities; (7) improving aesthetics; and (8) addressing public safety concerns, all while protecting the viability of the agricultural sector. The authors feel that with more intensive management, it will be possible to meet a wide range of multi-objective goals without too strongly penalizing any one user or interest.

Reclamation's Provo Area and Denver Offices have been working with StoneFly, USU, and several Utah water user groups to develop low-cost real-time monitoring and control systems to address the need for improved operation of existing river basin control facilities.

## TECHNOLOGY DEVELOPMENT AND APPLICATION

One combination of technologies that can enhance the way river basins are managed is the "virtual" river basin: an accurate, real-time representation that can be displayed over the Internet. Critical parts of a "virtual" river basin include: (a) comprehensive real-time environmental monitoring system (including real-time images); (b) low-cost automation systems; (c) Internet displays that provide accurate real-time visualizations of basin conditions; (d) enhanced and alternative methods of real-time database access; and (e) decision-support software. We have made significant progress with items (a) and (b), and have a good start on (c), (d), and (e). Results to date show that better and timelier information leads to better decisionmaking, and with automatic remote-control, required actions can be quickly taken. The "virtual" river basin thus helps meet the growing need for a constant and precise matching of water supply and demand.

### Real-Time Environmental Monitoring

In the 1990's several Utah water user groups began programs to closely monitor their irrigation canals and rivers. This was accomplished by adding dataloggers and radio telemetry equipment to existing flow monitoring sites, water quality monitoring sites, and weather stations. These diverse smaller projects eventually coalesced into something approaching basinwide monitoring systems (see Table 1.) These monitoring systems proved useful for improving water management, particularly with river commissioners and the larger canal companies.

### Low-Cost Automatic Remote-Control

The dataloggers used for the above monitoring systems had the ability to control as well as datalog. This opened up the possibility of automatic remote control on all major water control structures. Unfortunately, at the onset of these projects,

there was little to control as most gates were operated manually. One major obstacle to adding motors was the lack of affordable commercial power.

Table 1. Utah River Basin Websites
General Information

| River Basin | Website (www.-) | Since | Sponsor | Water Monitor/ Control | Weather/ Webcam | Total |
|---|---|---|---|---|---|---|
| Sevier (including San Pitch) | sevierriver.org | 1998 | Sevier River WUA* | 19/21 | 4/5 | 49 |
| San Rafael | ewcd.org | 1999 | Emery WCD** | 60/4 | 5/2 | 72 |
| Duchesne/ Strawberry | duchesneriver.org | 2002 | Duchesne/ Strawberry WUA* | 5/5 | 1/0 | 11 |

Another obstacle was the dearth of commercially available gate actuators that could be easily solar-powered. Reclamation developed several designs for low-cost, 12-VDC gate actuators that can be easily retrofitted onto existing slide and radial gates, (Hansen et. al., 2001). In the meantime, several gate actuator manufacturers developed their own 12 and 24-VDC models that can be powered by small solar panels and deep-cycle batteries. These developments have made the jump to automatic remote control very doable and cost-effective. Today, every major water control structure in the Sevier River Basin is fully automated, most sites using solar-powered gate actuators.

## River Basin Website Development

In the past, monitoring and automation systems generated substantial amounts of data, but it was unavailable to all but a few water managers. This was a constant source of frustration to the excluded water managers and others who needed the information to improve their operations. Meanwhile, the rapid rise in the development and use of the Internet meant that many water managers were either getting "on-line" or considering it. It became apparent that getting the real-time data onto the Internet would be a good way to distribute the information to a wide audience without requiring the purchase of specialized equipment.

In 1997, StoneFly developed a plan to connect the real-time databases to the Internet. Reclamation agreed to assist with the project. The initial effort began in 1998 for the Sevier River Basin, Utah. (The development of the Sevier River website is being partially funded through a grant from the Technology Opportunity Program of the U.S. Department of Commerce). A second website was installed for the San Rafael River system in 1999. By the start of the 2002 irrigation season, a similar site has been installed for the Duchesne Rivers system.

