RECLAMATION
Managing Water in the West

Science & Technology Highlights

Contents

U.S. Department of the Interior
Bureau of Reclamation

Finding effective schedules for cleaning agricultural drains

Iron reducing bacteria are very common in the western U.S., often growing in agricultural drains where they can create a sufficient biomass to plug the drain. Irrigation districts use brushes or high pressure water jets to clean the bacterial film from these drains and restore their capacity. Cleaning schedules are usually arbitrary, and thus may not be very efficient.

This Science and Technology (S&T) research project partners with the University of North Dakota, North Dakota State University, and state agencies to determine the optimal schedule for drain tile cleaning and maintenance. This can lead to more efficient management, lower maintenance costs, and reduced impacts to downstream water quality for Reclamation projects where drain tiles are used.

The 2009 summer activities conclude the field work for this project. This summer's field activities at the Oakes study site included additional chemical tracer tests to determine hydraulic conductivity near the drain tiles and additional denitrification tracer tests.

Preliminary results of this study indicate that the dominant bacteria type present in the tested drain tiles is a manganese oxidizing bacteria. Unlike iron bacteria, manganese bacteria typically do not create the thick, sludge deposits, and therefore do not greatly influence flow rates or nutrient transport in tile drains. Results obtained throughout this project will be analyzed and compiled into Best Management Practices regarding drain tile cleaning schedules. These Best Management Practices are expected to be submitted to the S&T Program by the end of December, 2009. Alison K. Schlag, (701) 221-1276

Creating smart automated irrigation systems to use water efficiently

Despite urbanization, agriculture is still by far the major water user in the Lower Colorado Region, using over 80 percent of the total water consumption. About 95 percent of agricultural water use is through flood irrigation, where gates are opened to let water across the field.

Proper decisions on when water should be cut off to a field must be made based upon the extent of water advancing across the field, but this is difficult at night or with tall, dense crops. Therefore, it is common for the irrigator to over-compensate by over-irrigating. Further, trained irrigation labor is becoming more difficult to hire and retain. Automating controls that are now manually operated could help these systems improve efficiency.

This S&T research project is constructing and testing automation systems on two types of surface irrigation—level basins and graded borders—on existing farms in cooperation with the Universities of California and Arizona. These automation systems will use "smart" programmable logic controllers. We have completed the initial construction of the systems. We are now solving problems with some of the electronic components as well as mechanical problems with gate actuators prior to attempting automated operation. The next step will be programming the "Smart" controllers and de-bugging of the control software, which is scheduled to begin December 2009.

Future plans are to incorporate control of the district delivery flow rate and telemetry of the water delivery data to translate the on-farm water savings into overall district water-savings. Tom Gill (303-445-2201)

Measuring flows more effectively

Improving water management depends on the ability to accurately measure flows at key locations in a water delivery system. Long-throated flumes (figure 1) have become increasing popular as a way to measure open channel flows, as they are highly accurate and cause a comparatively low head loss for critical flow operation. Critical flows are flows moving through a canal faster than slower

moving “sub-critical flows” but slower than “super-critical flows.” Unfortunately, even though long-throated flumes cause little head loss, there are locations in almost all canal systems where there isn’t enough head availability for flume operation during critical flows. Even more vexing is finding that a flume site may not have enough head available for critical flow flume operation under all flow conditions—after installing a long-throated flume.

Figure 1. Long-throated flume at the head of YCWUA’s Cumming Lateral operating under excessive submergence

To overcome these issues, Reclamation Technical Service Center’s Hydraulic Investigations and Laboratory Services Group and the Water Conservation Program at Reclamation’s Yuma Area Office are finding ways to use long-throated flumes under lower flow conditions. The flow measurement system measures water levels in the flume approach section plus the level in the throat section of long-throated flumes, then calculates a discharge rate at the two measured sections. This is exactly the same approach as measuring flow for a pipe venturi meter, thus researchers have dubbed it the “long-throated flume venturi solution.”

We established two field test sites at existing long-throated flumes that are occasionally submerged in cooperation with the Yuma County Water Users Association (YCWUA). At two additional sites—one in cooperation with the Unit B Irrigation District and a second at the University of Arizona Extension Service Valley Farm—we constructed new flumes where excessive submergence was expected under all operating conditions.

