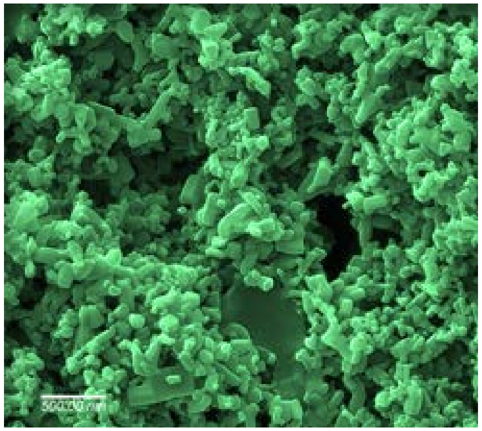
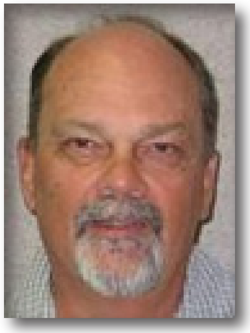




Utah Water Research Laboratory

2011-2012 ANNUAL REPORT

UtahStateUniversity

Message from the Director



Mac McKee
UWRL Director

When the Utah Water Research Laboratory (UWRL) opened its doors in the 1960s, it was among the first research institutions in the world to begin computer modeling of hydrologic systems. This early modeling effort involved simulating salinity in the Colorado River using a primitive hybrid digital/analog computer.

Over 40 years later, UWRL researchers are still charting new territory. The research projects highlighted in this year's report show some of the ways we are reaching beyond our current knowledge and working to make lasting positive impacts on scarce water resources in Utah and around the world.

One example is our research into development of the hydrologic cyberinfrastructure that will make vast quantities of data easily available to anyone with a browser and an internet connection. Directed by Drs. Jeff Horsburgh and David Tarboton, our researchers are among the leaders in the world in development of this capability that stands to improve our understanding and management of water resources systems.

Rapid developments in nanotechnology present tremendous potential benefits to society, but little is known about the possible environmental and health impacts these particles might have as they make their way into the environment. Prof. Joan McLean and other USU researchers are seeking to identify, quantify, and understand those impacts.

Only a handful of people in the world are actively engaged in research incorporating temperature into transient storage modeling. As a young faculty member, Dr. Bethany Neilson is already internationally recognized as a leader in this field, and her use of high resolution imagery opens up some unique research opportunities in this area. Her research will result in tools and knowledge that will improve the management of temperature-constrained waters, such as exist on the Virgin River and elsewhere in Utah.

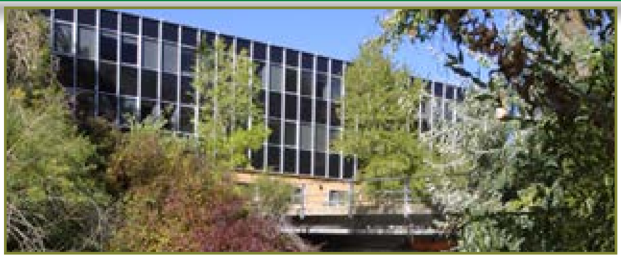
Water and energy play intertwined roles in the US economy and in society, and the energy cost of water—to treat it, to heat or cool it, and to move it—can be gigantic, even on a smaller scale in individual homes. Dr. David Rosenberg and his students are working to better understand the relationship between water use and energy costs in order to provide useful information to homeowners and large water purveyors alike.

This report can only provide a brief snapshot of the wide range of research ongoing at the UWRL. For more information, please visit our website at:

http://uwrl.usu.edu/

INSIDE

The Utah Water Research Laboratory – Facilities



The Utah Water Research Laboratory (UWRL) is a stand-alone facility located at Utah State University on the Logan River in Logan, Utah. The UWRL operates within an academic environment in the College of Engineering, but also collaborates with government and the public sector to address all aspects of water-related issues.

More than 113,000 ft^2 of state-of-the-art laboratory, computer and office facilities support students and faculty researchers alike and make possible the nearly 300 research projects ongoing at the lab at any given time.

Environmental Quality Laboratory

The 11,000 ft^2 Environmental Quality Laboratory (EQL) at the UWRL is equipped for analyses of organic and inorganic constituents in air, water, and soil. The EQL consists of chemistry, microbiology, radiological, and analytical instrumentation laboratories; two constant temperature rooms and research project areas.

Experiments at the UWRL Environmental Quality Laboratory

Hydraulics Laboratories

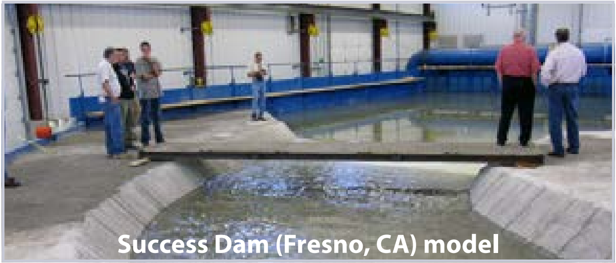
The UWRL contains two fully-equipped hydraulics laboratories:

- The 50,000 ft^2 hydraulics laboratory within the main UWRL building, and
- The new 11,000 ft^2 hydraulics laboratory building constructed in 2009.

