MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2011

for

Office of the Legislative Fiscal Analyst
State Capitol Complex
House Building, Suite W310
Salt Lake City, UT 84114

by

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Foreword

The Utah Water Research Laboratory (UWRL) located at Utah State University (USU) has been a leader in water and environmental research for over 50 years. The UWRL receives 2 % of all deposits made to the Mineral Lease Account, "to be used for activities… having as a purpose the development and exploitation of water resources in the State of Utah."

This report is submitted to the Legislature in compliance with House Bill 103 passed during the 1993 General Session. This legislation requires the UWRL to "provide the Legislature, through the Office of the Legislative Fiscal Analyst, with a complete accounting of the use of that money (MLF) on an annual basis." Following the requirements of the legislation, this report presents the following accounting of those funds:

1. Actual expenditures for FY 2010

2. Budgeted expenditures for FY 2011

3. Planned expenditures for FY 2012

As a general overview, the introduction to this report summarizes the role and history of the UWRL.

The activities of the UWRL are organized into research areas with specific projects that address a broad spectrum of high priority water resources needs and issues in the state. This report contains a summary of each project including a statement of the need and purpose, the specific benefits to the citizens of Utah, and areas benefited. The UWRL also seeks to leverage the accomplishments and expand the benefits of these projects through collaboration and partnership with local, state, and federal agencies. As today's water resources management problems become more complex, our internationally renowned faculty and their students are meeting current challenges and finding solutions to tomorrow's water and environmental problems now.

The Community and Economic Development Appropriation Subcommittee of the Legislature reviews this report as part of its normal budgetary process under Title 63, Chapter 38, Budgetary Procedures Act. The UWRL welcomes any comments or questions that result from this review.

Mac McKee
UWRL Director

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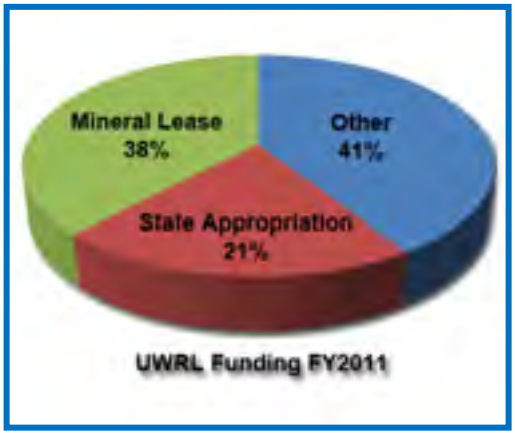
Introduction

Role of the Utah Water Research Laboratory

Research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and are also recognized throughout the nation and the world. The State of Utah provides state-appropriated funds (SAF) and mineral lease funds (MLF) for research support at the UWRL. These funding sources directly target problems facing the State of Utah. In FY 2011, MLF funding of almost 3.3 million accounted for 38% of total UWRL expenditures. With additional funding from federal, private, and other state sources (as shown in the pie chart), the total UWRL expenditures for FY 2011 were almost $9 million.

The UWRL's projects are organized into six major research programs:

1. Drinking Water and Wastewater Treatment.
2. Environmental Quality Management and Remediation.
3. Surface and Groundwater Quality and Quantity.
4. Water Conveyance, Distribution and Control.
5. Water Education and Technology Transfer.
6. Water Resources Planning and Management.



These programs are under the direction of engineers and scientists affiliated with the following departments within the College of Engineering:

Civil and Environmental Engineering
- (Environmental and Water Divisions).
Electrical and Computer Engineering.
Mechanical and Aerospace Engineering.
Biological Engineering.

Brief summaries of these major research programs under these four divisions are presented at the end of this Introduction section.

The UWRL research program related to MLF is very diverse as indicated by the project summaries in this report. The overall research program, funded by both state funds and external contracts and grants, is even broader. We continue to be involved in many field-scale soil and water remediation research projects. At several experimental watersheds, we are investigating hydroclimatological processes. Our hydraulics, erosion control, and environmental-quality laboratories are involved with a range of experimental work and service projects that utilize our unique facilities. Computer models, remote sensing, geographic information systems, digital terrain models, expert systems, and many other modern technologies are developed and applied in the research projects and are used to develop tools for water and environmental managers and professionals in Utah. The UWRL also prepares guidance materials for use by practitioners. Some projects are relatively small in scope while others involve interdisciplinary teams and collaboration with multiple agencies and with the private sector.

In addition to our research role, the Lab is involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships, as well as public and professional service, technology and information transfer, and public education. Almost all research and applied projects include graduate student involvements, and result in masters or doctoral degrees. Undergraduate student involvement in UWRL projects for the purpose of student education and training are also integrated into the basic and applied research programs.

UWRL Student Involvement FY2011

Graduate Students Supported (FY11)	70
Undergraduate Students Supported (FY11)	61

As students graduate and are hired by Utah employers, they become effective means of technology transfer from the UWRL to Utah's water and environmental organizations. Technology and information is also transferred through collaborating and partnering with engineers, scientists, and managers of the Utah Department of Natural Resources, Water Resources Division, the Utah Department of Environmental Quality, the twelve Utah local health departments, and several large water user districts and associations.

History of the Utah Water Research Laboratory

The Utah legislature authorized the establishment of the UWRL at Utah State University in 1959 as an important component of the State of Utah's commitment to water resources research. Construction was completed in December 1965, and included one of the best hydraulics laboratories in the United States and a unique erosion testing facility with a large rainfall simulator. Sixteen years later, an extensive remodeling project, including the addition of an environmental quality laboratory was completed. The UWRL completed a new hydraulics modeling and testing laboratory in 2009 to support hydraulics research activities associated with releases from dams in Utah (and related hydraulic phenomena, such as venting), for a total of more than 113,000 square feet of state-of-the-art laboratory, computer, and office space. A state-of the art hydraulics modeling and testing laboratory was completed in 2009 to facilitate ongoing research that supports the design of hydraulic structures in Utah, such as the new irrigation lift stations on Utah Lake.

In 1964, Congress approved the Water Resources Research Act that created a water research institute in every state. The Utah institute, known as the Utah Center for Water Resources Research (UCWRR), was established at the UWRL as part of a national network of water research institutes. With total research funding through the UWRL of nearly $9 million, it is one of the largest institutes in the nation. As shown in the table below, it is also highly productive in terms of research publications and graduate student education.

There are currently 35 faculty and 35 support staff at the UWRL. During FY 2011, 38 master's students and 32 doctoral students received support from UWRL projects. An additional 61 undergraduate students assisted with UWRL research. UWRL faculty collaborate with colleagues from other USU departments, faculty from other institutions, professionals form the private sector, and government agencies in Utah and elsewhere. Several of our faculty members, including the former UWRL Director, have been awarded the Utah Governor's Medal for Science and Technology. In addition, our faculty have received many national honors and recognition, and served on national and international engineering and science panels and committees.

UWRL Financial/Academic Summary (FY 2011)	
Research Products (FY11)	
Number of Active Projects	274
Dollar Value of Active Projects	$8,682,681
Scholarly Publications in Peer-Reviewed Journals	55
Scholarly Presentations at Professional Conferences	106
Outreach Products (FY11)	
Short courses and Field Training	14
Degrees Granted	
Ph.D.	8
MS	20
ME	2

Management of USGS 104 Program for State Benefit

The Water Resources Research Act of 1964 created a national network of Water Resources Research Institutes (WRRIs) in the United States and an allotment program providing funds for the institutes, called the Section 104 Program. The Utah Institute, known as the Utah Center for Water Resources Research (UCWRR), is located at the Utah Water Research Laboratory (UWRL). Currently, the Section 104 Program is funded at an annual level of approximately $92,000 of federal funds through the U.S. Geological Survey (USGS). This year, the base grant in combination with MLF directly benefit the State of Utah in areas of (1) developing a capability to evaluate and implement drought indices on a spatial basis for inclusion in a National Integrated Drought Information System (NIDIS) pilot study creating a drought early warning system for the Upper Colorado River Basin, (2) assessing changes in wetland vegetation over time using high resolution imagery in several spectral bands obtained with low-cost unmanned aerial vehicles along with genetic sampling to determine the relative contribution of seeds vs. rhizomes in the spread of invasive *Phragmites* patches in a Utah wetland, (3) assessing the use of unmanned aerial vehicles (UAVs) in gathering real-time data during emergency flooding conditions in support of flood emergency management decisions, and (4) developing a system to predict reservoir sedimentation based on natural factors and specific reservoir characteristics in order to prioritize Utah reservoirs for sediment management actions aimed at maintaining necessary water supplies for the population. In the future, the USGS 104 Program will be used to support applied research tools and accomplish information and technology transfer to address Utah's water quantity and quality problems, other source water protection strategies, and development of tools and programs across the State of Utah.

Mineral Lease Fund Expenditures

The table at the beginning of the next section summarizes the actual, budgeted, and planned expenditures of MLF allocated to the UWRL for FY 2011 and FY 2012 in the six major research program areas. A breakdown of these expenditures by individual projects is contained in tables presented at the beginning of each research program section of this report. UWRL administration and technology transfer expenditures accounts for approximately 7% of total MLF budgeted and planned expenditures in FY 2011 and FY 2012.

Relevancy and Benefits of the Mineral Lease Fund

In more ways than one, Utah is the second driest state in the union. It records only 13 inches of water a year, mostly in the form of winter snowfall, which must then sustain the social, economic, and environmental water needs throughout hot, dry summer periods. As has often been emphasized by our state leaders over the decades, water is indeed the key resource essential to Utah's quality of life and economic vitality. Therefore, it is critically important to protect, manage, and wisely use our precious water for the benefit of Utah's citizens.

Research Program

The goal of the UWRL research programs is to identify and develop projects that will help assure that Utah will be able to meet the water needs of its citizens and economy in the future. This requires a broad and deep understanding of our surface and groundwater resources in the context of climate and environmental change, the complex physical and biological processes that affect water quantity and quality, and the dynamic interaction of human activity in our own use of land and water in our arid environment.

In order to focus research on problems and needs that are both relevant and current, the UWRL engineers and scientists work closely with state and local agencies and are actively involved with and serve on many state and local organizations, committees, and boards. The UWRL Director, Associate Director and most of the faculty meet frequently with state and federal agency managers and personnel from local water organizations to discuss research needs and identify opportunities for the UWRL to respond to these needs. The UWRL has worked with the following network of organizations over the past fiscal years.

The Utah Center for Water Resources Research (UCWRR) at the UWRL participated as an active member of the National Institutes for Water Resources (NIWR). UWRL faculty members were also active in state sections of professional organizations, and served on state, local, and national committees. Participation in national and international professional water and environmental organizations helps to bring recognition and external project funding to the state, provides opportunities to learn from other research and best practices worldwide, and helps to identify current and future research needs that will affect our state and the nation. This strengthens the UWRL research identification process to maintain the relevancy of our research programs to Utah.

Utah Department of Natural Resources Division of Water Resources State Engineer – Division of Water Rights	**Utah Department of Environmental Quality** Drinking Water Water Quality Solid and Hazardous Waste
State Regulatory and Advisory Committees DEQ Water Quality Board Utah Solid and Hazardous Waste Control DEQ Drinking Water Board	**State Water Associations and Organizations** Utah Center for Water Resources Research (UCWRR) Utah Rural Water User's Association Water Environment Association of Utah Utah League of Cities and Towns Utah On-Site Wastewater Treatment Association (UOWA)
Professional Organizations and Associations American Water Resources Association American Society of Civil Engineers American Water Works Association	**Regional and National Research Alliances** Lake Powell Technical Advisory Committee Universities Council on Water resources (UCOWR) Inland Northwest Research Alliance (INRA) National Institutes for Water Resources (NIWR)

Outreach

The mission of the UWRL includes outreach activities related to public service, information dissemination, technology transfer, and short courses. These activities are provided for the benefit of Utah state and local agencies, elected officials, Utah citizens, and the nation. Outreach is provided by faculty, staff, and students associated with the UWRL. Additional outreach is provided through our World Wide Web (WWW) site: http://uwrl.usu.edu.

Public Service

UWRL faculty members serve on state and local advisory panels to provide technical expertise, input, and review of water-related issues. Specific panels include:

Utah Water Quality Board
Utah Solid and Hazardous Waste Control Board
Lake Powell Technical Advisory Committee
Salt Lake county solid Waste Management Council
State of Utah Wastewater Treatment Plant Operator Certification committee
Utah Drinking Water Board
Weber-Morgan Health Department Wastewater Advisory Committee

In addition, UWRL personnel are frequently invited to provide technical and informational presentation before state and national professional groups such as the American Water Works Association.