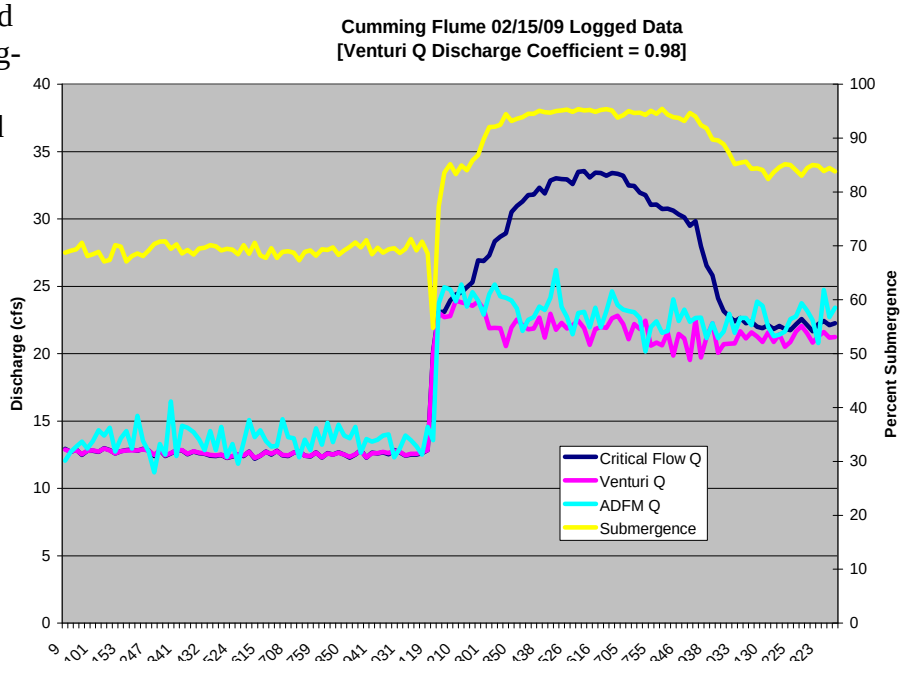


Figure 2. Example plot of logged data

Verification testing has been completed at the YCWUA sites. For flows below the flume's modular limit (about 85 percent submergence for this flume) the venturi solution and the critical-flow flume rating produce essentially identical discharge rates. At submergence rates over the modular limit, the critical-flow flume rating (the blue line in figure 2) produces an erroneously high discharge reading while the venturi solution produces a lower discharge rate (the pink line in figure 2). Under all submergence conditions, there is reasonable agreement between the venturi solution discharge and the acoustic Doppler flow measurement (ADFM) output. Hence under critical flow or excessive submergence conditions, the venturi solution calculated flow rate can provide accurate measurement at long-throated flumes without needing to determine the actual submergence rate. Tom Gill, 303-445-2201

Understanding salinity and ground water levels for more efficient agriculture

Ground water levels can rise into the root zone and cause crop production loss and also cause salinity movement up into the root zone by capillary action. Continuous shallow water tables, without adequate downward leaching or drainage, can cause continually increasing soil salinity.

Water logging and salinization are ancient problems for irrigated agriculture. About 20-25 percent of the world's irrigated land is affected by saline high water tables, with an estimated productivity loss is valued at about $10 billion per year world wide. About 27 percent of U.S. irrigated land, is afflicted with these problems. Salinity and water logging corrective actions range from irrigation management to tile drain construction to land fallowing. But to use these actions effectively requires knowing the extent of the problem.

The Science and Technology Program is working with Colorado State University and Dr. Luis Garcia to create a computer model to predict changes in ground water levels and soil salinity levels based on irrigation and drainage. This model can be used to evaluate irrigated agriculture in areas that are subject to shallow water tables and determine what actions would be most effective for controlling salinity and producing crops. Dr. Luis Garcia has been monitoring water levels and salinity in irrigated crop fields in Colorado, where salinity is particularly a problem. In the lower Arkansas River Basin of southeastern Colorado, salinity problems have led to changes in cropping patterns, reducing crop yields by 13 to 20 percent and adding 14 tons of salt per acre to the Arkansas River annually. We have used the data collected in the Arkansas River Valley to provide design data for subsurface drainage and also to provide on-farm field data for use in calibrating and correcting the Colorado State University Irrigation and Drainage (CSUID) computer model. We are now beta testing the model with these field data.

This model considers impact to soil and crop production due to both salinity and water table depth and can be field tested and calibrated with actual field data collected under on-going research of CSU in the Arkansas River Valley. Inputs are elevations of ground surface, impermeable layer, and initial water table; salt concentrations of initial aquifer and irrigation water; soil hydraulic conductivity, crop type, and irrigation scheduling and crop yield response factors. The model computes soil moisture movement and salinity concentrations in a 3-D grid. It computes relative yield estimates based on a combination of matrix, osmotic, and water logging stresses throughout the period of modeling. The model can be used to evaluate both downstream impacts throughout the region and implications of water transfers, leasing, exchanges, etc. The CSUID model can serve as a tool to measure and evaluate various solutions to the waterlogging and salinity problem which will also help to reduce non-beneficial uses and constituent loadings in return flow.

Developing an enterprise approach to data stewardship and management

Reclamation's Science and Technology Program provided Data Stewardship and Management training to Reclamation's senior management in Denver on October 7, 2009 as a part of its Biological Resources Data Stewardship (BRDS) research and development effort. This training was provided to brief managers on the need and benefit of sound data stewardship practices for Reclamation's mission and to gain their support for the implementing best practices in data stewardship.