An upstream reservoir provides water for both facilities at rates exceeding 200 cfs and 100 cfs, respectively, at any season of the year. Balanced Logan River inflow and outflow constantly freshen the stored water used in research studies, while the level of the river never changes.

The main lab contains a variety of flumes, channels, pumps, pipelines, equipment, and instrumentation for conducting physical model studies, hydraulic research, valve testing, and flow meter calibrations. Steel piping networks and channels located under the floor supply water to various parts of the lab and conduct water from experiments to precise flow measurement facilities, re-circulating pumps, or back to the river. The new hydraulics scale modeling laboratory receives water directly from the Logan River through small diversions into a 194,480 gallon tank located under the building. Water is lifted out of this tank by any or all of three 150-horsepower turbine pumps for use in scale models and then is allowed to flow back into the tank. Some of the initial projects conducted in the new hydraulics building include:

Susu Dam (Malaysia) model



Success Dam (Fresno, CA) model

Success Dam (CA): The first physical model study in the new building. This model project involved seven different state and federal agencies and was so large that another model for this project had to be conducted in the main lab at the same time.

Susu Dam (Malaysia): A physical model study conducted to decrease costs and increase the safety of the hydraulic structure by identifying and eliminating potential problems in the design phase.

Utah Lake Pumping Station (UT): A physical model to test a new pumping station designed to increase capacity, allow for simpler operation, and meet current safety standards.

Utah Lake Pumping Station (Utah) model

Jeffery S. Horsburgh is a Research Assistant Professor of Civil and Environmental Engineering at Utah State University and the Utah Water Research Laboratory. His general areas of research interest include watershed hydrology, surface water quality, and hydrologic information systems. His focus is on the development of new technology (including observing systems, sensor networks, and cyberinfrastructure) aimed at increasing understanding of environmental processes. Dr. Horsburgh is currently leading a team of students, programmers, and technicians in the development of cyberinfrastructure supporting collaborative data sharing, analysis, and modeling. (**jeff.horsburgh@usu.edu**).

Installation of a continuous water quality monitoring site in the Little Bear River

Research Highlight

Cyberinfrastructure for Collaborative Data Sharing and Modeling

New technologies are making available a growing volume of observational data—an exciting prospect for those addressing serious water management issues. However, the ever increasing volumes of data are challenging to manage. Scientists often spend 50-80% of their time on data management tasks, taking up time that could be better spent on the analysis and modeling that will lead to new water management solutions.

Scientists, engineers, and water managers need new, more efficient, and collaborative ways to store, manage, analyze, and share digital information.

Research

Researchers at the Utah Water Research Laboratory (UWRL) are developing innovative new cyberinfrastructure tools, including data models, database systems, and web applications that will support the development of new resources such as:

- Environmental sensing networks.
- Catalogs of existing data resources within the state of Utah.
- Web-based collaboration tools that will allow researchers across the state to work together and share results.

The UWRL is leading the cyberinfrastructure development for two multi-million dollar research collaborations involving scientists from all of Utah's major research universities and many of the state's smaller campuses.

Results

Little Bear River Observatory at the UWRL is the model for new monitoring systems in Utah and elsewhere. The high-frequency data from the continuous monitoring sites has provided new insights into the timing and magnitude of sediment and nutrient fluxes that would not have been possible with low-frequency monitoring.

Hydroserver is a suite of software tools developed by UWRL researchers as part of the CUAHSI Hydrologic Information System, a national cyberinfrastructure development effort aimed at increasing access to hydrologic data.

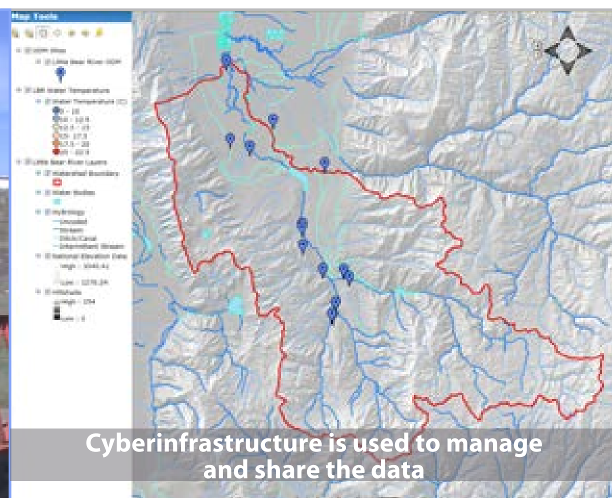
Hydroinformatics is a newly developed graduate level course that was offered simultaneously via interactive video conferencing at Utah State University, University of Utah, and Brigham Young University. The course is designed to better prepare students for data-intensive research and project work environments.