Information Dissemination and Technology Transfer

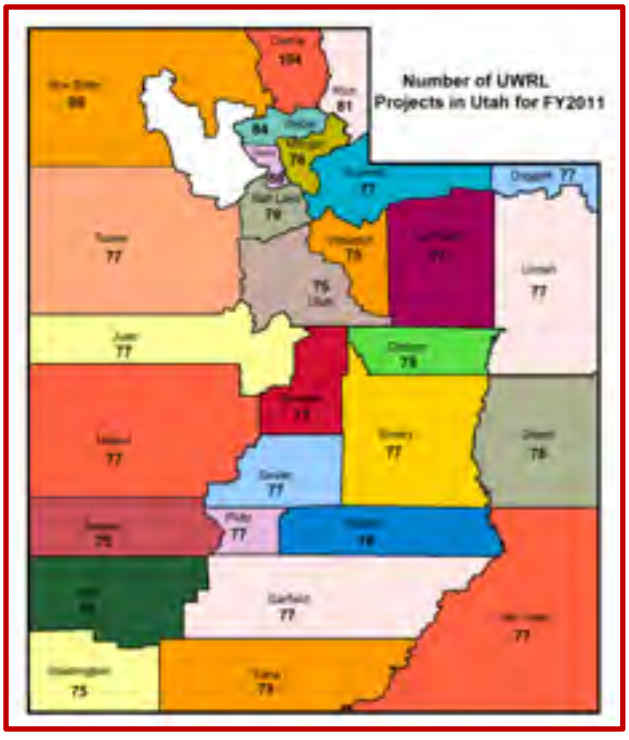
UWRL information dissemination, outreach, and technology transfer activities include the publication of research results in professional journals, distribution of information on various UWRL and UCWRR web pages, presentations before various professional societies at organization and association meetings, in the state and around the country, and sponsorship and participation in numerous short courses and training programs.

The UWRL web page (http://uwrl.usu.edu) provides general information about the UWRL and its personnel and from time-to-time provides a feature article on different research projects, faculty, and students at the UWRL. The Utah On-Site Wastewater Treatment Training Program at the UWRL provides on-site wastewater training in support of the State of Utah certification program for on-site wastewater treatment professionals. Undergraduate and graduate students participate in projects that involve hands-on, real-world activities. Additional information can be found at: http://uwrl.usu.edu/partnerships/training/.

On the international level, the UWRL hosts numerous delegations from other countries that have interest in the research conducted at the UWRL and in the capabilities that UWRL professionals can offer to the solution of their water problems. In the past year, these have included visits by the Water Availability and Access theme leader for the International Water Management Institute (IWMI) in Sri Lanka and the director of the International Center for Agricultural Research in Dry Areas (ICARDA) in Syria, as well a Proctor & Gamble Fellowship for Doctoral Study in Environmental Science recipient from Argentina who came to study plant uptake with faculty at the UWRL.

Benefits to the State of Utah

Specific state benefits resulting from MLF research projects are summarized for each project in the following sections of this report. As shown in the map, UWRL projects have been conducted in every county in the State during the past year, and these projects have produced benefits for every county of the state as well. The following summarizes the recent and current benefits produced by MLF funding in the UWRL's six program areas.



Drinking Water and Wastewater Treatment

The program is developing engineering approaches for the treatment and production of drinking water and the treatment and reclamation of waste water for recycling and reuse of municipal and industrial wastewater, as well as evaluating the effectiveness of various septage treatment options in Utah environments. Research in this area is also creating new processes for the sustainable production of bioplastics from Utah wastewater.

Environmental Quality Management and Remediation

This program emphasizes an integrated engineering and science approach to environmental quality of land, water, and air. It includes characterization and remedial design approaches for contaminated subsurface environments at laboratory scale along with the largest field scale research of any similar academic program in the nation. Varied research in this area includes bioreactor processing of environmental materials and engineering scale-up of biologically-based reactions are being developed in diverse areas of specialization including composting, waste reuse, biosolids processing, management of environmental biotransformation, and engineering bioprocess-optimization of wetlands. In addition to the research on water and land processes, this area also includes work on indoor and outdoor air quality problems in the state, including winter inversions.

Surface and Groundwater Quality and Quantity

This diverse program has strengths in both the theoretical and applied aspects of surface and groundwater. Surface water research includes modern surface water hydrology, including climate modeling, rainfall processes, snow hydrology, floods, droughts, terminal lake analyses, soil erosion, stream water quality modeling, water-quality management, assessment and control of nonpoint source pollution and storm water, characterization and control of dissolved and particulate natural organic matter (NOM). Current research in the groundwater area ranges from theoretical developments in the stochastic and numerical analysis of pollution transport in groundwater, conventional and toxic contaminants in natural and engineered systems, and the practical aspects of designing technologies to clean up and manage contaminated sites in Utah's aquifer systems. Work is also ongoing in the development of more accurate low-cost water quality sensors.

Water Conveyance, Distribution and Control

This program utilizes UWRL's unique hydraulics laboratory for physical modeling of hydraulic structures, including optimal design for weir structures, hydraulic structures for flood control and flood bypass, testing and evaluating hydraulic machinery and piping systems, and flow meter calibration. Analytical aspects of the program include design of pipe networks for water supply, air vent sizing for small to medium sized embankment dams, sediment transport, non-contact flow measurement, open channel flow, and dam safety risk assessment, failure loss estimation, and safety management.

Water Education and Technology Transfer

Several projects conducted by the UWRL, including many that are funded from sources other than Mineral Lease Funds, have substantial education, outreach, and training components. Resources provided by Mineral Lease moneys are sometimes used to enhance the development of technologies, training modules or educational materials, sometimes to provide technical support to Utah's state and local agencies on water-related issues.

Water Resources Planning and Management

This program area addresses various institutional and legal aspects of water, such as rights transfers, distributed water demand and supply modeling using geographical information systems, and cost

allocation and determination of user fees for multiple purpose water resources projects. Additional areas include reservoir operating policies, water conservation, river basin planning, habitat monitoring and restoration, user-driven decision support systems for water planning, and incorporation of remote sensing technology to improve water resources management.

Administration

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
UWRL Administration

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
Business Office	$136,051.05	$140,132.58	$144,336.56
Laboratory Infrastructure Support, Travel and Special Request	$26,378.13	$27,000.00	$27,810.00
Project Management of USGS 104	$25,530.42	$26,296.33	$27,085.22
Publications Office	$50,960.47	$52,489.28	$54,063.96
UWRL Administration	$62,148.44	$64,012.84	$65,933.26
Total	**$301,068.51**	**$309,931.03**	**$319,229.00**

Administration, Advisory Support, and Special Equipment

The numerous projects conducted by faculty and students at the Utah Water Research Laboratory (UWRL) with financial support from the MLF program are administered by the officers of the UWRL. The Director and Associate Director of the UWRL also work to maintain liaison with water planning and management officials across the state. Frequently, faculty from the UWRL are requested for technical or advisory support on water problems by various state or local agencies and, to the extent that it lies within the mission of the UWRL to provide such input, MLF funds are sometimes used to cover expenses required to support these activities until other funding opportunities can be developed. Finally, when a number of Utah-based research needs arise that require specialized equipment that cannot be made available through other means, MLF resources are sometimes used to acquire these items.

Administration of the MLF Program

The costs of administering the MLF program at the Utah Water Research Laboratory are deliberately held as low as possible, consistent with the needs of evaluating the productivity of the research supported by MLF funds. Collaboration with water managers and policy makers in state and local agencies identifies where applied research can contribute toward the solution of important water resources problems. MLF money spent on administration at the UWRL provides minimal salary support for the UWRL Director and Associate Director and supports the administration of the USGS 104-B program funding that comes to the state. FY 2011 administrative costs represented approximately 9% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL are almost $9 million, and at any point in time there will be approximately 300 active research contracts administered at the UWRL. These projects require significant support from the UWRL Business Office in the form of accounting and financial oversight. Further, they benefit from assistance that comes from the UWRL Publications Office, which provides support for outreach activities (such as the production of presentations, maintenance of the UWRL and UCWRR web pages, etc.). MLF expenditures in FY 2011 on these support activities accounted for 7% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2011 for advice and collaborative help on various water problems in the state. In FY 2011, the UWRL provided support to defray travel costs from MLF sources so UWRL faculty could participate in meetings in the state to coordinate UWRL activities with ongoing water problems, to work to identify and seek funding for new applied research in the state, and to provide expert advice relative to current water management issues faced by various state and local agencies. These activities are enumerated in the project reports section of this document.

Special Equipment

Numerous communities in Utah face problems with the management of soils and aquifers that have been contaminated by hazardous materials. The UWRL is active in providing state-of-the-art scientific input to understand these problems. Similarly, the UWRL tries to maintain an active program of coordination with state agencies such as the Utah Division of Water Rights on problems associated with the operation of safety of dams.

Investments in state-of-the-art equipment are also made from MLF resources. New equipment acquisition and their integration into research are described in specific project reports.

Research Project Summaries

Research Project Summaries

This section of the report provides a summary of each project and its benefits to the state and areas benefited. The projects are organized into the previously noted program areas as follows:

Drinking Water and Wastewater Treatment

Environmental Quality Management and Remediation

Surface and Groundwater Quality and Quantity

Water Conveyance, Distribution and Control

Water Education and Technology Transfer

Water Resources Planning and Management

Drinking Water and Wastewater Treatment

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Drinking Water and Wastewater Treatment

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
Algae Biotechnology for Nutrient Removal in Wastewater Treatment Lagoons: Aerial	$15,616.40	$136,084.89	$157,804.33
Biological Phosphorus Removal from Lagoon Wastewater: Pilot-Scale Rotating Algae Biofilm Rotating Bioreactor (RABR)	$98,591.78	$11,549.53	$0.00
Biological Phosphorus Removal from Wastewater Using a Zeolite-Based Algae Biofilm Bioreactor	$34,537.53	$5,573.66	$0.00
Evaluation of Deep Installations of Septic System Drain Fields in Utah: Performance and Treatment Effectiveness	$38,403.31	$39,555.41	$0.00
Producing Bioplastic Materials Using Microbe-Based Processes	$12,440.48	$12,813.69	$13,198.11
Weber-Morgan Health Department Wastewater Advisory Committee	$1,743.78	$0.00	$0.00
Designated Projects		$127,740.00	$10,500.00
Undesignated research projects in program area		$62,980.00	$7,000.00
Total	**$201,333.28**	**$396,297.18**	**$188,502.44**

Algae Biotechnology for Nutrient Removal in Wastewater Treatment Lagoons: Aerial Monitoring for Algae Harvesting

Principal Investigators:
Ronald C. Sims
Charles Miler
Richard Cutler

Partners/Collaborators:

- ***Local:*** *Issa Hamud, City of Logan*
- ***State:*** *Ed Macauley, UDEQ*
- ***Business and Industry:*** *WesTech, Inc.*

Project Description

- Need and Purpose:

The need exists throughout Utah for upgrading wastewater systems that utilize lagoons and do not meet near-future water quality standards, including the City of Logan Wastewater Treatment Lagoons. Improvements in the design and operation of existing lagoon systems for wastewater treatment may be possible based on an understanding of the growth and management of algae. Similar to agricultural crops, algae growth within a lagoon system is affected by changes in seasonal patterns, planting time, temperature, and pH (Figure 1). This project follows up a previous aerial characterization of the sites within a large lagoon system where maximum production of algae occurs, which would allow maximum removal of nutrients from the lagoon by removing the algae (crop).

- Benefits to the State:

Aerial monitoring to identify and select the best sampling sites and operating parameters in lagoon systems to remove algae that contain the nutrients phosphorus and nitrogen will save significant costs related to water quality sampling and analyses. Aerial monitoring will also enable other communities in Utah to utilize the technology for the treatment of reservoirs and wastewaters that are based on improved systems with regard to efficiency and performance.

- Geographic Areas:

Study Area: 460-acre City of Logan Wastewater Reclamation Facility that treats the wastewater of Utah State University and the Cache Valley cities of Logan, Hyde Park, Smithfield, North Logan, Nibley, and Hyrum.

Areas Benefited: All areas of the state of Utah that utilize ponds or lagoons for the treatment of wastewater, as well as reservoirs and lakes contaminated with algae in northern and southern Utah.