Data stewardship is formalized management of an organization's data assets, shown in figure 1.

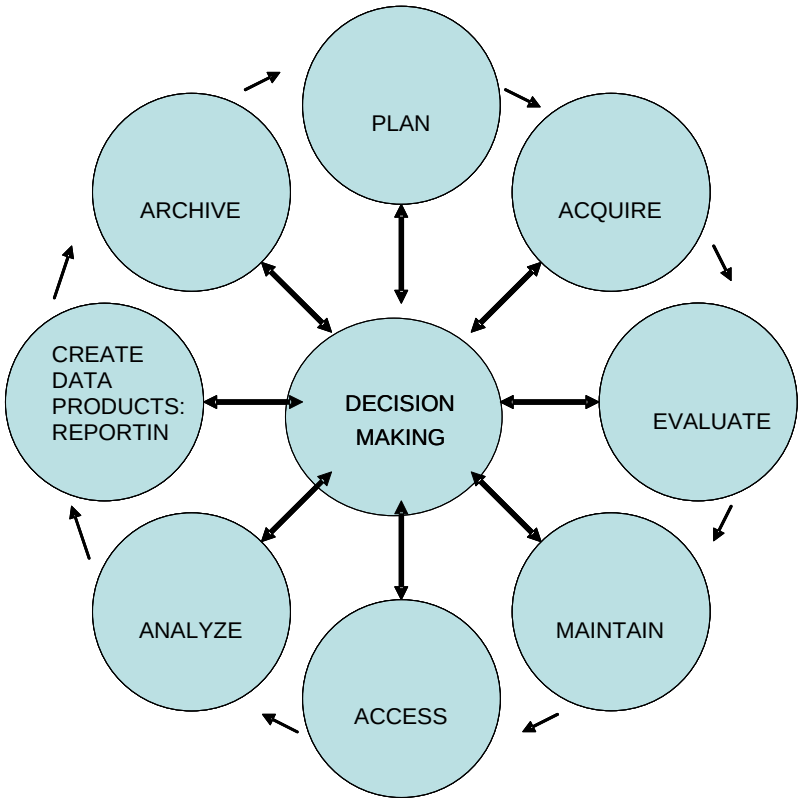


Figure 1. Data Life Cycle

1. **Plan:** Define how all of the life-cycle components will be accomplished. This involves the characterization of data requirements based on the business and/or decision needs of the agency.

2. **Acquire:** Collect, purchase, convert, transform, share, exchange, or create data selected to meet the business and/or decision needs of the agency

3. **Evaluate:** Provide quality control. Implement processes for complying with the Information Quality Act. Ensure that collected data meet agency business requirements. Test data for conformity with standards, completeness, consistency, accuracy, and relevance. Identify and publish data assets and data gaps (both internal and external) as they relate to business-driven or decision-driven requirements.

4. **Maintain:** Provide processes and systems to house, update, and share the data. Establish schedules for data retention and disposal.

5. **Access:** Ensure that the data and metadata are secure and can be found and used as appropriate by staff, managers, offices, other agencies, and the public to meet their business requirements. Protect data integrity. Secure and protect proprietary and pre-decisional data.

6. **Analyze:** Translate the data into information most useful and relevant to the decision or project.

7. **Create Data Products:** Provide timely and useful reports to appropriate personnel, or other entities.

8. **Archive:** Implement procedures for the required retention of data and the data's retirement into long-term storage. Implement procedures for disposal of data in compliance with National Archive and Records Administration requirements.

Research Director, Curt Brown, provided opening remarks that detailed the history of the BRDS effort and why data stewardship is critical for Reclamation: sound and transparent decision making, obtaining greatest return on investment, enhancing program and scientific credibility, and improving data quality.

The trainers, Ms. Barb Kett and Mr. Tom Chatfield from the Bureau of Land Management, covered subject areas ranging from what data stewardship is and is not, to the data life cycle, the data standards process, data quality evaluation, and data management tools.

Reclamation's organizational structure is highly distributed. In addition, much of the Bureau's data gathering is project-driven, not program-driven. These two realities create challenges for achieving consistency and comparability in data

acquisition, evaluation, maintenance, accessibility and analysis. Senior management recognized that drafting policies, procedures, and standards will be one of the challenges of the ongoing BRDS effort.