Looking to the Future

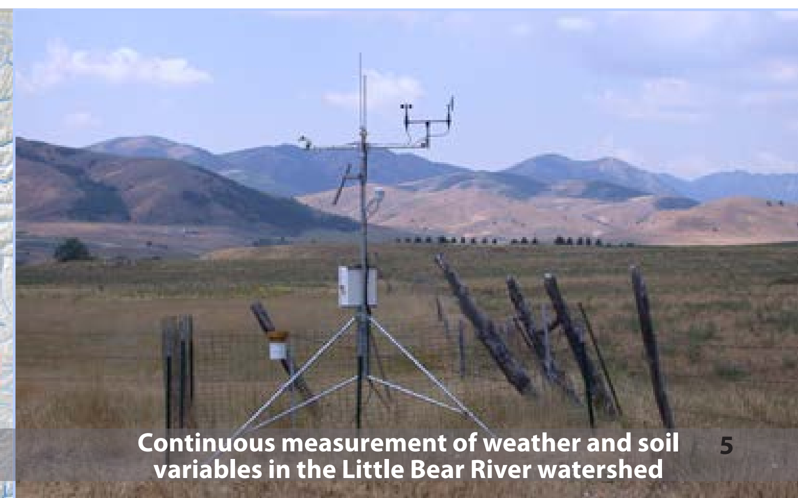
This research will continue to focus on developing the cyberinfrastructure to link observational data with models of natural and human engineered water resource systems.

The cyberinfrastructure developed will support a new environmental observatory network under Utah's NSF-funded EPSCoR program.

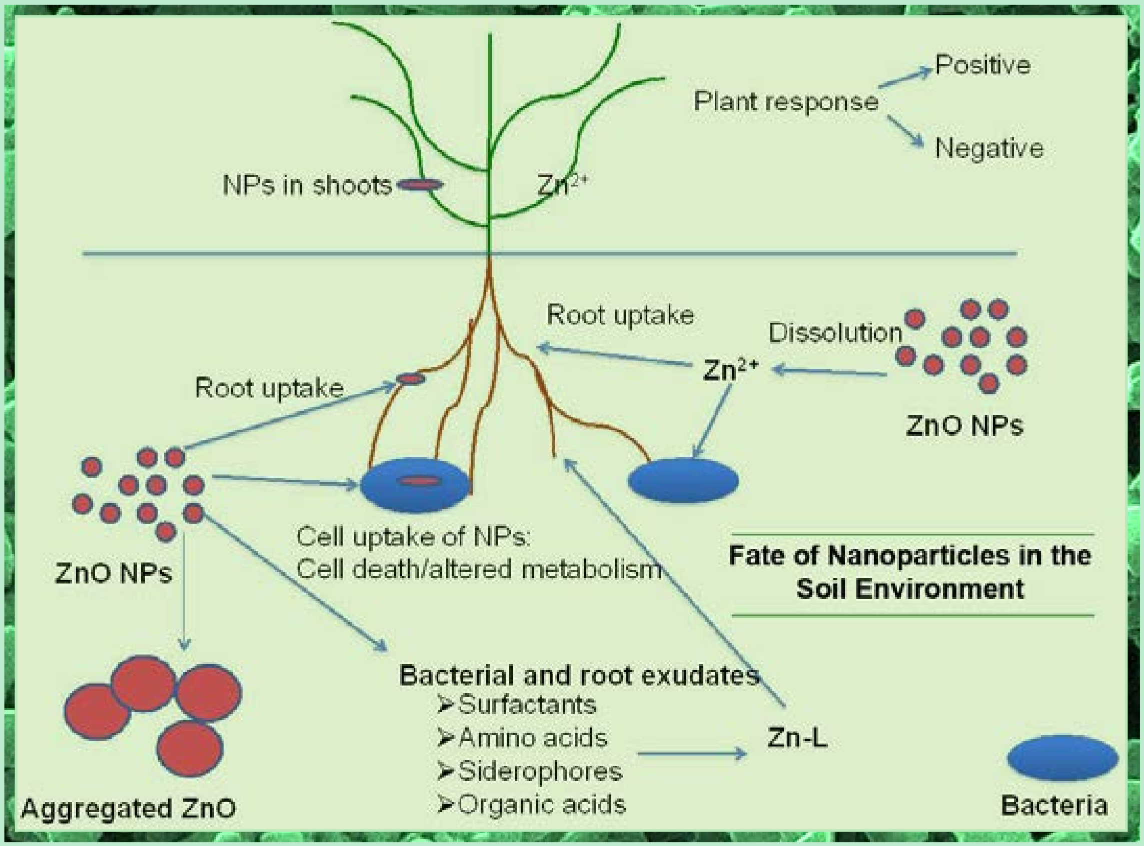
Sensors paired with automated samplers provide a more complete water quality record



Cyberinfrastructure is used to manage and share the data



Continuous measurement of weather and soil variables in the Little Bear River watershed



Joan E. Mclean is a Research Associate Professor at the Utah Water Research Laboratory in the College of Engineering at Utah State University. Her research interests over the last 25 years have focused on the biogeochemistry of pollutants in soil/water environments, with emphasis on heavy metals and metalloids. Current research areas include the development of bacterial biosensors for determining bioavailable metals in soil and water, evaluating microbial reduction of iron-containing minerals, investigating microbial processes controlling arsenic release to groundwater and investigating how nanoparticles of silver and the oxides of copper and zinc affect plant root – bacteria interactions. Her research is a unique blending of physical, chemical and biological processes leading to engineering solutions of environmental and energy related issues. (**joan.mclean@usu.edu**).