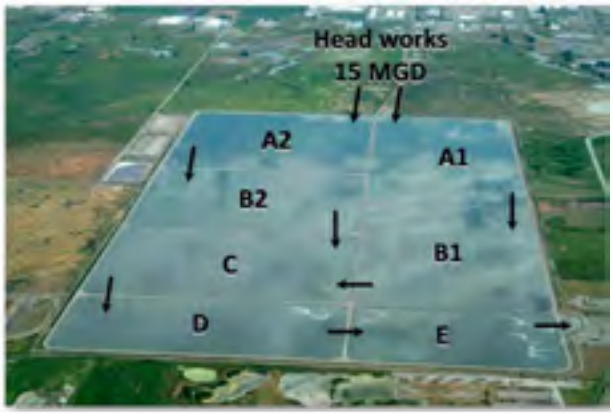


Figure 1. Logan Lagoon treatment system of seven algae ponds and flow of 15 million gallons per day (MGD). Parallel ponds include A1/B1 and A2/Bs while ponds C, D, and E are sequential, with total treatment time of 60-90 days

- Accomplishments:

Findings: Last year, the AggieAir™ autonomous, multispectral remote sensing platform developed at the Utah Water Research Laboratory was used to obtain data on algae distribution across the Logan Lagoon system (Figure 2). Results indicate non-uniform distribution of algae within the ponds comprising the Lagoon system (Figure 3). The uneven

distribution of algae is due to the lack of mixing within each pond, and the sites indicated by yellow, orange, and green colors in Figure 3 are the areas within the lagoon with the highest concentrations of algae for harvesting. This year a sampling and analysis plan for algae and water quality indicators was developed that was based on data and information provided by the AggieAir™ platform.

Results: Logan Lagoon Pond C was selected for engineering and management to accomplish increased growth and recovery of microalgae that will take up nutrients and produce high biomass yields. Data provided by the AggieAir™ platform clearly indicated the lack of mixing within the lagoon ponds that results in inconsistent and unpredictable patterns of algae growth. Increased mixing of water will be added to Pond C, and nutrients from the anaerobic digester will be returned to Pond C in order to stimulate microalgae growth. The increased growth will result in improved water quality that will meet State of Utah standards within the established 5-year time limit. Harvesting the algae in Pond C will remove the associated nutrients, nitrogen and phosphorus, from the reclaimed wastewater that enters a receiving system. The receiving system for the City of Logan is Cutler Reservoir. The AggieAir™ sensing platform was useful for identifying the patterns of algae distribution and associated water quality distribution.

Work Plan FY11/FY12

Project completed.

Informational Resources

Contact: Mr. Issa Hamud, Director, Logan City Environmental Department, (435) 716-9752, E-mail: issa.hamud@loganutah.org

References:

Sims, R.C. (2011). Algae Growth and Harvesting for the City of Logan, Utah. *Institute of Biological Engineering 2011 Annual Conference*, Atlanta, GA (March).

Jones, J.D. (2010). *Statistical Analysis of Wastewater Remediation and Biofuels Production of Algae*. M.S. degree (Plan B), Mathematics and Statistics Department, Utah State University, Logan, UT.

Figure 2. AggieAir™ remote sensing platform for algae monitoring in the Logan Lagoons operated by Austin Jensen of the Utah Water Research Laboratory

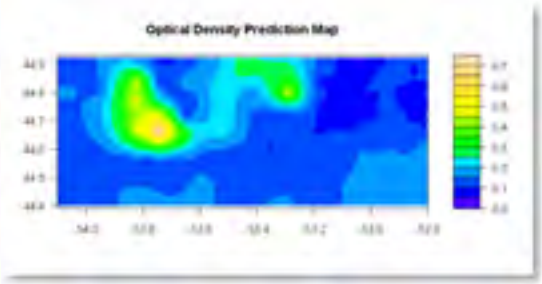


Figure 3. Algae distribution and levels in the Logan Lagoon System. (yellow, orange, green = best sites)

Biological Phosphorus Removal from Lagoon Wastewater: Pilot-Scale Rotating Algae Biofilm Bioreactor (RABR)

Principal Investigators:
Ronald C. Sims
Charles Miller
Logan Christenson (student)

Partners/Collaborators:
- ***Local:*** *Issa Hamud, City of Logan*
- ***State:*** *Ed Macauley, UDEQ*
- ***Business/Industry:*** *WesTech, Inc.*

Project Description

- Need and Purpose:

  A biological-based engineering process to enhance the current performance of the Logan Lagoon Wastewater Treatment System specifically related to nutrient removal, including phosphorus and nitrogen, could save in excess of $100 Million compared with the installation of a chemical precipitation system. Pilot-scale tests for algae growth and phosphorus removal using a rotating algae biofilm reactor (RABR) are being evaluated for the purpose of upgrading Lagoon performance.

- Benefits to the State:

  Development of an economical biotechnology based process to upgrade municipal wastewater treatment will provide new engineering jobs and services in Utah. The new RABR technology will also enable the Utah Department of Environmental Quality to reduce the amount of support in the form of loans and grants to communities for upgrades to wastewater reclamation facilities utilizing lagoon treatment systems.

- Geographic Areas:

  Study Area: Northern Utah region that includes the cities of Logan, Hyde Park, Smithfield, North Logan, River Heights, Providence, Nibley, and Utah State University.

  Areas Benefited: All areas of the state of Utah that utilize ponds or lagoons for the treatment of wastewater, which includes Northern, Central, and Southern Utah.

- Accomplishments:

  Findings: A novel pilot-scale rotating algae biofilm reactor (RABR) was successfully constructed and operated (Figure 1). The bioreactor enhanced algal growth, which simultaneously enhanced uptake of phosphorus and nitrogen (Table 1).

  Results: Phosphorus uptake into the RABR algae is the result of enhanced algae growth on the biofilm reactor, and is approximately an order of magnitude (ten times) higher than phosphorus associated with suspended algae. The concentration of phosphorus in the wastewater was significantly reduced as the concentration of algae increased in the algae biofilm reactor. The results demonstrate that phosphorus removal is greatly improved using algae biofilm rotating bioreactor technology. In addition, algae biomass harvested from the RABR contained 12-16% solids, which is equivalent to more expensive methods of harvesting, including centrifugation.

Work Plan FY11/FY12

Future research will include evaluating reactor performance with seasonal changes in light intensity and duration, as well as temperature, and mathematical modeling of biofilm growth and performance.

Informational Resources

Contact: Mr. Issa Hamud, Director, Logan City Environmental Dept., Phone (435) 716-9752, E-mail: issa.hamud@loganutah.org.

References:

Christenson, L. and R.C. Sims (2011). Algal Biofilm Production and Harvesting System for Wastewater Treatment with Biofuels By-product. *Institute of Biological Engineering National Conference*, Atlanta, GA, March 3.

Christenson, L. and R. C. Sims (2011). Production and Harvesting of Microalgae for Wastewater Treatment, Biofuels, and Bioproducts. *Journal of Biotechnology Advances*. doi: 10.1016/j.biote4chadv.2011.05.015.

Figure 1. Pilot-scale rotating algae biofilm reactor designed and operated to improve algal growth and harvesting and phosphorus uptake for the Logan Lagoon wastewater treatment system. RABR Design: Diameter = 7 feet, Length = 5 feet, Water Depth = 3 feet in a continuous flow wastewater system

Table 1. Pilot-scale rotating algae biofilm reactor performance characteristics

Biomass Productivity	Grams/day/square meter	30
Phosphorus Uptake Rate	Grams/day/square meter	4.1
Nitrogen Uptake Rate	Grams/day/square meter	22
Harvested Solids Concentration	Percent (%)	12-16

Biological Phosphorus Removal from Wastewater Using a Zeolite-Based Algae Biofilm Bioreactor

Principal Investigators:
Ronald C. Sims
Charles Miller
Ashton Young (student)

Partners/Collaborators:
- ***Local:*** *Issa Hamud, City of Logan*
- ***State:*** *Ed Macauley, UDEQ*
- ***Business/Industry:*** *WesTech, Inc.*

Project Description

- Need and Purpose:

  A biological engineering process based algae biofilm growth for the removal of phosphorus from domestic wastewater treated in the Logan Lagoon Wastewater Treatment System could save in excess of $100 Million compared with the installation of a chemical precipitation system. If more nitrogen could be made available for growth, then more phosphorus could be removed through more algae growth. Therefore, a nitrogen-accumulating natural zeolite was used as the biofilm surface to retain nitrogen and allow more algae to grow in order to remove more phosphorus.

- Benefits to the State:

  Direct benefits to the State include reduced loans and grants needed by Utah communities for wastewater treatment to remove phosphorus, allowing the Department of Environmental Quality to reduce the amount of support in the form of loans and grants for upgrades to wastewater reclamation. Benefits to individual communities will include reduced utility bills and costs for meeting water quality standards for phosphorus, while maintaining excellent water quality.

- Geographic Areas:

  Study Area: Northern Utah region that includes the cities of Logan, Hyde Park, Smithfield, North Logan, River Heights, Providence, Nibley, and Utah State University.

  Areas Benefited: All areas of the State of Utah that utilize ponds or lagoons for the treatment of domestic municipal wastewater that includes Northern, Central, and Southern Utah.

- Accomplishments:

  Findings: Significant uptake of nutrients, including phosphorus and nitrogen, into biofilm algae was observed. The algae grew on ammonium selective biofilm rotating bioreactors that were designed, constructed, and tested for attachment and growth of algae that are naturally present in the Logan Wastewater Reclamation facility (Figure 1). Algae biomass could be removed by simply scraping the reactors. Algae growth and regrowth phases over a three-month period of time were successful, demonstrating low-cost and effective operation and maintenance.

  Results: The results demonstrate that nitrogen can be retained by the zeolite and the retained nitrogen is bioavailable to the algae. The zeolite-based biofilm reactor provided an effective way to remove nutrients from wastewater and maintain the algae in a biofilm from that could be easily harvested through mechanical scraping. The harvested algae provides a source of biomass

for the generation of methane gas within anaerobic reactors that provides a sources of heat, power, and transportation fuel for the Logan City Environmental Department.

Work Plan FY11/FY12

No plan for additional research with the zeolite-based reactor is planned.

Informational Resources

Contact: Mr. Issa Hamud, Director, Logan City Environmental Department, Phone: (435) 716-9752, E-mail: issa.hamud@loganutah.org

References:

(March 2011). Zeolite-based Algae Biofilm Rotating Photobioreactor for Algae and Biofuel Production. *Institute of Biological Engineering National Conference*, Atlanta, GA.

Figure 1. Zeolite-based rotating biofilm bioreactor in the Logan Wastewater Treatment Lagoon System

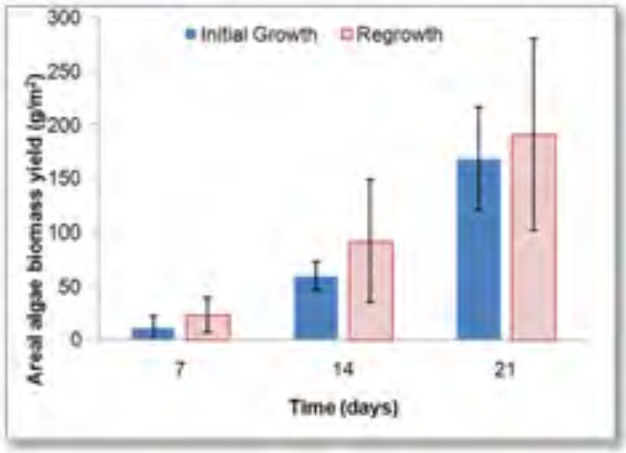


Figure 2. Initial and regrowth biofilm biomass yields ± standard deviation of algae

Evaluation of Deep Installations of Septic System Drain Fields in Utah: Performance and Treatment Effectiveness

Principal Investigators:
Judith L. Sims
James Beardall (student)

Partners/Collaborators:
- ***Local:*** *Richard Worley, Bear River Health Department*

Project Description

- Need and Purpose:

  Common practice in the field of on-site wastewater treatment is that drain fields should be located at shallow depths in order to maximize aerobic decomposition of organic wastewater contaminants and enhance evapotranspiration. This practice results in less transport of contaminants to ground water and increased removal of nutrients (nitrogen and phosphorus) through vegetative uptake. However, in Utah, drain fields have often been, and continue to be, installed at depths of 8 to 10 feet or even deeper. This practice started many years ago in order to install the systems in soil materials that are more permeable than surface layers. The concern then was to dispose of the wastewater, but little attention was given to the ability of the soil system to accomplish degradation of wastewater contaminants. The practice of deep installation continues today, in some cases because disposal is still emphasized instead of treatment and also because the design process for deep systems results in much smaller systems. The concern is that treatment is not effective at the depths that septic systems are installed in Utah. Data are being developed to evaluate this issue.

- Benefits to the State:

  Utah's local health departments are presently permitting deep on-site systems without clear indication that these systems are adequately treating wastewater contaminants. Results of this research will provide information to the health departments on whether they can either continue permitting these types of systems with confidence or should eliminate the use of the systems.

- Geographic Areas:

  Study Area: Cache County.

  Areas Benefited: All areas of Utah where deep systems are commonly used for on-site wastewater treatment.