The BRDS team is currently developing both an action plan for implementing data stewardship in Reclamation and an umbrella policy. In FY2010, the team will be providing its implementation plans to leadership Doug Clark
(303) 445-2271

Reviewing current project operations practices to communicate risk and uncertainty and incorporate climate information

Developing and communicating interannual operations outlooks are crucial to operating Reclamation facilities and managing water. These outlooks let stakeholders and planners know the forecasted volume and timing of water supplies for up to two years in the future. However, these outlooks are limited in time and certainty. Communicating these limitations—and how and why the outlooks may change—is essential to effectively planning for conditions (e.g., reservoir levels). Decision makers and stakeholders thus need Reclamation to provide understandable and accessible information on outlook uncertainty and performance risks. Incorporating climate information into the development of these operational outlooks may better characterize risk and uncertainty and thereby benefit decision makers and stakeholders.

The Science and Technology Program hosted a workshop for Reclamation operations managers and outlook developers, Federal science agencies, and a selected set of outside agencies with direct interests in climate- informed operations as well as academic experts in uncertainty and risk analysis on June 16-17, 2009. The workshop explored the types of operational outlooks that are made within Reclamation, how these currently incorporate weather and climate information, and the uncertainties associated with outlook development and how those uncertainties are communicated to stakeholders.

A workshop report is in preparation based on discussions at the workshop. The report will:

1. Document critical risk questions asked by stakeholders and stakeholders' perceptions on planning uncertainties

2. Document current practices to assess input uncertainties in operational outlook development at each Reclamation office represented at the workshop, focusing on the 1-month to 2-year look-ahead horizon for outlook development

3. Determine common types of uncertainty represented or absent in the analysis, and common methods for handling uncertainty

4. Explore ways to improve communicating risk and uncertainty with management and stakeholders

5. Outline the next steps to improve uncertainty and risk representation and communication

Jim Prairie (303) 492-8572 and David Raff (303) 445-2461

Modeling changes in water quality resulting from sediment delta interactions

Sediment deltas in reservoirs can be sources of nutrients and organic material which can increase algal growths and degrade water quality. These problems occur in many Reclamation reservoirs but the extent and triggers are not well understood. The S&T Program is investigating the interactions between sediment deltas and reservoir basins using Deer Creek Reservoir on the Provo River in Utah as a field laboratory. The study results will include tools for quantifying water quality impacts from sediment delta interactions. These tools and other findings will help Reclamation managers and planners understand and prepare for these impacts.

Brigham Young University is conducting the field studies of Deer Creek Reservoir twice a week (figure 1). Data collected during field trips included profiling reservoir temperature, chlorophyll, nitrates, pH, conductivity, dissolved oxygen, and turbidity and acquiring high resolution sonar data. The data are used to monitor temporal and spatial changes in water quality, provide data for the reservoir model, and support research into specific interactions. Research of specific interactions includes characterizing and estimating nutrient content in the sediment delta; determining the amount of organic matter in the water column from samples and from fluorescence measurement of particles in the water column (figure 2); and developing detailed sediment movement data from high-resolution sonar data. Nick Williams (801) 524-3888