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Nanoparticle characterization and imaging of nanoparticle-bacterial interaction by Helium Ion Microscopy. Collaborating researchers for this project are Anne Anderson, Christian Dimkpa, Department of Biology; David W. Britt, Department of Biological Engineering; and Joan E. McLean, Utah Water Research Laboratory

Metal Nanoparticles in the Environment

Over the last 20 years, nanoparticles (NPs), such as zinc and copper oxides have been commercially synthesized on a massive scale for a wide variety of applications including:

- Medicine.
- Food safety.
- Personal care products.
- Agriculture.
- Technology.

Nanoparticles are highly reactive chemically and biologically, which makes them ideal for uses as biocides to human pathogenic bacteria. However, these same qualities may also lead to adverse effects in plants and soil microbial ecosystems.

Research

Researchers at the Utah Water Research Laboratory are collaborating with other USU researchers in Biology and Biological Engineering to investigate the bioavailability and toxicity of copper oxide and zinc oxide NPs to a beneficial soil bacterium typical of those that form beneficial associations with plant roots worldwide, using wheat as the example crop, and to identify the ways metals affect beneficial soil bacteria survival, carbon and nutrient cycling, and plant productivity.

Results

While sensitivity to copper oxide and zinc oxide NPs differs between bacteria, the beneficial microbe in this study, a fluorescent pseudomonad, showed some resilience to the presence of copper and zinc NPs. However, sublethal levels of the NPs caused changes in bacterial metabolism important to plant interactions.

The results showed that the presence of NPs could alter the function of the soil-plant-microbial ecosystem. Observed effects included:

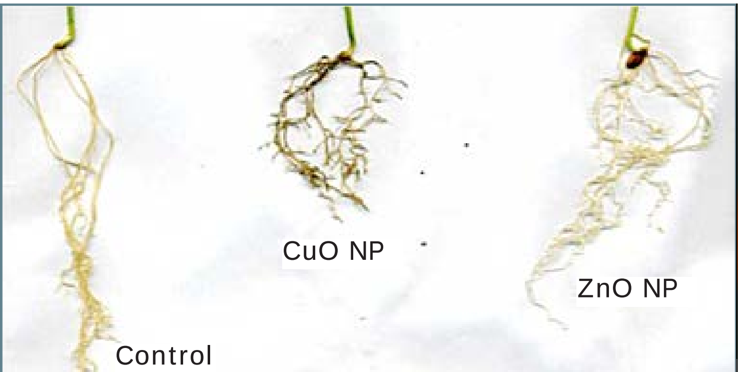
- Shorter root growth with increased branching in wheat seedlings.
- Dramatic decreases in antimicrobial phenazine production, which protect both the bacteria and the host plant, and increases in iron-chelating sidophores, which limit the growth of fungal plant pathogens, as doses of zinc oxide nanoparticles increased.
- Higher metal accumulation in plant shoots.

These results, however, also showed potential for novel uses of NPs in the AGRO world, such as:

- Commercial production of significant bacterial metabolites.
- Increased nutrition value in zinc deficient soils.
- Phytoremediation of metal-contaminated soils.

Looking to the Future

This ongoing study will continue to investigate the influence of NP size and chemistry in plant and bacterial responses versus the role played by the metal ions they release.



Effects of NPs on root elongation and proliferation in wheat. CuO and ZnO NPs have a negative impact on plant growth

Impact of ZnO NPs on the production of phenazine. The microbe produces an orange colored phenazine (control), which provides protection to the bacteria and to its host plant. With increasing concentration of NPs, the production of these phenazines decreases

Bethany Neilsonis an Assistant Professor of Civil and Environmental Engineering and the Utah Water Research Laboratory. Her research expertise includes developing data collection strategies for quantifying solute and heat transport in streams and rivers; developing and testing surface water quality models based on detailed process data; determining the role of groundwater/surface water interactions in mass and heat transport in rivers and streams; data analysis and surface water quality modeling approaches for total maximum daily load (TMDL), wasteload allocation (WLA), and nutrient criteria development; and optimization procedures for parameter estimation in surface water quality models.

(bethany.neilson@usu.edu)

Bethany Neilson conducting a dye tracer study in Curtis Creek, Utah

Research Highlight

Incorporating Temperature into Transient Storage Models

Careful management of streams and rivers is essential due to limited water resources and competing municipal, agricultural, industrial, and environmental interests.

Stream management often relies on mathematical and numerical models that incorporate the influences of biological, chemical, and physical processes to help guide management decisions related to water quality. Instream temperature is one of the critical physical characteristic of aquatic systems.

Research

UWRL researchers are investigating the complex ways that temperature impacts rivers and streams with projects that are developing, refining, and improving current models to incorporate those impacts. Some recent research topics include:

- Incorporation of heat transport in transient storage modeling to better quantify nutrient fate and transport.
- Effects of solar radiation fate in the water column on overall stream temperature.
- Effects of beaver dams on groundwater/surface water exchanges and temperature.
- Incorporation of spatially variable parameters into solute transport predictions by combining analytical solutions with a convolution approach.