- Accomplishments:

  Findings: With the cooperation of the Bear River Health Department, eight sites in Cache Valley were identified, and sampling equipment was installed in drain fields. Four of the sites utilize deep trenches for treatment of wastewater, while four utilize shallow trenches. Sampling of the sites will continue through June 2011. We have also worked with the owners of the sites to educate them on proper septic system use practices.

Results: Leachate samples from the drain fields have been analyzed for nitrate nitrogen, phosphorus, coliform bacteria, total suspended solids, and biological oxygen demand to determine treatment effectiveness in both the shallow and deep trench systems. Results indicate that satisfactory treatment of wastewater contaminants is occurring in both shallow and deep systems. These results include removal of total of suspended solids, phosphorus, and coliform bacteria, decrease in biological oxygen demand, and conversion of ammonia nitrogen to nitrate nitrogen that indirectly indicates the presence of oxygen, which can be used in degradation processes by microorganisms.

Work Plan FY11/FY12

During FY11-12 we will continue sampling and analyzing leachate produced within the eight study drain fields and continue to determine treatment effectiveness in shallow and deep drain fields.

We will change the primary focus of the project and will initiate a laboratory scale column experiment to investigate possible means of removing pharmaceuticals and other emerging chemicals of concern in wastewater applied to septic system drain fields. We will amend drain field trenches with materials that may be able to sorb these chemicals and prevent them from moving to the ground waters below septic systems. Materials that will be investigated include peat and burnt straw ashes.

Informational Resources

Contact: Judith L. Sims, (435) 797-3230, E-mail: judith.sims@usu.edu

Deep trench installation, Clarkston, November 2008

Deep trench system installation, Wellsville, November 2008

Site locations in Cache Valley

Producing Bioplastic Materials Using Microbe-Based Processes

Principal Investigators:
Ronald C. Sims
Charles Miler
Elizabeth Linton

Partners/Collaborators:
- ***Local:*** *Issa Hamud, City of Logan*

Project Description

- Need and Purpose:

  Methods for reducing the costs of bioplastic materials are needed in order to make microbe-based processes competitive with petroleum-based plastics. Domestic feedstocks, including wastes and waste chemicals, for the production of domestic sustainable plastics can be used in the environmental, commercial, and medical industries. Current processing of bioplastic materials, including separation, concentration, and purification steps add significantly to the costs.

- Benefits to the State:

  The production of bioplastic materials from microbes that use domestic feed sources will generate new technologies, businesses, and products in Utah. Applications range from commercial packaging to biomedical designs such as drug delivery systems, tissue engineering, and orthopedics. The bioplastic materials are biodegradable and will reduce petroleum-based plastic materials that accumulate in landfills in Utah communities.

- Geographic Areas:

  Study Area: Confined animal feeding operations (CAFO) areas in rural Utah and the Logan Wastewater Reclamation facility treating wastes from seven communities in Northern Utah.

  Areas Benefited: All areas of the State of Utah, including rural communities and cities.

- Accomplishments:

  Findings: Common bacteria were programmed, through principles of synthetic biological engineering, to induce the production and secretion of bioplastic polymers through the bacterial cell wall. Figures 1 and 2 show bacteria without and with the secretion system installed. Bacteria with the secretion system installed produced more bioplastic material than bacteria without the secretion system.

  Results: The bioplastic secretion system developed represents a scientific and engineering breakthrough that will significantly reduce the costs of bioplastic production and processing. The system developed eliminates the need for the destruction of the bacteria in order to remove, separate, and concentrate the bioplastic polymers. Rather, the bioplastic materials are released by the bacteria in the water environment where they can be collected and concentrated more easily and at lower costs. The system can be used on a variety of waste chemicals and complex mixtures, including food processing wastes and wastes from the production of biodiesel.

Work Plan FY11/FY12

Future research will involve scale-up of the bioplastic production, secretion, and purification steps using a variety of wastes as carbon sources for bacterial synthesis of the biopolymers.

Informational Resources

Contact: Dr. Ronald C. Sims, (435) 797-2785, E-mail: ronaldsims1@gmail.com

References:

Linton, E., M.K. Walsh, R.C. Sims, and C.D Miller (2011). Translocation of green fluorescent protein by comparative analysis with multiple signal peptides. *Biotechnology Journal*, 6:1-10.

Figure 1. Bacteria without the secretion system installed, but able to produce bioplastic polymers internally

Figure 2. Bacteria with the secretion system installed and bioplastic polymers produced and secreted externally

Weber-Morgan Health Department Wastewater Advisory Committee

Principal Investigators:
Darwin L. Sorensen

Partners/Collaborators:
- ***Local:*** *Brian Cowan, Weber-Morgan Health Department*

Project Description

- Need and Purpose:

  The committee's purpose is to provide scientific, technical, and socioeconomic information to the Health Department staff that will inform their decisions and counsel to the Board of Health relative to the use of on-site (e.g., septic system) wastewater treatment and disposal. Staff members of the Weber-Morgan Health Department who deal with on-site wastewater issues bring technical and technically-related policy issues to the wastewater advisory committee for advice. The committee comprises representatives from local government, land developers, consulting engineers, the Central Weber Sewer Improvement District, the Utah Geological Survey, and academia (Utah State University). The committee meets on an as-needed basis. Resolving conflicts between environmental protection policies, technical practice, and/or costs and benefits in the face of scientific uncertainty can be challenging for decision makers. A multidisciplinary evaluation of the issues and possible solutions, as is possible with the committee, can inform decisions about site specific applications of policy and technology.

- Benefits to the State:

  The Weber-Morgan Health Department serves all of Weber and Morgan Counties. The wastewater advisory committee was formed to provide technical advice to the staff of the Department and to the Board of Health. Some actions of the committee may provide guidance to other local health departments.

- Geographic Areas:

  Study Area: Weber and Morgan Counties.

  Areas Benefited: Weber and Morgan Counties.

- Accomplishments:

  Findings/Results: Historically, most issues addressed by the committee have been related to variance requests by citizens seeking to develop privately owned land that is not suitable for development under current Health Department rules. In these cases, the committee considers the scientific and public health protection principles underlying the rule and seeks to find ways for the land to be used without jeopardizing public health and environmental quality, which is possible in some situations when more detailed site information is made available and appropriate treatment technologies can be employed. In other situations, the committee advises against allowing a variance. Over its history the committee has considered a broad range of water quality protection issues including septic system densities in western Weber County and the development or redevelopment of relatively small plots in the environmentally sensitive Ogden and Weber River Canyons.

Work Plan FY11/FY12

It is anticipated that Dr. Darwin L. Sorensen will continue to serve as member of the committee in FY11/FY12.

Informational Resources

Contact: Dr. Darwin L. Sorensen, (435) 797-3207, E-mail: darwin.sorensen@usu.edu.

Environmental Quality Management and Remediation

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Environmental Quality Management and Remediation

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
Analysis of Microbial Diversity and Dechlorinating Potential at Solvent Contaminated Sites Throughout Utah	$21,122.29	$21,755.96	$0.00
Analyzing the spread of Phragmites Australis Over Short Time Scales Using Spatial and Genetic Tools	$38,414.46	$39,566.89	$0.00
Assessing Phosphorus-Transport from Biosolids Land Application Sites in Utah	$38,078.65	$39,221.01	$40,397.64
ATK Static Test Environmental Assessment	$26,454.61	$27,248.25	$0.00
Conditions Affecting the Clean-Up of TCE- Contaminated Aquifers in Northern Utah	$85,551.75	$30,685.35	$0.00
Environmental Impact of Expanded Recycling Programs in Salt Lake County	$6,330.95	$16,520.88	$0.00
Evaluation of Duckweed as a Technology for Management of Nutrients and Emerging Contaminants in Municipal Wastewater Systems	$47,395.26	$48,817.12	$50,281.63
Impact of Metals and Metal Ions on Soils and Plants	$6,027.20	$6,208.02	$6,394.26
Investigations into Elevated Wintertime Ozone in Utah's Uinta Basin	$35,300.54	$36,359.56	$37,450.34
Low Level Hexavalent Chromium (Cr-6) in Drinking Water	$67,831.38	$69,866.32	$71,962.31
Monitoring Organic Contaminants in Air Using Plants as Passive Samplers	$21,426.65	$22,069.45	$22,731.53
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$6,330.95	$6,520.88	$6,716.50
Remediation of Chlorinated Sovent Contamination of Groundwater	$80,379.89	$82,791.29	$85,275.03
Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)	$6,330.95	$6,520.88	$6,716.50
Risk Characterization Using Modified 3MRA at Biosolids Land Application Sites	$26,113.26	$26,896.66	$27,703.56
Study of Cache Valley's Vertical Ozone Profiles and Application to the Uintah Basin	$50,735.39	$52,257.45	$53,825.18
Uptake of Organic Contaminants from Groundwater and Transfer into Edible Plants: Species Differences	$29,359.54	$30,240.33	$31,147.54
Volatile Organic Compounds in Indoor Air: Source Identification, Emission Flux Determinations and Model Development	$27,998.91	$28,838.88	$29,704.04
Designated Projects		$531,014.65	$14,306.00
Undesignated Projects		$187,560.00	$12,000.00
Total	**$621,182.63**	**$1,310,959.83**	**$496,612.06**

Analysis of Microbial Diversity and Dechlorinating Potential at Solvent Contaminated Sites Throughout Utah

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen

Partners/Collaborators:

- ***Federal:*** *Kyle Gorder, Environmental Management Directorate, Hill AFB*

Project Description

- Need and Purpose:

  The use of chlorinated solvents has been historically widespread throughout Utah resulting in a legacy of contaminated groundwater sites at both former and currently operating industrial facilities. Chlorinated solvent impacted groundwater poses a significant threat to public health and the environment through exposure pathways, such as in fruit trees growing above groundwater plumes. Results at phytoremediation sites suggest that significant differences in TCE transformation and metabolic products are occurring in trees, which may be due to differences in microbial communities within the trees themselves (the endophyte community).

  The objective of this study was to determine (1) whether a correlation between TCE treatment and the endophytic community present in trees can be established in a controlled greenhouse environment, (2) whether the endophytes present in the tissues of these exposed trees originate from either the outside environment (i.e., soil, water, and air) or the parent tree, and (3) whether these endophytes play an active role in the bio/phytoremediation of TCE.

- Benefits to the State:

  Determining the significance of endophytic microbial communities on the transformation and fate of TCE in contaminated groundwater benefits the State in a number of ways including the following:

  1. Improving the understanding of the overall fate of TCE and its degradation products in contaminated environments located throughout the state.

  2. Improving the completeness of quantifying the fate of TCE and its degradation products as they move and are transformed within the environment at these contaminated sites.

- Geographic Areas:

  Study Area: Hill AFB in Weber County, Utah.

  Areas Benefited: All locations in the state with TCE impacted groundwater sources would potentially benefit from the findings of this project through improved understanding of the role of endophytic microbial communities impacting TCE degradation for site remediation.

- Accomplishments:

  Findings: Overall, the results of the hybrid poplar study showed that treating trees with TCE had a significant effect on the microbial community that developed within the tissues of the trees. The community associated with the roots and media of the trees was more susceptible to the treatment, but a significant effect was also observed in endophytes associated with the leaf and stem samples. The most interesting finding in this study was the sheer quantity and diversity of microorganisms that were found associated with all the tissues of the hybrid poplars.

  Results from TCE degradation product and metabolite analysis revealed that TCE was successfully delivered to all the tissues of the trees that were dosed. Observed concentrations were highest in the root tissue and media and decreased up the tree toward the leaves. Anaerobic microbial degradation was not significant, but elevated concentrations of TCAA in the leaf samples of dosed trees and TCEtOH in the leaf, stem, and root samples of dosed trees were observed. This indicates that the hybrid poplar trees were actively metabolizing TCE to TCAA and TCEtOH.

  This study suggests that the effect of these microorganisms is significant in the phytoremediation of contaminants such as TCE. Results from looking at diversity within tree tissues compared to diversity in the parent tree, and samples taken from the tree's immediate environment, showed some similarity in every case. This suggests that the community that develops within the tissue of a tree is affected by the community that was present in the parent tree, as well as the community that is present in the immediate environment (soil, water, and air).

  Results: Endophytic and plant-associated microorganisms including archaea, bacteria, and fungi are implicated in the degradation of contaminants in the rhizosphere and within the plants themselves at much higher rates than have previously been observed with bioremediation and phytoremediation alone. These microorganisms may also assist the plant by reducing toxicity, allowing for more effective phytoremediation, and decreasing the amount of harmful chemicals that are phytovolatilized. This interaction between plants and microbes could potentially be important at sites that are already using bioremediation and/or phytoremediation, and it is likely that the mass of contaminant that is actively being degraded is underestimated. These interactions should always be considered when selecting a remediation strategy, especially if that strategy involves phytoremediation.