Figure 1. Sampling at Deer Creek Reservoir

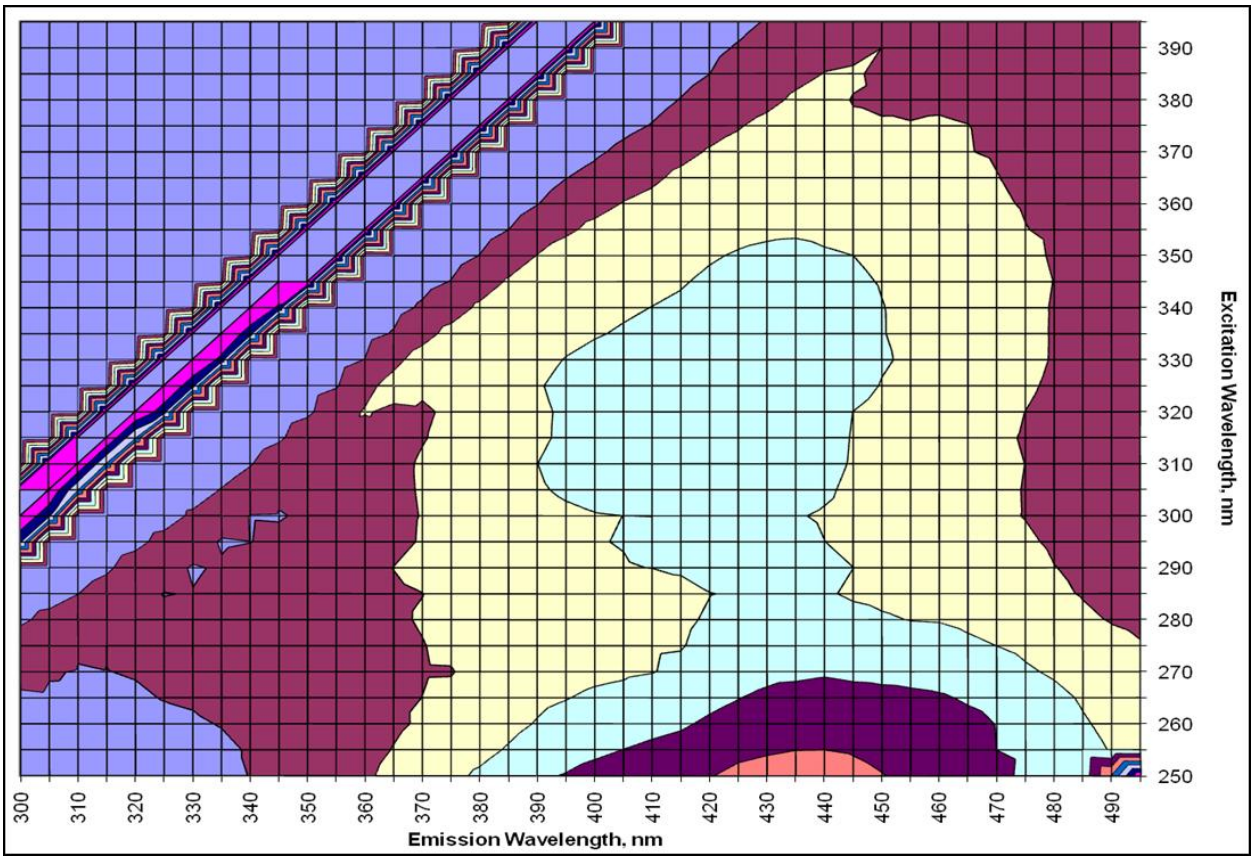


Figure 2. Fluorescence measurement of particles in the water column

Improving Water Delivery Reliability

Finding ways to operate projects efficiently and protect Pacific lamprey in the Columbia River Basin

Figure 1. Pacific lamprey in the laboratory

Pacific lamprey (*Lampretra tridentata*) play an important role in the Columbia River Basin ecosystem: they are of high cultural importance to native peoples of the Pacific Northwest, play a key role in stream nutrient recycling, and are an important food source for some native fishes. Pacific lamprey (figure 1) have declined significantly over the last half century throughout much of their native range, including the Columbia River Basin. Numerous human factors have contributed to the decline of Pacific lamprey, leading to their protected status by the state of Oregon and a recent petition for listed status under the ESA. Many tribes throughout the range of Pacific lamprey have an interest in improving and restoring lamprey populations because of their ecological and cultural importance.

Irrigation diversion dams and associated structures and facilities may impede the upstream migration of adult Pacific lamprey and the downstream migration of juvenile Pacific lamprey. Upstream passage criteria for adult salmonids are often not appropriate for adult lamprey, which are weaker swimmers with less stamina than salmonids.

Although juvenile lamprey generally spend 4 to 6 years burrowed in the soft sediments of streams, actions such as scouring events, electrofishing, and even favorable water discharges may cause them to be dislodged. These passively moving juveniles can enter canals or encounter physical barriers. Information about the swimming ability of juvenile Pacific lamprey can help improve designs and develop operating criteria for diversion structures and canals. The S&T Program is conducting two separate research efforts to ensure that Reclamation can help operate efficiently while protecting this valuable natural resource:

- **Understanding larval Pacific lamprey swimming capabilities.** Understanding the swimming capabilities of larval lamprey will help us develop operating procedures and innovative devices to protect them. The S&T Program conducted laboratory experiments to measure the prolonged-sustained and burst swimming speeds of wild larval Pacific lamprey. Prolonged-sustained speeds were measured using an annular variable speed swimming chamber and burst speeds were determined using a swimming raceway and digital video analysis. During prolonged-sustained swimming experiments, the mean length of time larval lamprey could swim in the chamber ranged from 43.0 minutes when exposed to a velocity of 10 centimeters per second (cm/s), to 0.4 minutes when exposed to 50 cm/s. The burst swimming speeds of lamprey tended to increase as their length increased from 107 to 150 millimeters and ranged from 33.3 to 75.0 cm/s. Our estimates of the overall swimming performance of this life-stage for this species are the first estimates ever reported and can provide important information when developing approach velocities and infrastructure to improve lamprey passage while minimizing entrainment loss. Zachary Sutphin (303) 445-2141

- **Developing and evaluating devices to enhance adult and juvenile lamprey passage.** We are evaluating potential adult and juvenile passage issues at Reclamation diversion structures in the Umatilla and Yakima basins to determine and document the extent of passage problems. We plan to investigate new adult and/or juvenile passage devices to provide safe and effective passage for lamprey.