Results

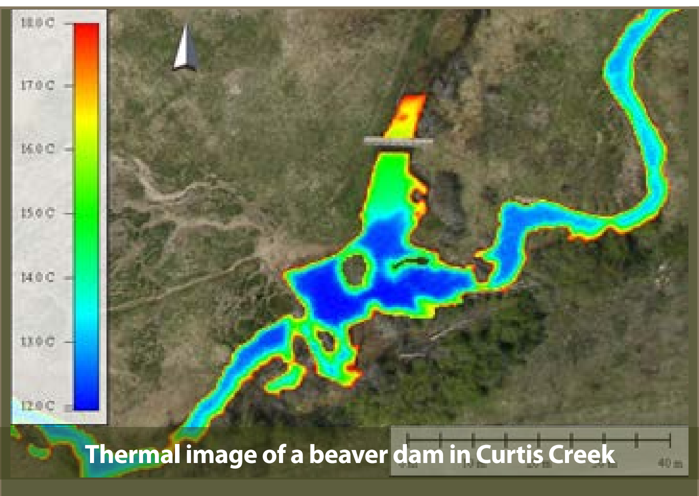
Some of the results from these related research topics include the following:

- More accurate heat and solute fate and transport predictions using two-zone transport models.
- Analytical solutions to describe transport processes that provide advances over traditional methods using numerical solutions.
- New techniques for using high-resolution multispectral and thermal infrared imagery obtained from low-cost unmanned aerial vehicles (AggieAir) to understand the influences of spatial complexity on predictive capabilities.

Looking to the Future

The overall objective is to fully integrate heat into solute models to increase understanding of nutrient fate and transport. Research is ongoing at the Utah Water Research Laboratory to resolve questions such as:

- What heat fluxes must be accounted for and how can existing data collection methods be used to determine these factors?
- What is the influence of spatially variable temperatures on biogeochemistry and habitat at a local vs. reach scale?
- How can geometric spatial variability be incorporated into transient storage models?



Thermal image of a beaver dam in Curtis Creek

Weather station at Curtis Creek

Measuring groundwater influences in Curtis Creek

David Rosenberg is an Assistant Professor of Civil and Environmental Engineering and is also affiliated with the Utah Water Research Laboratory. His research uses systems analysis—optimization and simulation modeling and data management—for water and resources management, infrastructure expansions, demand management, and conflict resolution at scales ranging from individual users to regional water systems. He is particularly interested to integrate engineering, economic, environmental, uncertainty, and when necessary, social and political considerations into the planning, design, operation, and re-operation of water systems. (**david.rosenberg@usu.edu**).

Jordan River at the outlet of Utah Lake

Research Highlight

The Water Energy Nexus

Historically, US water and energy conservation efforts have largely been implemented separately, although water and energy uses and costs are linked in many ways. Conserving water can:

- Delay costly infrastructure upgrades.
- Reduce the energy needed to extract, treat and distribute potable water and treat resulting wastewater.
- Reduce the energy needed to heat household water.

Heating water for showers, dishwashers, faucets, etc. accounts for 17% of total household energy consumption.

Research

Most current water and energy models consider only the typical or average household to estimate water demands and savings from conservation efforts. Yet household water and energy use vary significantly across the population due to a wide variety of contributing factors.

UWRL researchers have developed an integrated approach to model the linkages between household water and energy use that considers the variations in behavioral and technological water and energy use factors that affect residential water and energy use in the US.

Using a large national disaggregated household data set and national energy data, the researchers estimated heterogeneous energy uses for toilets, showers, faucets, clothes washers, and dishwashers. Model simulations estimated household water and energy uses and determined the relative effects of water and energy factors on household energy use.

Results

Distributions among households are heavily skewed, with 12% of users consuming over 20% of both water and energy. That means that a small number of households can conserve a lot of energy and water!

The most effective actions for reducing household energy use related to water included:

- Turning down the water heater thermostat temperature to 120 F.
- Installing high-efficiency water heaters, faucets, and showers.

Retrofitting faucets to be 10% more efficient can save more energy than a similar improvement in water heater efficiency. Thus, collaborative efforts can save more water and energy at a lower cost than separate efforts.

This approach improves on previous water-energy models and can help utilities select and size cost-effective collaborative water and energy conservation actions.

Looking to the Future

The next step for this ongoing research effort will be to develop a city-wide model that will incorporate the energy required to extract, treat, and distribute water to households. The city model will identify cost-effective actions that cities can take to meet their water and energy conservation targets.

Heating water for showers and other uses accounts for a significant portion of total household energy consumption

Central Valley Water Reclamation Facility, So. Salt Lake City, UT

Installing high efficiency water heaters, showers and faucets can reduce household energy use