Work Plan FY11/FY12

Research on the project is completed and efforts are underway to disseminate research findings via the refereed literature. No future work will be carried out on this specific research topic.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797-3227, E-mail: ryan.dupont@usu.edu.

Website: http://public.me.com/rdupo/UWRL Report Files/MicrobialDiversity_Study_Report_Files.

Analyzing the Spread of *Phragmites Australis* over Short Time-Scales Using Spatial and Genetic Tools

Principal Investigators:
Mac McKee
Austin Jensen
Bushra Zaman

Partners/Collaborators:
- ***Local:*** *Bear River Migratory Bird Refuge*

Project Description

- **Need and Purpose:**

  Phragmites australis is an invasive grass species that is rapidly outcompeting native cattails and bulrushes in US wetlands and causing a substantial loss of quality wetland habitat, especially in areas heavily used by highly valued migratory birds. This threatens the ecological, social, and economic services that wetlands provide. To control the spread of this invasive grass, managers need efficient and accurate ways to monitor its spread, quantify the habitat it displaces, and evaluate the degree to which control measures work.

  This project examined the use of AggieAir™ unmanned aerial vehicles (UAVs), developed and operated by the Utah Water Research Laboratory (UWRL) and the Center for Self-Organizing Intelligent Systems (CSOIS) at Utah State University, for acquiring remotely sensed imagery to detect wetland plant coverage and monitor the spread of *Phragmites* in the Bear River Migratory Bird Refuge (BRMBR), a large wetland in northern Utah. A multiclass relevance vector machine (MCRVM) model, also developed at the UWRL, was trained with remotely sensed vegetation reflectance data and on-ground sampling and used to classify previously unseen data into vegetation types, especially *Phragmites*, and to quantify its rate of spread over the growing season. Ground surveys also provided DNA samples of *Phragmites* to determine the different mechanisms of *Phragmites* spread (rhizomes versus seeds) under flooded and unflooded conditions.

- Benefits to the State:

  - This project provides wetlands managers with new, inexpensive, and valuable methods to evaluate the rates of *Phragmites* spread over the course of the growing season and the efficacy of their attempts to control it, as well as new information on the water and salinity levels that both encourage and discourage *Phragmites* spread.

  - These technologies will help wetlands managers to allocate scarce water, personnel, and budget resources to achieve Utah's wetlands objectives and support the hunting, birding, and recreation that are vital to the Utah communities that border the Great Salt Lake.

- Geographic Areas:

  Study Area: The Bear River Migratory Bird Refuge, UT.

  Areas Benefited: Any of Utah's wetlands and the communities that surround them.

- **Accomplishments:**

  Findings: This project has:

  - Tested the capability of UAVs to acquire imagery that can be used to automatically assess the location, abundance, and rate of spread of *Phragmites australis* at the BRMBR using a multi-class relevance vector machine.
  - Developed software that can locate *Phragmites* at very high resolutions with an overall classification accuracy of 95% using unique spectral signatures (approximately 25 cm spatial resolution), and determine its spread.
  - Collaborated with Watershed Sciences Department at USU to assess the method of spread of *Phragmites*, whether by seed or clonally by rhizomes (underground stems) in order to guide the type and timing of *Phragmites* control efforts at the BRMBR.

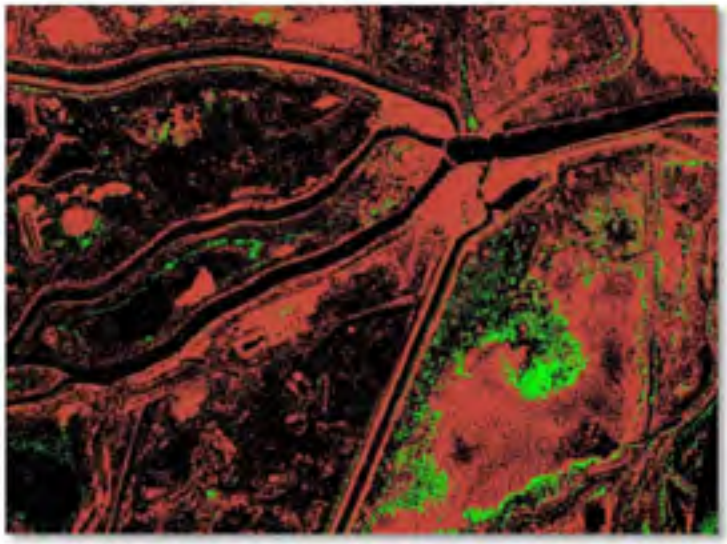
  Results: The AggieAir™ UAV platform has proven to be an inexpensive and highly effective tool to acquire useful multispectral data. The data acquired by this platform can be provided as input to a multivariate relevance vector classification machine to produce highly accurate quantitative descriptions of the types of land cover in the imagery. The combination of remote sensing UAVs and the MCRVM has the potential for broad application in agricultural and natural resource management.

Work Plan FY11-FY12

Future research will focus on evaluation of the effectiveness of *Phragmites* control efforts and the extent to which the data from the aerial imagery can be made to correlate with the DNA findings.

Informational Resources

Contact: Dr. Mac McKee, (435) 797-3188, E-mail: mac.mckee@usu.edu.
Website: http://aggieair.usu.edu.



Additional area occupied by *Phragmites* (shown in green) in the BRMBR between June and September, 2010

Assessing Phosphorus-Transport from Biosolids Land Application Sites in Utah

Principal Investigators:
Michael J. McFarland

Partners/Collaborators:
- ***State:*** *Mark Schmitz, Utah Division of Water Quality*
- ***Local:*** *Mohan Kumar, Utah State University; Leland Myers, Central Davis Sewer District*

Project Description

- **Need and Purpose:**

  Phosphorus Site Index (PSI) is a phosphorus transport assessment tool, to estimate the risk of P transport from soils. This study has considered two biosolids land application sites in Utah, which received biosolids amendments over time, to develop a specialized PSI for the state of Utah. Total P was correlated with the PSI estimation in one site, while P measured at a nearest water source was used as an indicator of risk estimability at the other site. Phosphorus from land application of certain types of biosolids has been considered a potential risk for eutrophication. While EPA part 503 regulations mandate certain application practices, a more accurate tool is necessary to estimate P losses from biosolids land application sites. The Phosphorus Site Index for two biosolids land application sites in Utah will be calculated, and its validity established. Erosion-Productivity Impact Calculator (EPIC) model will also be used to simulate P transport over these sites to further determine the accuracy of PSI. While application of the P-Index is not currently a regulatory requirement in Utah, increasing public and regulatory concerns have led to development of P-Index charts in various states, which can be used to estimate the potential risk of phosphorus mobility and environmental impact. A PSI worksheet will be developed in an easy to use form, covering recommended best management practices and methods of preventing P transport from soils.

- Benefits to the State:

  The information generated from this project will be implemented in a PSI worksheet software that will help Utah land managers, municipal wastewater treatment plants, biosolids generators, biosolids land appliers, and Utah agricultural producers to identify sustainable methods for biosolids land application for agricultural use. It is anticipated that the PSI worksheet will be used as a simplified estimator of phosphorus losses from biosolids land application sites in Utah, and that appropriate biosolids application rates will then be used to minimize any adverse ecological and/or environmental impacts.

- Geographic Areas:

  Study Area: Ensign Ranch biosolids land application site, Tooele County, Utah; Central Davis Sewer District biosolids land application site, Davis District, Utah.

  Areas Benefited: The above study areas where biosolids are land applied, as well as any future sites where biosolids maybe land applied for agricultural use in Utah.

- Accomplishments:

Findings: Current guidelines set by the 590 Nutrient Management Standard for the state of Utah severely restrict continued land application of biosolids over a given site. Figure 1 shows that multiple time application of biosolids on a site increases soil test P above 100 ppm, and application is not recommended. This restriction can be overcome by a better model that is able to assess the risk of P losses from the site.

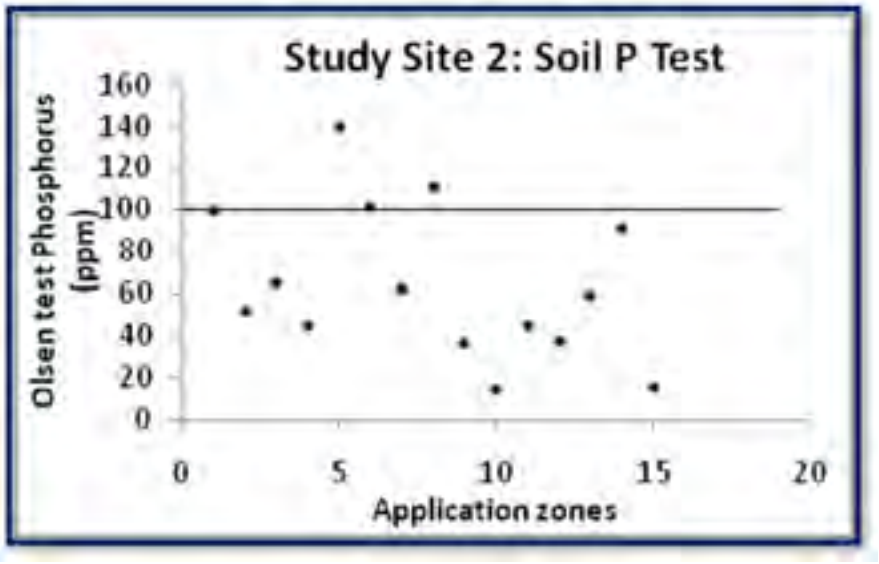


Figure 1. Olsen test P values for zones in study site 2.

Results: Preliminary results of the EPIC P simulation model and comparison with the Phosphorus Site Index ratings have indicated a significant correlation, and sufficient modeling data is available to increase the accuracy of the phosphorus site index to estimate p losses. Further modification of the PSI components will be done to increase accuracy and usability.

Work Plan FY11/FY12

- Improve accuracy of Phosphorus Site index for Utah based on phosphorus simulations using EPIC model.

- Develop easily usable Phosphorus Site Index worksheet based on phosphorus loss results obtained, to estimate P losses from site.

Informational Resources

Contact: Dr. Michael J. McFarland, Professional Engineer (PE), Board Certified Environmental Engineer (BCEE), Phone: (435) 994-0905, E-mail: farlandm@msn.com.

ATK Static Test Environmental Assessment

Principal Investigators:
William J. Doucette
Laurie E. McNeill
Scout Mendenhall (student)
Danny Ryan (student)

Partners/Collaborators:
- ***Business/Industry:*** *ATK*

Project Description

- **Need and Purpose:**

  The static testing of solid rocket motors at the ATK Promontory, Utah site can displace large amounts of soil that then become entrained in the combustion cloud. As the cloud cools, the soil condenses out of the cloud and drops on the surrounding area. The overall focus of this study is to determine any potential impacts on human and ecological health associated with the post-test deposition of this Test Fire Soil (TFS).

- Benefits to the State:

  This research will help ATK (a leading employer in the State of Utah) to better understand the environmental effects of their static motor tests. Results will also help to address the concerns of local residents about the effects of material deposited during the static tests.

- Geographic Areas:

  Study Area: ATK Promontory facility in Box Elder County.

  Areas Benefited: Box Elder County, including Thatcher, Tremonton, Corrine, and Penrose.

- Accomplishments:

  Findings/Results: Analysis of TFS from the February 25, 2010 (FSM-17) and August 31, 2010 (DM-2) static motor tests found elevated levels of chloride, aluminum, and pH, as well as lower carbon content relative to locally collected surface soils. TFS deposition rates during the FSM-17 test ranged from 1 to 5 g/min/m2.

  Mild steel sample coupons exposed to TFS from the FSM-17 motor test had accelerated initial corrosion rates and increased weight loss relative to non-exposed controls, but after six months the differences in corrosion rates became insignificant (Figure 1). The highest mild steel corrosion rates measured in this study were within the wide range of rates reported in the literature for some industrial and marine sites but less than those reported for the Kennedy Space Center in Florida.

  A follow-up field study exposed four different types of coupons to five treatments including 5% w/v sodium chloride solution, 0.1 M hydrochloric acid solution, soil/water slurry, FSM-17 TFS/water slurry, and 0.1 M hydrochloric acid solution followed by an application of FSM-17 TFS/water slurry. Mild steel coupons sprayed with the TSF/water slurry followed by a HCl solution or the TSF/water slurry alone had significantly higher corrosion rates than the control samples, while the coupons sprayed with NaCl, HCl, or native soil were no different than the

control (Figure 2). This suggests that the combination of chloride and moisture retained within TFS are the major factors associated with the slightly enhanced corrosion rates. In contrast, automotive steel, painted galvanized steel and vinyl coupons left in the field for six months showed no significant corrosion after the application of any of the five treatments.