Figure 2. Lamprey passage devices

We conducted some preliminary tests in the Umatilla River to assess the effect of a behavioral guidance device to guide juvenile Pacific lamprey. Further testing is needed to verify initial results. An appropriately designed and installed guidance device could reduce or eliminate entrainment of juvenile lamprey into canals. Adult passage can be facilitated with an adult passage "lamprey ramp." These are relatively simple devices that have been shown to provide effective adult passage. Having structures in place or ready to install to improve upstream passage for adult Pacific lamprey and to protect juveniles from entrainment into canals might reduce the potential that Reclamation would be required to consult with the Fish and Wildlife Service on project operations where lamprey occur and that might require Reclamation to implement actions as part of a biological opinion. Stephen Grabowski (208) 378-5030

Using fiber optic cables to map ground water contributions to mountain streams

Along parts of the Middle Fork John Day River, Oregon, substantial changes to channel processes and associated habitat have occurred since the 1800s. These changes have also occurred in many of the mountain streams that flow into the Middle Fork John Day River. As a result, populations of several important fish species have markedly decreased. Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration are working on salmonid habitat rehabilitation projects in the Columbia River Basin to help meet tributary habitat commitments in the 2008 Federal Columbia River Power System Biological Opinion.

Understanding ground water springs, primary sources for sustained cold water input to a stream, and their connection with streams is crucial to rehabilitating salmonid and trout habitat. Ground water springs can enter the stream below the water surface in the channel of the stream, where they can't be seen. They must be measured with temperature sensors. Standard measurement techniques use temperature sensors to measure temperature changes at distinct points along a channel, which can miss these springs.

To provide a full picture of the stream's longitudinal temperature profile, Reclamation's S&T Program is working with Dr. John Selker at Oregon State University to use fiber optic cables that are placed along the bottom of the channel (for up to 10 kilometers) to measure every cold water source along that cable. Reclamation is testing the Distributed Temperature Sensing (DTS) system on a mountain stream in Oregon to provide a full temperature profile so restoration strategies that benefit summer/fall steelhead, Chinook, and trout habitat can be better identified. The mountain stream was relocated to its historical alignment in 2008 to improve ground water connection, floodplain connection, and canopy cover among other purposes. The DTS cable was placed along the bed of the

mountain stream before it was relocated to continuously measure temperature fluxes along the entire length of the cable (to prevent data gaps between sensors). After the channel was relocated, the process was repeated and the results from each measurement are being compared. The fluxes within and between the two channels provide information on location of ground water springs. The daily temperature fluctuations in combination with numerical modeling of the thermal process can yield information on ground water upwelling, water flow, and oxygen levels in the gravels below the channel surface.

This type of technology can help Reclamation select rehabilitation projects of this type based on positive ground water connection, temperature improvement (lower in-channel temperatures because of higher ground water contributions) and aid in its role to provide salmon, trout, and other aquatic species habitat throughout the west. This technology may also be used in canals to identify temperature changes in these systems, to improve flow regulation.

Data from the cable have been collected and computer modeling of the thermal process is underway. Results are anticipated by the end of fiscal year (FY) 2010.
Toni E Turner (208) 378-5025

Figure 1: Mountain stream post-relocation during high water in spring 2009.

Creating water catchments to help wildlife at Reclamation's reservoirs.

Owhyee Reservoir boasts a wide range of wildlife, including big horn sheep (a critical species), deer, antelope, and wild horses, as well as many birds (doves, chukars) and small mammals. The reservoir is popular for not only wildlife watching, but hunting, fishing and boating. During the summer months when Owyhee Reservoir is drawn down for agricultural purposes and has minimal flowing water, blue green algae (toxic) blooms form along the stagnant banks of the reservoir. These algal blooms can be fatal if ingested by wildlife, dogs and possibly even humans. The Oregon Department of Health Services announces reservoir closures in Oregon for months during these algal blooms for public afety reasons. Other reservoirs may have similar problems during low flows.

Figure 1. Water catchment basin

Water catchments (figure 1) can help wildlife and recreational values at the reservoir. The Bureau of Land Management, Oregon Department of Fish, Wildlife Wild Sheep Foundation, and others are partnering with Reclamation's Science and Technology to choose locations and install water catchments to better serve the wildlife during the hot dry months. These water catchments not only conserve reservoir water, but to hold, save and use other sources of water (such as snow and rain runoff) to benefit wildlife.

Many of these catchments need to be monitored for upkeep and to determine if their placement is effective. Cameras at some of the water catchments monitor wildlife use (figure 2).

Figure 2. Rams hung out a water catchment from July to September, 2008

Though the water quality of the catchments may look bad, testing confirmed that the water was almost humanly drinkable, with low fecal counts and bacteria. The pH was high due to alkalinity of the soil. Testing in August and September of 2009 for algal toxicity was very low.

Monitoring water quality also allows better responses to warnings for public safety, if necessary.