Utah's UWRL

UTAH WATER RESEARCH

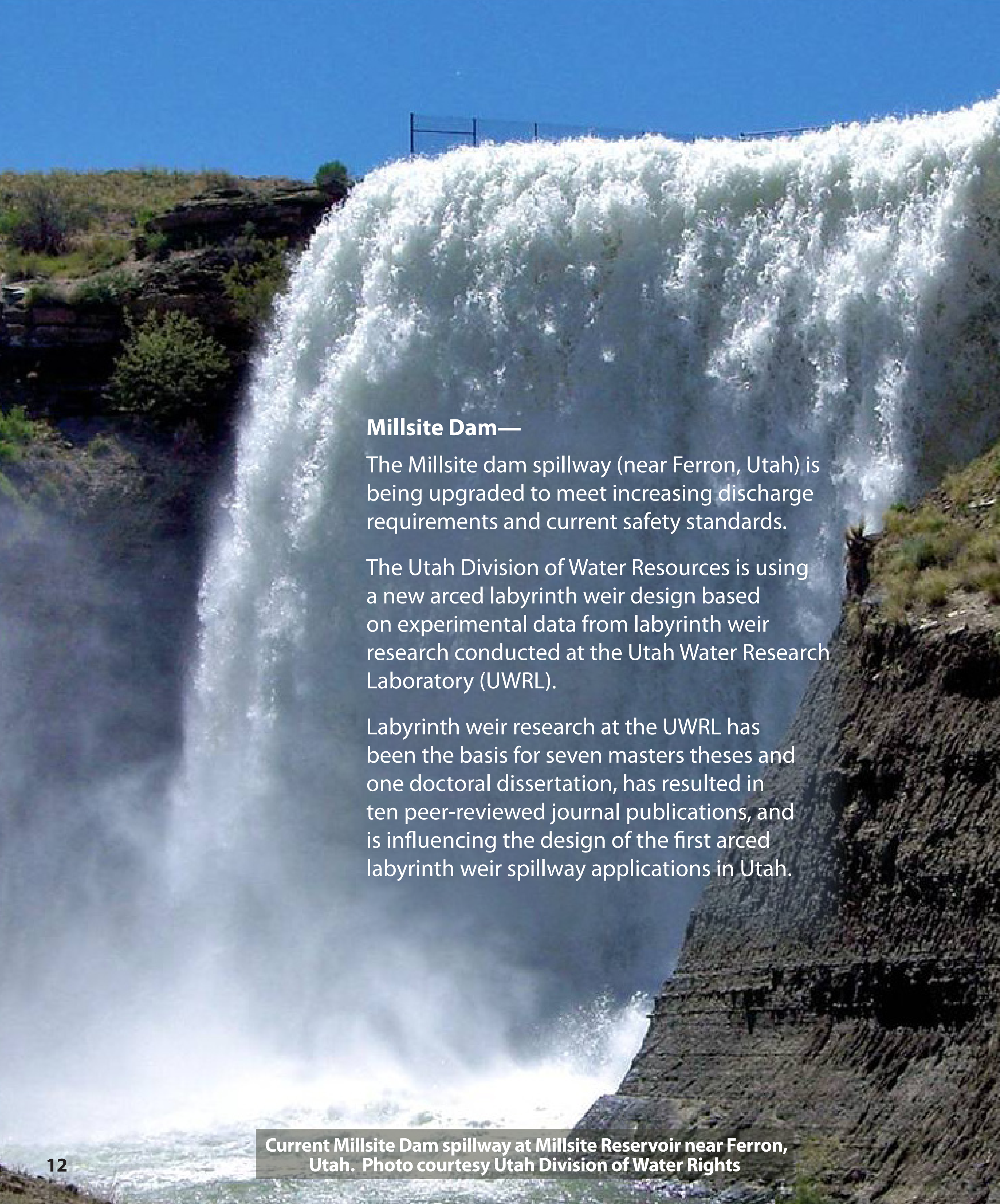
Research programs at the Utah Water Research Laboratory (UWRL) are recognized throughout the nation and around the world but also directly address Utah’s current and future water resources needs in significant ways.

Education

The UWRL is involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships.

Most projects involve graduate students and result in masters or doctoral degrees. As these students are hired by Utah employers, they become the means of technology transfer from the UWRL to Utah's water and environmental organizations.

Research at the UWRL contributes to a growing knowledge base and often helps to define current professional practice. The Utah Division of Water Resources' Millsite Dam spillway renovation is one example of UWRL research that is defining practice right here in Utah (see inset, left).



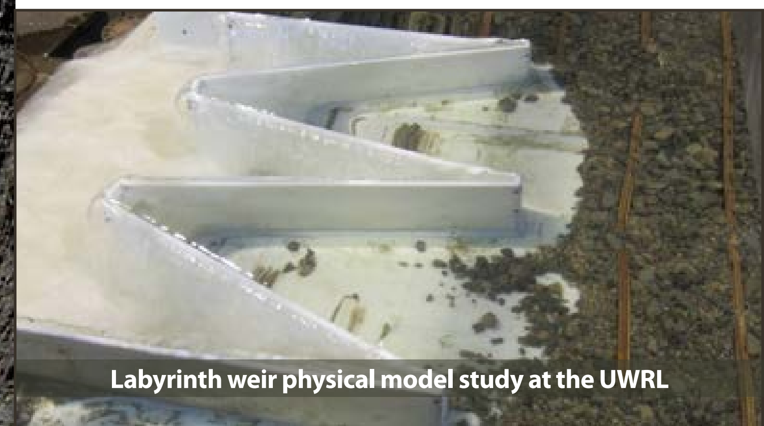
Millsite Dam—

The Millsite dam spillway (near Ferron, Utah) is being upgraded to meet increasing discharge requirements and current safety standards.