Any water manager or interested individual is now able to sit down at a computer and survey hydrologic and weather conditions throughout these three river basins.

The websites created by StoneFly are designed to serve a variety of users with a variety of displays. The log-in page gives the user several options. One popular display gives hourly flow data for the previous 7 days (see Fig. 1). Current river and canal flow information is displayed in spatial diagrams (see Fig. 2). Another popular display shows the real-time status of all major reservoirs throughout a Basin (see Fig. 3). Web cams are being integrated into all three websites.

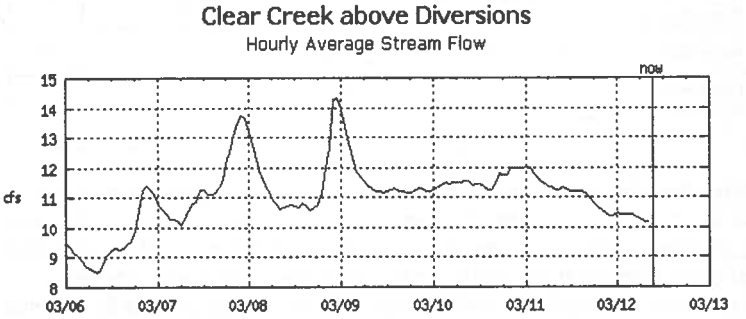


Fig. 1. This time-series plot displays hourly flows at a River gaging site for the previous 7 days.

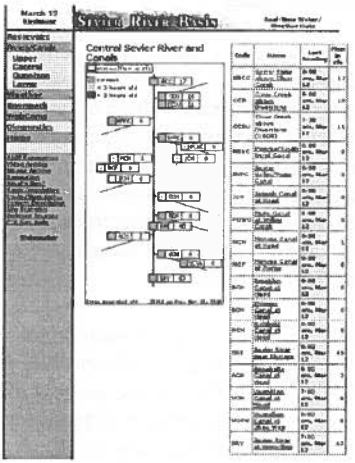


Fig. 2. Spatial diagram displaying real-time Sevier River

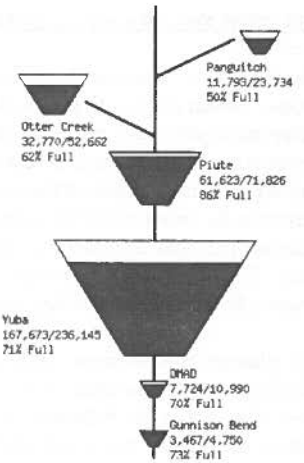


Fig. 3. Real-time status of all major water storage reservoirs in the Sevier River Basin

Progress made to date on these three Utah automation/Internet projects is outlined in Table 1. Fig. 4 shows the general locations served by the three websites.

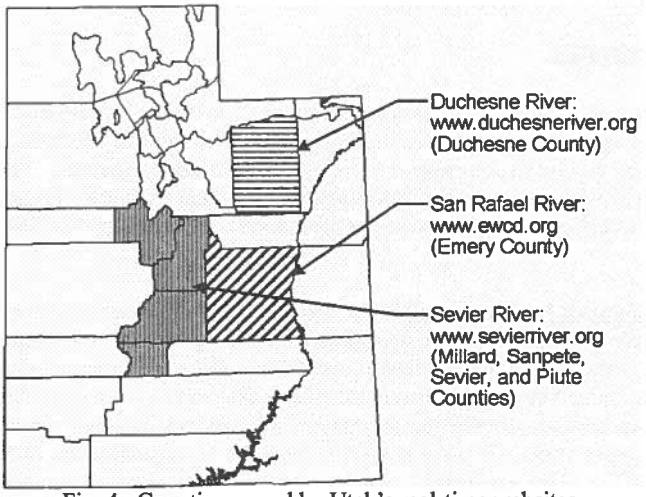


Fig. 4. Counties served by Utah's real-time websites.