A Biological Assessment for BLM includes placing 10 new water catchments (6 completed and 4 more proposed). Our partnership base is broadening to include the Oregon Native Desert Association and Western Watersheds. We are a developing plans to annually test the Owyhee Reservoir water quality for the months of August through October (pending weather) for algal toxins. In 2009, we started to collect these data, and are working on optimizing parameters to best test the Reservoir as well as the water catchments. To test for algal toxicity we are incorporating *Abraxis Mircrocystin* ImmunoStrips to test all the sample sites both in the reservoir and the catchments. Temperature Data Loggers will also be deployed in the catchments from May 2010 to September 2010. Gretchen K. Fitzgerald (208) 383-2231

Improving fish habitats when reservoirs are drawn down

Figure 1. "Log" type habitat structure with double deck design

Figure 2. Single deck construction structures in a small tributary

The S&T Program is evaluating "log" type habitat structures as a new way to balance the needs of protected fish species with water management. These log structures feature a very sturdy double (figure 1) or single (figure 2) deck design that helps to direct flow and provide security cover for all age classes and species of fishes. These fish habitat structures provide cover in tributaries that flow through the dewatered zone of a reservoir. These areas are typically void of habitat that protects fish like bull trout (a federally protected species).

This project began by researching a wide variety of habitat improvements and working with project partners to design a structure for these applications. Placement is designed to deepen the channel and provide hiding cover for migrating fish. Each

structure is secured with substrate anchors to minimize movement during inundation. During 2009, "log" type habitat structures of varying designs were placed in small and large tributaries to test for their effectiveness at providing fish habitat and withstanding seasonal inundation (in some cases greater than 50 feet in depth). Evaluating the habitat structures will be completed when low summer flows in 2010 allow for follow-up site visits.

If the habitat structures being evaluated prove durable and able to provide usable fish habitat then placement of similar structures on a larger scale may help to address habitat issues regarding ESA listed species without needing to alter existing water management. A completion report will be available in FY2011. Dmitri Vidergar (208) 383-2216

Allowing passage for green sturgeon at the Red Bluff Diversion Dam

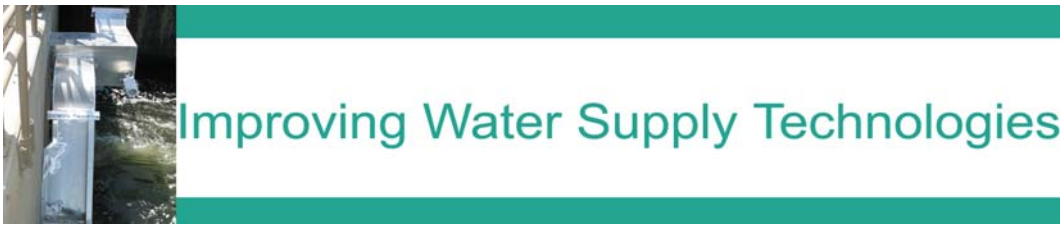
Operating the Red Bluff Diversion Dam (RBDD) in California could impact the federally listed green sturgeon (*Acipenser medirostris*) by blocking their upstream spawning migration when the dam gates are closed. Green sturgeon also risk being injured as they move downstream underneath the gates during post-spawning migration. In the past, the gates of the dam were closed on May 15th to fill Lake Red Bluff which supplies irrigation water by gravity to the Tehama-Colusa and Corning canals. However, in 2009, closure of the gates was delayed until June 15th with minimum gate openings of 18 inches to allow for downstream passage under the gates.

By monitoring and tracking the temporal and spatial movements of acoustically-tagged green sturgeon in the vicinity of the RBDD (figure 1), Reclamation can gain needed information regarding sturgeon behavior and movement. This information can lead to the adaptive management and operation of the RBDD to avoid potential impacts to this threatened species during migrational activities while continuing the delivery of water to the water users of Northern California.

Figure 1. Preparing green sturgeon for acoustic tagging (Photograph was taken by Richard Corwin, Reclamation)

In April and May, Reclamation and UC-Davis biologists captured and acoustically-tagged ten green sturgeons downstream of the RBDD. Monitoring

and tracking of these tagged sturgeons indicated that five of these sturgeon passed upstream of the RBDD before the gates closed. Three moved downstream passing the dam before the gates were closed and two passed downstream under the gates shortly after the gates closed. This indicates that the change in operations at the RBDD allowed green sturgeon to pass upstream to complete their spawning migration and return downstream of the dam safely. Richard Corwin (530) 528-0512



Treating produced water for beneficial use in the Western U.S.

The S&T Program is developing methods to manage water produced during oil and gas extraction. This water typically contains elevated concentrations of dissolved ions and may contain oil and grease, BTEX compounds, and other organic chemicals. If the water is not treated and disposed of properly, it may harm the surrounding environment and surface and subsurface water supplies. If treated to appropriate standards, produced water may be used to augment conventional water supplies in many areas of the Western U.S. for aquifer storage, stream flow augmentation, and agriculture uses.

In October 2009, the research team completed a technical assessment describing the benefits and limitations of all major produced water treatment technologies. This document also includes information on cost, infrastructure, chemical and energy requirements for each of the technologies. This document may be used by stakeholders interested in using produced water or oil and gas companies looking to treat and dispose of produced water.