The Utah Division of Water Resources is using a new arced labyrinth weir design based on experimental data from labyrinth weir research conducted at the Utah Water Research Laboratory (UWRL).

Labyrinth weir research at the UWRL has been the basis for seven masters theses and one doctoral dissertation, has resulted in ten peer-reviewed journal publications, and is influencing the design of the first arced labyrinth weir spillway applications in Utah.

Current Millsite Dam spillway at Millsite Reservoir near Ferron, Utah. Photo courtesy Utah Division of Water Rights



Labyrinth weir physical model study at the UWRL

Benefiting Utah

Training

UWRL faculty members and researchers are also involved in public and professional service, technology and information transfer, and public education. They provide training for a wide spectrum of water professionals, including those involved in protecting public health and the environment.

The septic-system certification courses and other workshops provided by the Utah On-site Wastewater Treatment Training Program are one example.

Collaborations

The UWRL collaborates and partners with engineers, scientists, and managers from the Utah Departments of Natural Resources and Environmental Quality; the twelve Utah local health departments; and several large water user districts and associations.

One example of UWRL collaborative research is the air quality study underway in Utah's Uintah Basin. UWRL researchers have worked with cooperating federal, state, local, and tribal agencies to investigate the unacceptably high levels of ambient ozone spread throughout the region.

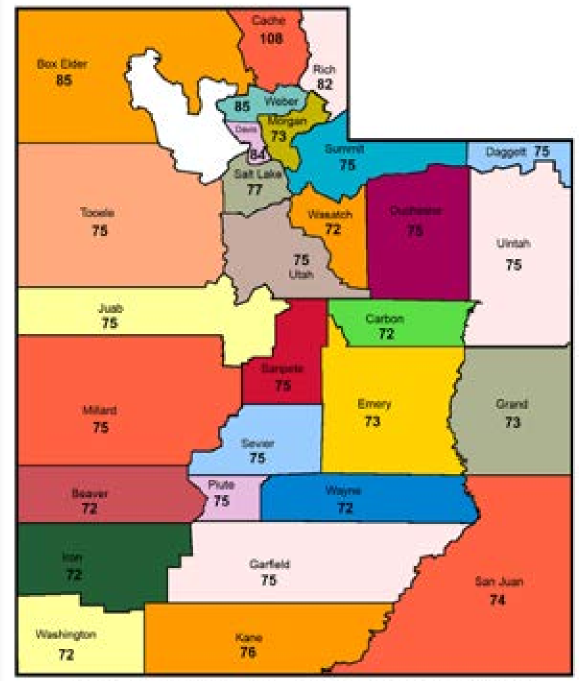
Accurately assessing these wintertime ozone issues will quantify the extent of the potential problem, determine the contributing causes of the elevated pollution, and help to identify the most effective remediation scenarios.

Research

The UWRL's diverse research program benefits each of Utah's 29 counties (see map, right). Some projects are relatively small, while others involve interdisciplinary teams in collaboration with multiple agencies and the private sector.

One example is a project to develop a reliable hydrologic model for Utah's Sevier River Basin that can predict water availability and expected reservoir volumes using prior year information and measured winter snowfall data. Water allocation is a challenge to water managers each year, given the uncertainty of expected spring runoff.

An accurate model for the Sevier River Basin, which has managed flows from multiple reservoirs, could provide valuable information to water managers in the rural, agricultural communities in the area. This model could ultimately be applied to other basins in Utah, as well.



Number of UWRL Projects Benefiting Utah Counties in FY 2012

On-Site wastewater treatment workshop demonstration

Inversion layer above Bonanza Power Plant in Uintah Basin, UT

Sevier River near Leamington Canyon, Utah

Outstanding Contributions

Visiting Scholar

Inga Maslova

Inga Maslova, former USU graduate (MS 2005, PhD 2009) and current Assistant Professor of Mathematics and Statistics at American University in Washington, D. C. recently spent several, months collaborating as a visiting scholar with UWRL hydrologists, civil engineers, and researchers in climate and environmental studies.

These projects involved innovative methods that coupled wavelet-based techniques with Multivariate Relevance Vector Machine Learning methods to forecast long-term streamflow months in advance and to forecast evapotranspiration (ET) up to 16 days in advance.

Dr. Maslova's primary research interests are time series analysis, wavelet techniques, and functional data analysis.

Dr. Maslova at First Dam near the UWRL

International Conference

Blake P. Tullis

In July 2012, Utah Water Research Laboratory Associate Professor, Dr. Blake Tullis, hosted the 4th International Junior Researcher and Engineer Workshop on Hydraulic Structures at Utah State University (USU).

This international conference addresses the conventional and innovative design, construction, operation, monitoring, maintenance and rehabilitation of hydraulic structures, and provides an opportunity for young researchers and engineers to present and publish their research.

This workshop series was organized by the Hydraulic Structures Committee of the IAHR, and is co-sponsored by ASCE-EWRI. Previous workshops have been held in Montemor-o-Novo, Portugal; Pisa, Italy; and Edinburgh, Scotland.