Although not a main focus of the study, air sampling conducted during the FSM-17 test also indicated that the particulate matter levels (PM 2.5, PM 10 and TPM) at the sampling sites within the plume were not significantly different from the control site.

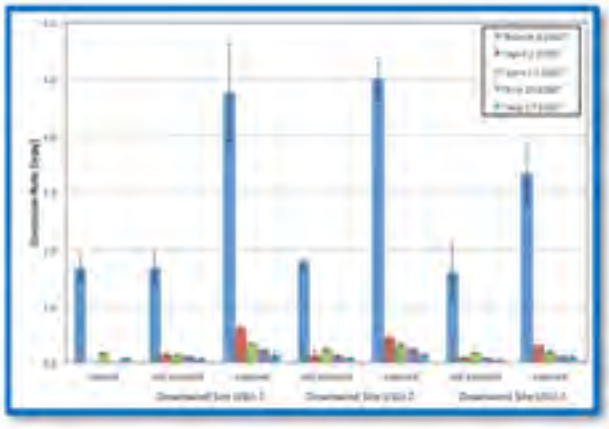


Figure 1. Corrosion rates for mild steel samples exposed to TFS from FSM-17 motor test

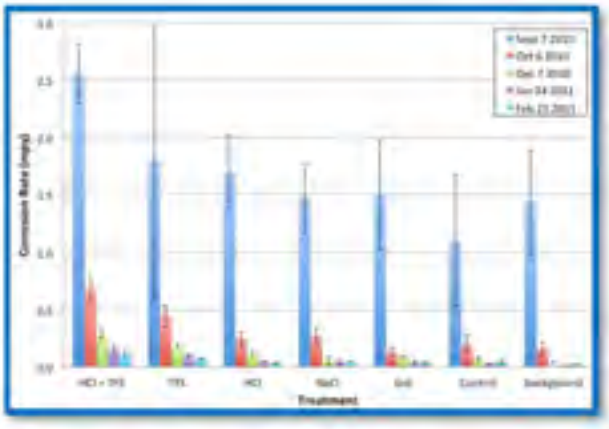


Figure 2. Corrosion rates for mild steel coupons subjected to various treatments

Work Plan FY11/FY12

The corrosion experiments have been concluded, and results will be submitted for publication in a peer-reviewed scientific journal. The project scope has now shifted to evaluating the effect of TFS on corn and alfalfa crops. Controlled greenhouse experiments will be conducted, and results will be compared to data collected from field crops grown in the area subjected to TFS deposition. Specific objectives include the following:

1. Corn and alfalfa plants will be grown in three different soil-TFS mixtures, to simulate growth conditions that are expected in the field.
2. Corn and alfalfa plants will also be grown to conduct a foliage application study, which will observe the effects of TFS on photosynthesis and leaf health.
3. Leachate properties of TFS will be determined when TFS is applied to soil and when tilled into soil.
4. Soil from several locations surrounding ATK property will be collected and characterized by performing a simple water extraction for anions.
5. The bioavailability of aluminum to ruminants will be simulated with a four-stage digestion.

Informational Resources

Contact: Dr. William J. Doucette, Phone: (435) 797 3178, E-mail: william.doucette@usu.edu.
Dr. Laurie McNeill, Phone: (435) 797-1522, Email: laurie.mcneill@usu.edu.

Conditions Affecting the Clean-Up of TCE-Contaminated Aquifers in Northern Utah

Principal Investigators:
Darwin L. Sorensen
Subathra Muruganandam

Partners/Collaborators:
- ***Federal:*** *Mark Roginske, Hill AFB*

Project Description

- Need and Purpose:

  Chlorinated solvents, especially trichloroethene (TCE), have been widely used in industry. TCE is a suspected human carcinogen. However, cleanup of spills or improper disposal of these slow-to-degrade solvents has proven difficult and expensive. Methods that rely on in-place degradation of the solvents by microbial activity provide hope for effective cleanup at relatively low cost. Early laboratory experiments have indicated that biostimulation for dechlorination of solvents in some aquifer materials at a site near Hill Air Force Base (AFB), Utah may be delayed or may not become established. Investigations into the cause for this potential treatment failure are being conducted.

  Laboratory-scale experiments using microcosms (serum bottles) and mesocosms (flow-through columns) can control several environmental factors while maintaining much of the complexity of the microbial community and physical/chemical environment. Experiments have been conducted at both of these scales to determine the physical and biological conditions influencing the onset of dechlorination.

- Benefits to the State:

  Chlorinated solvents in ground water environments represent a threat to public health, and environmental regulations demand the cleanup of this kind of contamination. Evaluating the probability of success for a cleanup technology represents an opportunity to improve the Utah environment and protect the health of the citizens of the State. Avoiding the misuse of technology can hasten cleanup and avoid the wasteful expenditure of limited cleanup funds. The project has been focused on Hill AFB but will have application to TCE and other chlorinated ethene contamination at several locations within Utah.

- Geographic Areas:

  Study Area: The cities of Sunset and Clinton in Davis County along with Hill Air Force Base.

  Areas Benefited: Communities surrounding Hill Air Force Base, in Davis and Weber Counties, and several other industrialized areas in the state where groundwater has been contaminated with chlorinated solvents.

- Accomplishments:

  Findings/Results: This year work has focused principally on analysis of large flow-through aquifer material columns made using TCE contaminated aquifer material collected in Clinton, Utah, and operated in a 15°C (59°F) laboratory for 7.5 years. Experiments to enhance solvent

dechlorination involved adding whey or emulsified vegetable oil with lactic acid solutions to the top of the columns. Data analysis from the extensive chemical and biological analyses of multiple layers from each of the seven columns is continuing but some preliminary results include the following:

- Biostimulation with whey resulted in complete TCE degradation within the first sampling layer (3.5 in; 9 cm; 1 day flow) compared to partial and no TCE degradation in emulsified oil and non-biostimulated control columns, respectively.
- Quantitative, real-time polymerase chain reaction (qPCR) analysis of the whey column samples revealed an increase in TCE reductase gene (tceA gene) copy numbers (log 7.5/g) compared to emulsified oil (log 7.0/g) and no carbon treatments (log 4.5/g).
- Gene expression studies from all treatments illustrated that the top 23 cm of the biostimulated columns were microbiologically more active than rest of the column.
- Geochemical evidence of long-term, highly reducing conditions corresponded to complete dechlorination in whey-treated columns.

Work Plan FY 11/FY12

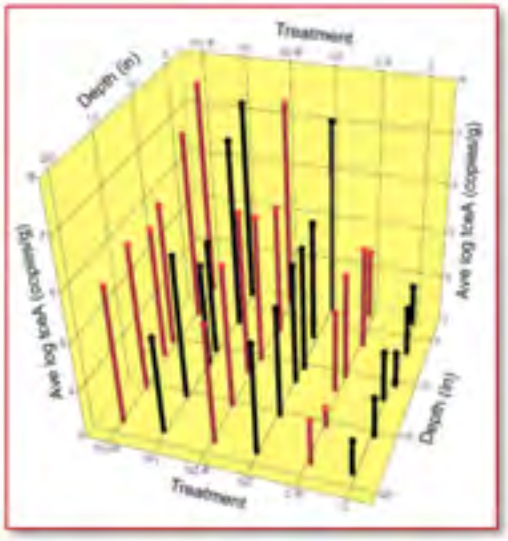
Preserved samples of bacterial DNA from the surface of each column will be sequenced using new high-throughput techniques (pyrosequencing) to reveal the diversity of bacteria associated with each treatment and the associated dechlorination capability. Data reduction and publication of results from this and existing data is our goal.

Informational Resources

Contact: Dr. Darwin L. Sorensen, (435) 797-3207, Email: darwin.sorensen@usu.edu.

References:

Zaa, C.L.Y., J.E. McLean, R.R. Dupont, J.M. Norton and D.L. Sorensen (2010). Dechlorinating and iron reducing bacteria distribution in a TCE-contaminated aquifer. *Ground Water Monitoring and Remediation*, 30(1):46-57.



Concentrations of the TCE reductase gene (tceA) with depth in the top 20 inches of the columns by treatment: C, control; C-B, control bioaugmented; NZ, emulsified oil and lactate; NZ-B, emulsified oil and lactate plus bioaugmentation; Wy, whey; WY-B, whey plus bioaugmentation.

Environmental Impact of Expanded Recycling Programs in Salt Lake County

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:

- ***Local:*** *Patrick Leary, Public Works Director, Salt Lake County*
  Rick Graham, Public Works Director, Salt Lake City
  Russ Willardson, Public Works, West Valley City
  John Loannou, Manager, Salt Lake Valley Solid Waste Management Facility

Project Description

- Need and Purpose:

  This project has assisted solid waste managers in Salt Lake County, Salt Lake City, and West Valley City to evaluate the environmental impact of implementing an expanded curbside green waste collection program in Salt Lake County, expanding food waste composting in Salt Lake City, adding municipal solid waste (MSW) recycling options for the community of West Valley City, and improving the overall carbon footprint of Salt Lake County, including Green House Gas (GHG) emissions. The West Valley City project also included a cost evaluation for additional collection routes moving from bi-weekly to weekly recyclables collection.

  Various scenarios were presented that assume different levels of public participation in recycling programs, and comparisons were made to the current Base-Case situation and increased recycling efforts in terms of changes in projected GHG emissions, energy requirements, and costs.

- Benefits to the State:

  Evaluating the environmental impact and costs of solid waste management options can lead to reduced carbon emissions, reduced energy use, and more efficient and less costly solid waste management throughout Salt Lake County and throughout the State. Solid waste management evaluation methodology, based on the U.S. EPA's WAste Reduction Model (WARM), can be used to explore ways to reduce carbon emissions and improve energy utilization in all Utah communities and counties by (1) identifying the carbon and energy footprints of current solid waste management practices and (2) identifying options for solid waste management such as source reduction, recycling, composting, and incineration that can be used to modify carbon and energy footprints and enhance sustainability of solid waste management practices within Utah.

- Geographic Areas:

  Study Area: Salt Lake City, West Valley City and Salt Lake County.

  Areas Benefited: Solid Waste Management activities occur statewide so all counties in the state would potentially benefit from this project.

- Accomplishments:

  Findings: Results indicated that eliminating the green waste recycling program in Salt Lake County would result in the most significant reduction in GHG emissions and energy utilization of all options considered because of the landfill gas collection and energy generation that take place at the SLVSWMF due to carbon sequestration by landfilling, and reduced energy requirements for composting. Green waste collection for composting significantly increases the

GHG emissions and energy consumption required to manage this material. Diverting food waste from the Salt Lake City waste stream into the on-going composting operations of the SLVSWMF, however, shifts the energy and carbon footprint balance significantly. Food wastes degrade rapidly under both composting and landfilling conditions, but composting of this material is preferred in terms of lower carbon footprint. Eliminating additional cost and energy expenditure to collect this food material makes the composting option even more favorable. Finally, weekly collection of recyclable material is not recommended due to low recyclable recovery rates and high costs for collection.

Results: The benefits of green waste diversion and composting programs include revenue generation, landfill space preservation, and a salable commodity in compost. It appears prudent for Salt Lake County to pursue a voluntary green waste recycling program using commercial collection and to encourage food waste collection for composting by Salt Lake City.

An increasing in food waste composting at the SLVSWMC by diverting only 3% of the food waste component (2,803 T/yr) yields a net reduction in the facility's carbon footprint by 715 metric T/yr and produces an annual energy savings of more than 2,000 million BTUs. Salt Lake County data indicate that weekly collection of recyclables would increase overall MSW diversion by only 3% at an additional cost of more than $1 million/yr. Even this small additional diversion rate could result in significant reductions in the carbon footprint (1,353 metric T/yr) and energy consumption (19,654 million BTU); however, the region and nation would realize these significant environmental benefits at a very high cost to West Valley City.

It is recommended that cities provide additional recycling containers to households desiring to increase recycling levels and continue the current bi-weekly collection, thereby encouraging additional MSW diversion with no significant increase in waste management costs.

Work Plan FY11/FY12

- Disseminate the findings of this project through FY12 to interested parties including the Salt Lake County Sanitation Division, the SLVSWM Council, Salt Lake City, West Valley City and other solid waste management entities in the State.

- Continue energy and environmental footprint analyses for Salt Lake County, Salt Lake City, and other communities in the Salt Lake Valley related to improving the efficiency of their MSW management programs.

Informational Resources:

Contact: Dr. R. Ryan Dupont, Phone (435) 797-3227, E-mail: ryan.dupont@usu.edu.