## Enhanced and Alternative Methods of Database Access

The value of the data on river basin websites is enhanced by improving Internet access. When information is available over high-speed, full-time connections, water managers make much greater use of the websites. Because these three Utah projects are in rural areas, access to broadband Internet service was extremely limited. It was determined that connecting a few of the key water managers' homes to the Internet full time would be an important step in the project's success. This was achieved by using low-cost, license-free spread spectrum radio links. The water managers with "full-time" connections access the website frequently throughout the day, sometimes more than 20 times.

One planned enhancement to the real-time data access system is the addition of telephone touch-tone data retrieval, since water managers often find themselves in need of access to the information while in the field. StoneFly is in the process of adding equipment which will enable anyone to call in on a telephone and retrieve specific real-time data by entering the proper number on a telephone keypad. This will allow cell phone access to the system.

A second alternative method of remote real-time data access is the web-enabled cell phone. These phones allow the users to view very small renditions of web pages. At the moment, the availability of web service on the rural cellular systems is limited. In the future, however, this service will be more wide spread so there are plans to create alternative versions of data display pages which would be optimized for cellular phone web browsers.

## Decision-Support

Within the next few years, we anticipate being able to build a system that is capable of operating a river basin with little or no direct human intervention required, by tying decision-support models to the automation systems. This will allow a system to operate at maximum efficiency around the clock. To this end, we are working on several decision-support models. Two of these are discussed below.

Decision Support for Water Rights. All western water rights are established by legal decree or statute. In Utah, regulation of water rights is an administrative procedure executed by river commissioners acting under the direction of the State Engineer. In the Sevier River Basin, the river is managed by two commissioners using procedures so complex that few people fully understand them. The most difficult aspect of the allocation procedure involves the determination of the primary flow and the segregation of this water from storage water. Another confusing aspect is the division of the flow into zones.

In view of the importance of water rights in the management of water resources, Dr. Wynn Walker, Head, Department of Biological and Irrigation Engineering at USU, and Roger Walker, retired Sevier River commissioner, developed a computerized water rights allocation model—SEVIER—for use by the river commissioners and others (Walker, 1991). SEVIER duplicates the computations and record analyses performed by the two river commissioners.

To provide water rights updates in a timely manner, Dr. Walker is currently working with StoneFly to connect his model to the Sevier River monitoring system (river flows, canal diversions, and reservoir storage). This will provide the river commissioners, water users, and others with water rights information that is updated daily. By posting this information on the Internet, each irrigator will have continually updated information on the status of his/her water rights and will be notified when additional water is available. This Internet software is being tested during water year 2002.

Decision Support of Long-Term Water Forecasts. Improving the management efficiency of complex systems requires better information about both current and potential future water availability. Since 75 percent of available fresh surface water in the western United States comes initially in the form of snowfall (McManamon et al., 1993) the ability to forecast future water availability is limited by uncertainty in snowpack estimation and the timing and quantities of future runoff from snowmelt.

To address this issue, Dr. Mac McKee, Associate Director at the Utah Water Research Laboratory, USU, has proposed using military decision-support systems to improve forecasts of snowpack and snowmelt. The situation faced by water managers at the river basin scale is in many ways analogous to that of a battlefield commander. Just as battlefield commanders must make decisions about the deployment of troops and weaponry in the face of uncertain enemy strengths and intentions, the water manager must make decisions based on uncertainties related to future water supplies.

Considerable progress has been made in recent years in developing automated and interactive sensor data fusion techniques for military and intelligence applications. Sensor fusion involves a deductive process whereby data is interpreted in terms of models of situational elements, relationships, and behaviors (Bowman and Steinberg, 2001). These techniques can be applied to problems in estimating and predicting the state of regional terrestrial processes, such as water supply.

The USU project would employ information dissemination techniques to make the improved database readily available to water managers, decision-makers, and stakeholders in the three river basins (initially concentrating on the Sevier River Basin). This will require an outreach component that will enable the water users

to transfer the analytic capability that is developed and make it available via the river basin websites.

## ADDITIONAL BENEFITS

In addition to optimizing management of a water distribution system, these new automation/Internet/decision-support systems can: (1) build trust through complete disclosure; (2) encourage collaboration in water resource management; and (3) allow for adaptive management practices.