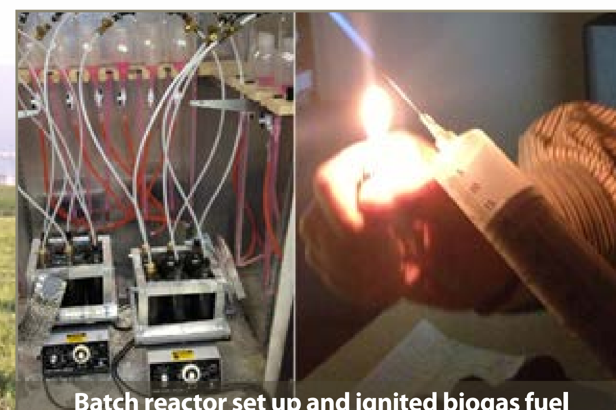
Hydraulic model of an oblique weir at the UWRL

Professor to Student

Yousef Soboh

Yousef Mostafa Soboh first came to Utah State University as a USAID faculty development program short-term scholar in 2009. With an MS in Environmental Science and a BS in Chemical Engineering, Yousef was a faculty member in the Technology Education Department of the Palestine Technical Colleges/ Arroub/Hebron.

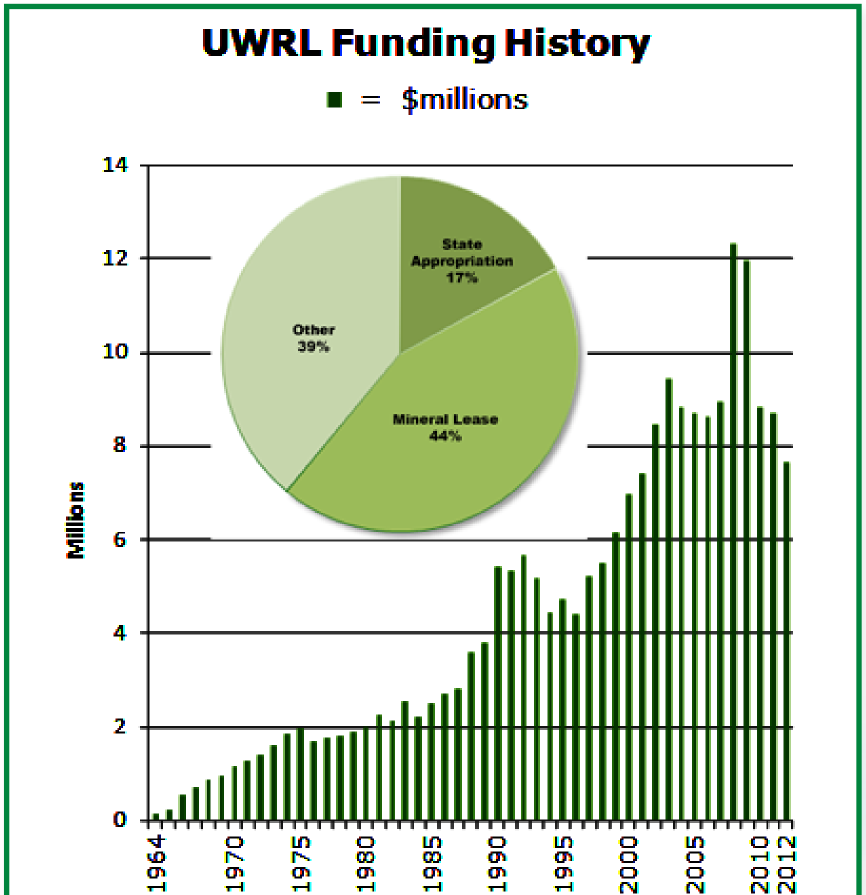
Now as a PhD student at USU, Yousef is conducting research with UWRL faculty members to identify the optimum carbon-to-nitrogen ratio for high rate, continuous flow anaerobic co-digestion of wastewater-produced algal biomass using an up-flow anaerobic sludge blanket (UASB) reactor. The methane-rich gas from this process is a potential energy source, and the residual materials have soil enrichment value.



Batch reactor set up and ignited biogas fuel

Financial / Academic Summary

Measures of academic research productivity continue to improve at the UWRL, even as research expenditures have suffered during the economic downturn. In FY '12 the number of scientific articles published by UWRL personnel remains high—more than triple the number of a decade ago. Both the number of active projects and the number of graduate assistants supported also remain at record levels. These accomplishments during difficult economic times reflect the hard work and commitment of UWRL faculty, students, and staff.



*Other Sources include: Other state awards, local, federal, and private sources

Products (FY 12)

Number of Active Projects	269
Dollar Value of Active Projects	$ 7,652,675
Scholarly Publications in Peer-Reviewed Journals	65
Scholarly Presentations at Professional Conferences	87

Outreach Products (FY 12)

Short Courses and Field Training	22

Academic Training Facilitated (FY 12)

Number of Graduate Research Assistantships Funded	64
Number of Undergraduate Students Supported	68

Degrees Granted (FY 12)

PhD	13
MS	24
ME	5

UtahStateUniversity

Utah Water Research Laboratory

8200 Old Main Hill, Logan, UT 84322-8200 • (435) 797-3155 • uwrl.receptionist@usu.edu • http://uwrl.usu.edu