Website:
http://public.me.com/rdupo/UWRL Report Files/SLCounty_Green_Waste_Study_Report_Files

Evaluation of Duckweed as a Technology for Management of Nutrients and Emerging Contaminants in Municipal Wastewater Systems

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
William J. Doucette
Jon Farrell (student)
Maureen Kesaano (student)

Partners/Collaborators:
- ***Local:*** *Don Hartle, City Manager, Wellsville City, UT*
  Issa Hamud, Director, Environmental Department, Logan City, UT

Project Description

- Need and Purpose:

  Nutrients, particularly phosphorous, and other contaminants such as personal care products and pharmaceuticals (PCPP) in municipal wastewater systems are a growing concern due to their effects on aquatic systems receiving wastewater treatment plant effluents. Conventional wastewater treatment systems are not effective in their removal. Current chemical or advanced biological treatment alternatives are often prohibitively expensive to implement, particularly for small, rural communities.

  This study is evaluating the effectiveness of a duckweed-based system (*Lemna minor* and *Wolffia globosa*) for the uptake and transformation of nutrients and PCPP contaminants from municipal wastewater, especially in communities like Wellsville City and Logan City that have lagoon wastewater treatment systems currently in place.

- Benefits to the State:

  Protection of surface water quality from nutrient enrichment and PCPPs is a concern in many watersheds in the state. This project is developing an effective low-cost method for removal of nutrients and PCPPs from wastewater that also has a net positive energy and environmental footprint.

- Geographic Areas:

  Study Area: Cache County, UT.

  Areas Benefited: All locations in the state with actual or potential nutrient and PCPP impacted surface water where low-cost, sustainable nutrient management systems are required for water quality improvements.

- Accomplishments:

  Findings: Duckweed-based nutrient removal systems can be feasibly implemented at the Wellsville lagoons based on significant duckweed growth rates and high concentrations of nutrients that accumulate in the duckweed biomass. The effectiveness of such a system is dependent, however, on the efficient and cost effective harvesting and stabilization/processing of the generated biomass. Studies focusing on biomass processing have found that duckweed can be utilized as a high quality animal feed supplement, that it is amenable to anaerobic conversion to methane, and that it is fermentable to ethanol.

Results: More than 250,000 lbs. of dried duckweed material could be harvested from the 56 ac of Wellsville lagoons on an annual basis. This amounts to approximately 2,500 lbs. of phosphorus being recovered in the harvested material. Duckweed used as animal feed has more than twice the value of alfalfa based on its digestibility and the organic matter, protein, and crude fiber content. This quantity of dried material could serve as a substitute for soybean meal feed supplement for approximately 120 animals. Based on observed duckweed digestibility and methane generation in laboratory digesters, this mass of dried material could generate 1,000,000 ft^3 of methane or an equivalent of 1,000 million BTUs of energy per year for Wellsville City. Finally, ethanol fermentation studies have indicated that fermentation of duckweed biomass is feasible, but does not generate sufficiently high concentrations of ethanol to make it economically viable.

These results indicate that modest value would be associated with the processing and conversion of harvested duckweed biomass to animal feed, or methane even at the scale of the Wellsville lagoons. The main benefit of the technology is clearly to provide a low cost alternative to much more costly advanced biological or chemical treatment processes, about $150/lb. N or P removed.

Preliminary results for the analysis of PCPPs have indicated that the levels of five common consumer products associated PCPPs are lower in Wellsville City lagoon effluent than from mechanical plant discharges of similar size. This suggests enhanced removal of PCPP compounds via duckweed systems.

Work Plan FY11/FY12

Laboratory flask studies to evaluate the potential for duckweed species to bioconcentrate nutrients and bioconcentrate and metabolized hazardous PCPP contaminants in municipal wastewater are currently on-going. The impact of this bioconcentration on subsequent sludge processing steps (animal feed, anaerobic digestion, ethanol fermentation) is also being considered. Field studies are underway to develop long-term growth and harvesting performance data to further define the sustainability of duckweed-based treatment, and provide baseline data for modeling the nutrient removal and water quality improvement provided by these systems.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.

Website: http://public.me.com/rdupo/UWRL Report Files/Duckweed_Study_Report_Files.

Field Duckweed Growth Rate Apparatus

Duckweed Cover on the Wellsville Lagoons

Impact of Metals and Metal Ions on Soils and Plants

Principal Investigators:
Joan E. McLean
Anne Anderson (Biology)
David Britt (Biological Engineering, USDA Project PI)
Christian Dimkpa (Biology)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Metal oxide nanoparticle and silver nanoparticles are manufactured for use in a variety of applications in medicine, food safety, personal care products, agriculture, and various other manufacturing operations and industries. Because of the ubiquitous use of metals in industrial and domestic products, metals are common pollutants in landfills and in wastewater treatment systems. Use of manufactured metal nanoparticles in various industries and in agriculture may lead to adverse effects on plants and soil microbial ecosystems. This project is investigating the bioavailability and toxicity of metal oxide nanoparticles of copper oxide and zinc oxide and silver nanoparticles on a beneficial soil bacterium and on wheat in order to identify the ways metals affect beneficial soil bacteria survival, impact carbon and nutrient cycling, and ultimately, plant productivity.

- Benefits to the State:

  Results will directly benefit the counties in Utah with current metal contamination from abandoned and active hard rock mining and counties planning to expand industrial development by protecting environmental quality and human health as related to metal exposure.

- Geographic Areas:

  Study Area: Counties with abandoned and active mining operations and counties with industrial operation—all counties in Utah.

  Areas Benefited: All counties in Utah

- Accomplishments:

  Findings: Silver, copper oxide, and zinc oxide nanoparticles released to the environment could create persistent impacts on susceptible beneficial soil microbes and on plant productivity.

  Results: We have shown that bacteria and plants (wheat) respond differently when exposed to metal ions and metals associated with nanoparticles (NP). We have found novel sub lethal effects on production of metabolites from an environmental bacterium and plants (Figure 1). Some of these responses are NP-dependent and they affect metabolites of importance in plant interactions.

Work Plan FY11/FY12

We will continue to explore changes in the metabolism of bacteria and plants when challenged with NP metal. These changes may be beneficial in production of metabolites of commercial value.

Informational Resources

Contact: Ms. Joan E. McLean, (435) 797-3199, E-mail: joan.mclean@usu.edu.

References:

Dimkpa, C.O., A. Calder, D.W. Britt, J.E. McLean, and A.J. Anderson (2011). Responses of a soil bacterium, Pseudomonas chlororaphis O6 to commercial metal oxides nanoparticles compared with responses to metal ions. *Environ. Pollution*, 159:1749-1756.

Dimkpa, C.O., A. Calder, P. Gajjar, S. Merugu, W. Huang, D.W. Britt, J.E. McLean, W.P. Johnson and A.J. Anderson (2011). Interaction of silver nanoparticles with an environmentally beneficial bacterium, Pseudomonas chlororaphis. *J. Haz. Mat.*, 188:428-435.

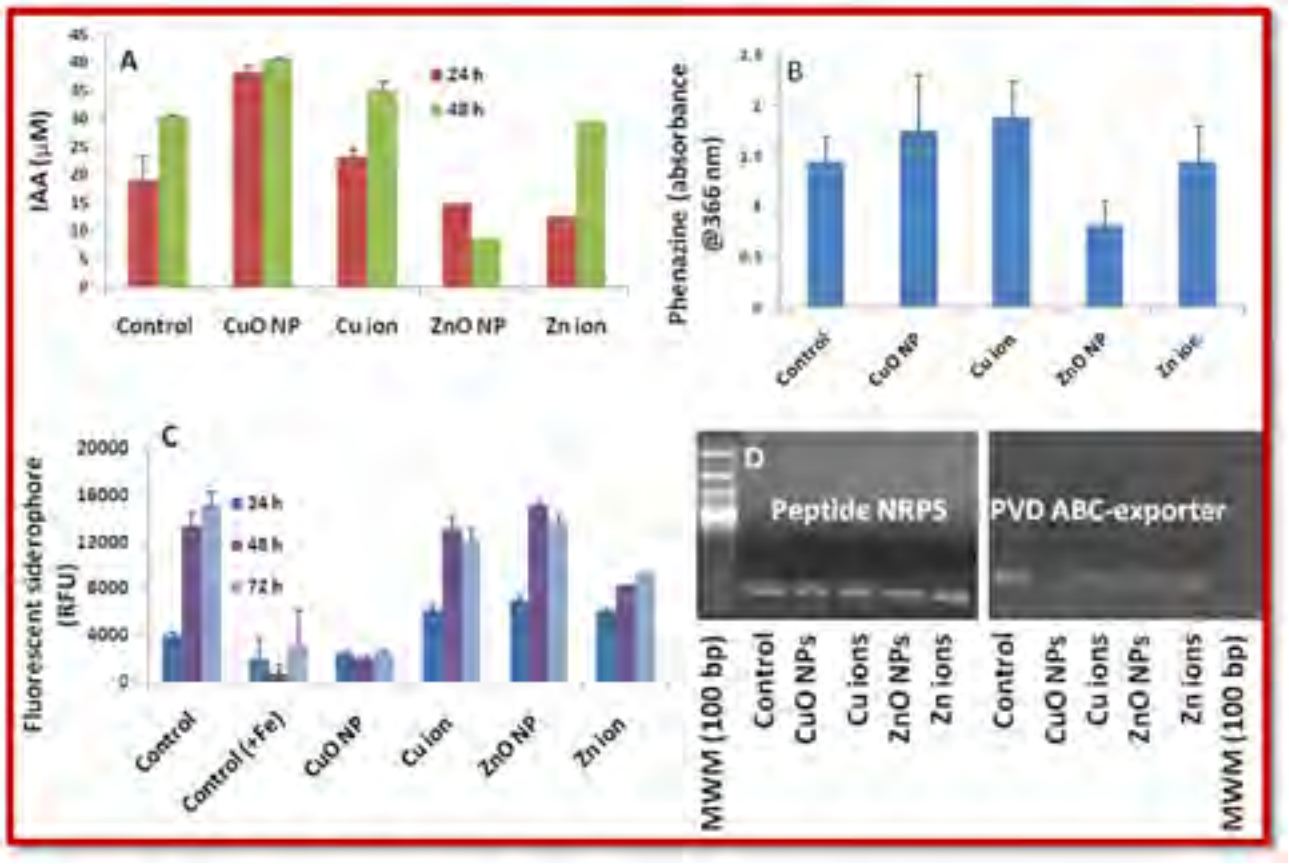


Figure 1. Differential effects of NPs and ions on production of various metabolite in soil bacteria, IAA, phenazines and siderophores (A-C) and PCR analysis of genes encoding the siderophore peptide and an inner membrane transporter (D).

Environmental Quality Management and Remediation

Investigations into Elevated Wintertime Ozone in Utah's Uinta Basin

Principal Investigators:

Randal S. Martin
Wendy (Meiners) Merkley (student)
Crystal (Viator) Wood (student)
Kori Moore (student/EDL Fellow)

Partners/Collaborators:

- ***Local:*** *Uintah Impact Mitigation Special Service District (UIMSDD)*
- ***State:*** *Utah Division of Air Quality (UDAQ) & Air Monitoring (AMC), USURF's Energy Dynamic Laboratory – Logan and Vernal Branch, USU – Vernal campus Bingham Research Center*
- ***Federal:*** *US Environmental Protection Agency (EPA), Bureau of Land Management (BLM), National Park Service (NPS), National Oceanic and Atmospheric Administration (NOAA)*

Project Description

- **Need and Purpose:**

  Measurements at a few locations in northeastern Utah's Uinta Basin during the winter of 2010/2011 found unacceptably high levels of ambient ozone (O_3). If these measurements were obtained under EPA regulatory authority, the area would have more than exceeded allowable current O_3 standards. The need for assessing the extent and possible causes of these O_3 exceedances has been recognized as a key priority. An initial study was undertaken with support largely from the Uintah Impact Mitigation Special Service District (UIMSSD). Combining efforts through MLF funding, as well as other cooperating partners, allowed more resources and personnel to be contributed to the successful completion of this first year's study.

- Benefits to the State:

  Ultimately, accurately assessing the wintertime O_3 issues in the Uinta Basin will quantify the extent of the potential problem, determine the contributing causes of the elevated pollution, and hopefully, identify the most effective remediation scenarios.

- Geographic Areas:

  Study Area: Utah's Uinta Basin (primarily Uintah and Duchesne counties).

  Areas Benefited: The population and industry of the Uinta Basin, including areas which extend into Colorado, would be the direct beneficiaries of the described study. Additionally, similar issues are currently under study by cooperating investigators in the Pinedale, Wyoming area and it is expected the lessons learned from each area will be shared across the region.