We developed a database based on the information presented in the technology assessment. This database is used to assist in the selection of produced water treatment technologies for a given application based on the raw produced water quality and the water quality requirements of the desired beneficial use for the water. Treatment technologies are selected based on their ability to meet to the beneficial use water quality and their performance based on key design criteria for produced water applications (figure 1). Design criteria for produced water applications include chemical and energy demand, cost, reliability, flexibility, and mobility. The selection module selects the minimum number of technologies

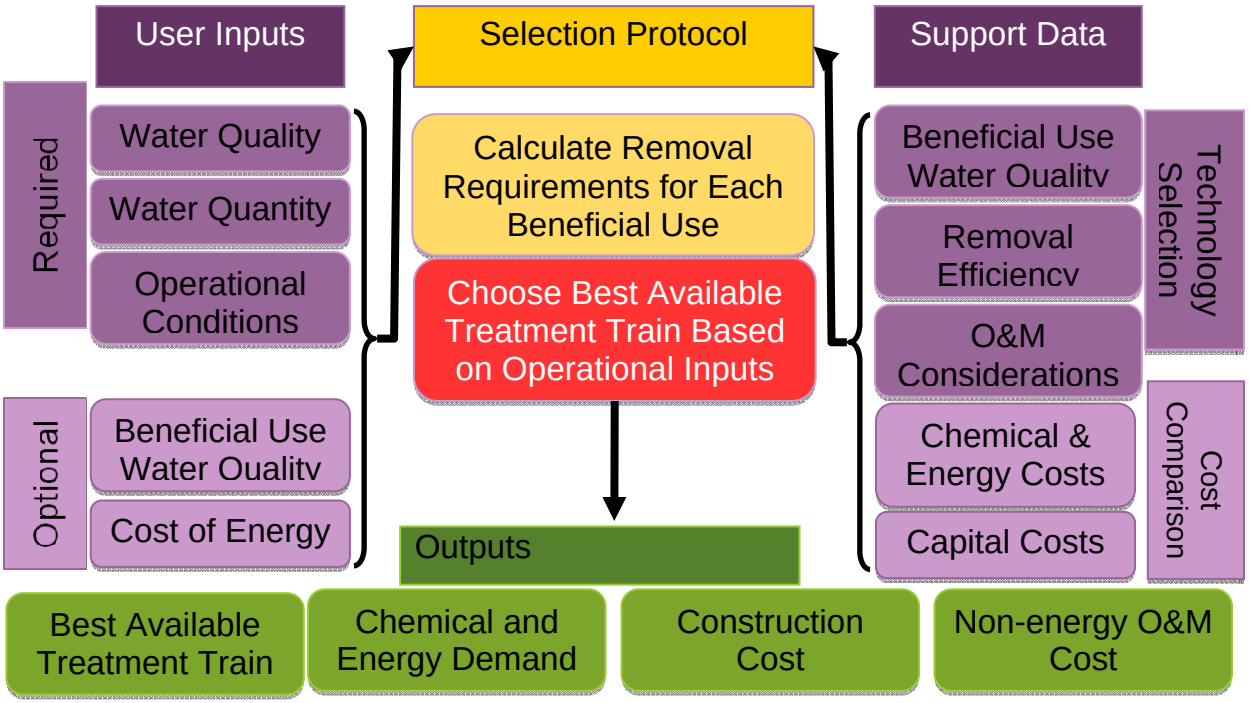


Figure 1. Treatment Selection Algorithm Schematic

required to meet the treatment goals while maximizing the use of these technologies based on the design criteria.

The treatment selection algorithm will be validated using sample produced water applications. The results of the selection module will be compared against standard water treatment technology selection methods. A sensitivity analysis will also be performed on the design criteria to describe how the treatment technology selection varies based the importance and ranking of the design criteria.

Figure 2. Ceramic ultrafiltration membrane module.

We are also researching ceramic ultrafiltration membranes as a new treatment technology for produced water. Ceramic membranes are robust, chemically and thermally resistant, can produce high flux rates, and have high mechanical strength (figure 2). This study will identify the optimal operating conditions for ceramic membranes to determine whether they are more cost effective than conventional polymeric membranes. We found that operating parameters (e.g., membrane configuration, flow velocity, and backwash) significantly affect the membrane flux and that there are significant interactions between the factors that can be used to determine optimal operating conditions for ceramic membrane systems.

We are now conducting experiments to augment the previous ceramic membrane experimental design. The new data will be used to determine optimal levels of each factor to minimize the flux decline while maximizing the absolute flux of the system. These ceramic membrane operating conditions will be used to conduct a side-by-side comparison of the performance and cost of ceramic and polymeric membranes. Katie Guerra 303-445-2013