### Complete Disclosure

Observers of our evolving global economy claim that the concept of transparency, or complete disclosure, is essential to economies which hope to prosper in the future. They argue that information about financial data and transactions should be available to all in a timely and consistent fashion. This ensures that sound decisions can be made by investors and that financial problems don't fester until they explode with unfavorable consequences. We believe that the same principal applies in the case of water resources. When all the stakeholder groups — irrigators, municipalities, sports enthusiasts, boaters, and environmentalists — are privy to the same information, no one can hide their actions. While this may be painful to some in the short run, in the long term we believe it to be good for all. When the www.sevierriver.org went live, there were concerns voiced about making the information available to everyone. After more than 3 years of operation, however, we have not yet heard of anyone wishing for the days when information was scarce and out of date.

### Collaboration

It has been widely reported in the national news media that attitudes are changing in the western United States. For example, a recent edition of *Time Magazine* (MacCarthy, 2001, p. 21) quoted Patricia Limerick, a history professor at the Center of the American West in Boulder, CO: "There has been a tremendous surge in collaborative conservation groups and watershed alliances in the past 10 years. This evolution toward broader input into decision-making is, in part, the result of over-allocated or over-stressed resources and changing values.

The trend toward collaborative and localized decision-making is well served by real-time monitoring/Internet technologies because the latter provides information to everyone with access to the Internet (which is rapidly becoming everyone). There is no more information elite. Better and timelier data, universally available, is leading to better decision-making and improved water management. Websites like www.sevierriver.org reports real-time conditions throughout the Sevier River Basin (including river and canal flows, reservoir storage, snow and weather conditions, water quality, etc) for everyone to see. Decisions are made

with a better understanding of present (and recent past and historic) conditions.

**Adaptive Management**

Environmental monitoring websites can provide timely feedback on important management issues like the effectiveness of salinity control programs or erosion control projects. The benefits of "adaptive management" have long been touted. But adaptive management depends upon carefully monitoring the effects of management actions on the environment, and then using that information to refine our understanding of the system and to adjust our decision-making and management plan (Western Water Policy Review Advisory Commission, 1998, pp 30-31). What better way to assess the effectiveness of management strategies than with real-time monitoring systems coupled with comprehensive decision-support software.

## CONCLUSIONS

At the start of the river basin automation/Internet project, Reclamation and Stonefly staffs were hesitant to speculate on where the projects might be headed, for fear of scaring off the water users. Today the water users are frequently ahead of the technologists. The water users are continually inventing new uses and innovations for their river basin websites.

Admittedly, the process of using low-cost automation/Internet technologies to improve water management is still in its infancy. But, any measure, the river basin websites have been successes. According to one water user: "When something goes down and I have to go back to the old way of doing things, it is like being blind after being able to see."

## REFERENCES

Berger, B., R. D. Hansen, and I. Cowley, 2001. "Developing a Virtual Watershed: Sevier River Basin," In D. F. Hayes and M. McKee (eds.) Decision Support Systems for Water Resources Management, American Water Resources Association, June.

Bowman, C. L., and A. N. Steinberg, 2001. "A Systems Engineering Approach for Implementing Data Fusion Systems." In D. L. Hall and J. Linas (eds.) Handbook of Multisensor Data Fusion, Chapter 16, CRC Press, London.

Hansen, R., F. Woodward, D. Menicucci, and L. Moore, 2001, "Solar Powering Water Resource Automation Projects," in Proceedings of the First Asian Conference of the International Committee on Irrigation and Drainage, Seoul, Korea, September.

MacCarthy, P., 2001. "High Noon in the West," Time, July 16.

McManamon, A., G. N. Day, and T. R. Carroll. 1993. "Snow Estimation—A GIS application for Water Resources Forecasting." In C. Y. Kuo (ed.) Engineering Hydrology, pp. 856-861.

Walker, W. R., 1991. User's Manual: Sevier River Water Allocation Model, Department of Biological and Irrigation Engineering, Utah State University, Logan, UT.

Western Water Policy Review Advisory Committee, 1998. Water in the West: Challenge for the Next Century, NTIS, June.