- Accomplishments:

  Findings: The overall project found significant levels of wintertime ozone throughout the Uinta Basin, with only five of the 16 monitoring locations not exceeding the current O_3 National Ambient Air Quality Standard (NAAQS) for O_3 (8-hr average >75 ppb, regulated at 4th highest). Furthermore, comparison studies in Vernal and at Redwash (closer to the developed gas/oil fields) found more chemical precursors and likely O_3 formation in the production areas. The included figure shows a map of the sample locations and an interpolated representation of number of exceedances of the NAAQS (recall that more than three exceedances would be classified as non-attainment).

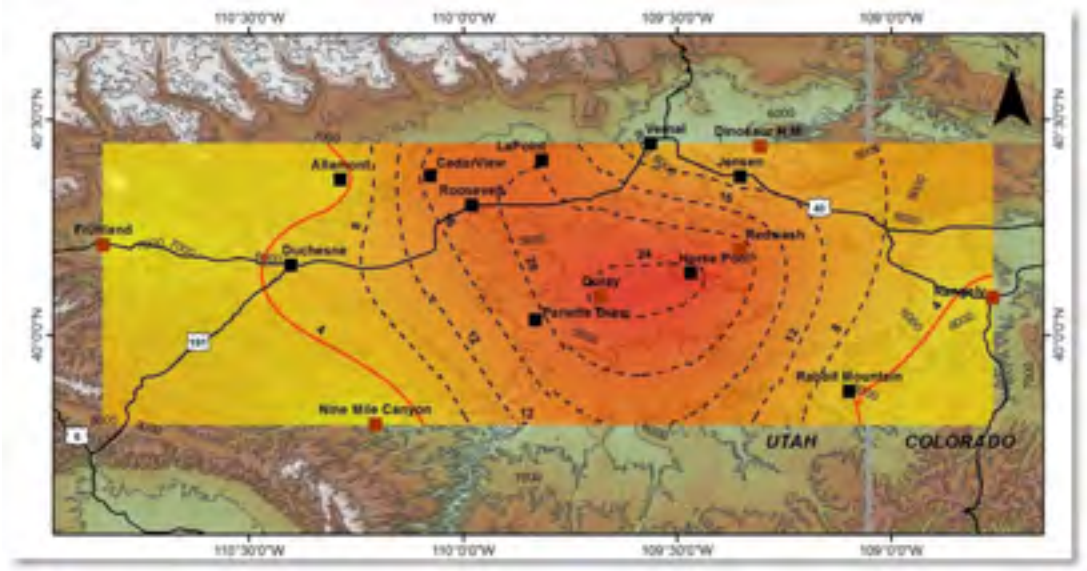


Figure 1. from Uinta Basin Winter Ozone and Air Quality Study: December 2010-2011" (EDL/11-039).

Results: The combined results from the 2010/2011 are indicative of a potentially serious violation of current O_3 standards and are leading directly to continuation and expansion of the study. One of the particularly interesting findings directly funded thought the MLF program was that ambient methane (CH4) was 3-4 times higher at the Redwash site than in Vernal (or Logan) and similarly in excess when comparable to global backgrounds. This is likely due to fugitive emissions from the well fields, and adds further weight to related immoderate emissions of even more reactive hydrocarbons.

Work Plan FY11/FY12

Work is continuing on the Uinta Basin ozone issue, including the development of plans for further 2011/2012 Basin-wide ozone and precursor characterization and intensive photochemical studies at source (Horsepool) and receptor (Roosevelt) sites with several cooperating partners and agencies. Significant external funding has been obtained through the UIMSSD and is still be sought through other sources. Cooperative support through the MLF funding will also strongly contribute to follow up studies, which are tentatively planned to continue through the next three to five years.

Informational Resources

As a part of the larger project, a project final report "Uinta Basin Winter Ozone and Air Quality Study: December 2010-2011" (EDL/11-039) was produced, and to date, two abstracts have been submitted for presentation at the December 2011 meeting of the American Geophysical Union.

Contact: Dr. Randal S. Martin, (435) 797-1858, E-mail: randy.martin@usu.edu.

Low Level Hexavalent Chromium (Cr-6) in Drinking Water

Principal Investigators:
Laurie McNeill
Joan E. McLean
Kathita Chittaladakorn (student)
Suzy Smith (student)

Partners/Collaborators:

- ***Local**: Salt Lake City Public Utilities*
  Logan City

Project Description

- Need and Purpose:

  In December 2010, the Environmental Working Group (EWG) issued a public report about hexavalent chromium (Cr-6) occurrence at very low levels in US drinking water sources. In that report, Salt Lake City, UT was targeted as a system of concern due to a detection of 0.3 parts per billion (ppb) of Cr-6, which was the 11th highest level of the 35 cities tested. SLC easily complies with the current Maximum Contaminant Level (MCL) for Total Cr, which includes both trivalent chromium-3 (Cr-3, a trace nutrient) and hexavalent chromium (Cr-6, a likely human carcinogen). Nevertheless, this report generated a lot of concern within the SLC Department of Public Utilities, other drinking water systems in Utah, and the public they serve. The US Environmental Protection Agency (USEPA) is currently reviewing toxicology data for Cr-6, and may establish a new MCL specifically for Cr-6. A new federal MCL for Cr-6 is likely to be substantially lower than the current MCL for Total Cr, which will have an enormous impact on drinking water systems across the US.

  In order for drinking water utilities to understand the chromium chemistry within their water and comply with a Cr-6 MCL, they must be able to measure Cr-6 at those low levels. A second issue is that, with these very low levels of Cr-6 being of concern, any Cr-6 that leaches from stainless steel components of pumps, pipes, wells, and other water plant infrastructure may now produce a significant level of contamination. If the new MCL for Cr-6 is set below 1 ppb (as some people have predicted), then utilities might exceed the MCL due to Cr-6 leaching into their water, even if there is no Cr-6 contamination in their source water. Any Cr-3 present can also be oxidized to Cr-6 by chemical disinfectants present in water distribution systems.

- Benefits to the State:

  If USEPA sets a MCL for Cr-6, every water system in Utah must comply. This project will provide a thorough evaluation of preservation and analysis techniques for Cr-6, and various UT treatment plants will be sampled to determine sources of chromium to drinking water and possible treatment techniques for removing Cr-6. This will help water utilities understand sources and behavior of Cr-6 and evaluate the best way to comply with regulations related to chromium.

- Geographic Areas:

  Study Area: Salt Lake City (Salt Lake County), Logan (Cache County).

  Areas Benefited: All drinking water treatment utilities in the State of Utah.

- **Accomplishments**:

  Findings/Results: The Utah Water Research Laboratory's analytical capability for measuring Cr-6 has been successfully updated so that very low levels (<0.1 ppb) of Cr-6 can now be measured. A series of experiments has been initiated to evaluate preservation techniques for Cr-6 in a range of water qualities. The PIs have been invited to participate in USEPA's evaluation of an updated method for low-level Cr-6 analysis.

  Preliminary results from this MLF project were used to leverage a new $180,000 research grant from the Water Research Foundation to further investigate Cr-6 in drinking water.

Work Plan FY 11/FY12

1. Continue laboratory experiments related to preservation and analysis of Cr-6.
2. Conduct second lab verification of USEPA's new Cr-6 analytical method.
3. Collect samples from various water treatment plants across UT to look at sources and treatment of Cr-6.

Informational Resources

Contact: Dr. Laurie McNeill, (435) 797-1522, Email: Laurie.McNeill@usu.edu.
Ms. Joan E. McLean, (435) 797-3663, Email: Joan.McLean@usu.edu.

Monitoring Organic Contaminants in Air Using Plants as Passive Samplers

Principal Investigators:
William J. Doucette
Julie Chard
Todd Wetzl

Partners/Collaborators:
- ***Local:*** *Kyle Gorder, Hill AFB, UT*
  Erik Dettenmaier, Hill AFB, UT

Project Description

- Need and Purpose:

  Concerns about elevated concentrations of volatile organic compounds (VOCs) in indoor air have increased as energy conservation methods have reduced the introduction of outdoor air. Volatile organic compounds, including some that have documented adverse health effects, are emitted by a wide array of consumer products and building materials including: paints, lacquers, fuels, paint strippers, cleaning supplies, pesticides, copiers/printers, correction fluids, glues, adhesives, permanent markers, and photographic solutions. All of these products can release VOCs during use and storage. Indoor air concentrations of VOCs vary widely, depending on the materials used in construction and the specific consumer products contained within the building, but concentrations are generally five to ten times higher indoors than outdoors. The use of ornamental plants has been suggested as a simple, unobtrusive, cost effective method for sampling and purifying indoor air. The waxy surface of the leaves is thought to provide a good surface for the passive capture (sorption) of VOCs. However, the efficiency of capture (sorption) and potential release (desorption) has not been well characterized.

- Benefits to the State:

  Results from this study will contribute to our basic understanding of indoor air quality and the potential to use ornamental plants to monitor and improve indoor air quality. This project will have a direct and positive impact on citizens throughout the state of Utah because of the high percentage of time spent in indoor environments, especially by children and the elderly. An improved understanding of the fate of VOCs in indoor air by regulatory agencies such as the Utah DEQ will also enable the more efficient expenditure of public dollars based on risk management prioritization that will be made possible by this information.

- Geographic Areas:

  Study Area: State of Utah.

  Areas Benefited: Indoor air quality is a statewide issue, so all counties in the state would potentially benefit.

- Accomplishments:

  Findings/Results: Representative VOCs commonly found in indoor environments (e.g. trichloroethylene, tetrachloroethylene, benzene) are introduced into a flow through chamber system (see photos below) with and without plants at known, environmentally relevant concentrations. Environmental conditions within the chamber are controlled to maintain adequate plant health while mimicking those commonly found in residential dwellings. Variables being evaluated include plant species, plant growth medium (soil, soil with activated

carbon, soilless plant growth media), chemical concentration and type, and individual chemicals versus chemical mixtures. Chemical removals are measured by comparing the measured concentration of chemical introduced into the chamber to that exiting the chamber as shown in the figure below for trichloroethylene. The ability of plants to act as passive samplers and purifiers is being evaluated and compared to more conventional methods.

Work Plan FY11/FY12

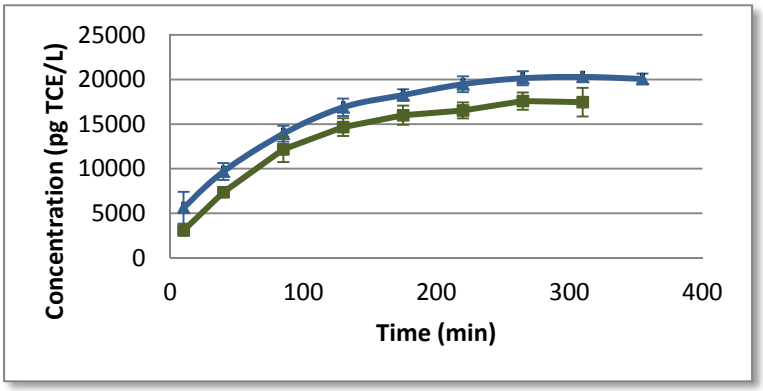
Additional chemicals and plants will continue to be evaluated.

Informational Resources

Contact: Dr. William J. Doucette, Phone (435) 797-3178, E-mail: william.doucette@usu.edu.

Flow through chamber system

Plant being introduced into chamber system



Concentration of TCE in air exiting chamber with (green) and without (blue) plant

Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen
Subathra Muruganandam

Partners/Collaborators:

- ***Local:*** *Issa Hamud, Logan City Environmental Department*
- ***Federal:*** *Kyle Gorder and Mark Roginske, Environmental Management Directorate, Hill AFB*

Project Description

- Need and Purpose:

  The use of molecular biology tools in environmental engineering has been growing in importance over the past decade. Qualitative tools for determining the presence or absence of particular microorganisms or functional genes have been the predominant means of investigating contaminated sites and evaluating the performance of bioremediation systems. RT-PCR now provides a means for quantitatively describing microbial communities and function, and has become a standard technique for engineering application of molecular biology concepts to bioremediation.

  The objective of this project is to facilitate development of routine quantitative molecular biology capabilities within the Utah Water Research Laboratory's Environmental Quality Lab (EQL) to support the development of advanced molecular biology research.

  RT-PCR instrumentation provides the EQL with quantitative molecular biology capabilities to generate information regarding the numbers of organisms and functional gene copies in a wide range of environmental soil and groundwater samples. This instrumentation is being utilized by a number of researchers to carry out quantitative analyses of DNA from field and laboratory generated soil, groundwater, plant, and reservoir samples; These RT-PCR tools are being used in conjunction with other microbial community analysis techniques, primarily ARISA analysis, and pyrosequencing to aid in exploring the make-up of impacted microbial communities and understanding interactions in natural and engineered contaminant environments.

- Benefits to the State:

  RT-PCR instrumentation provides quantitative capabilities for the low-level detection of specific microorganisms and functional genes in environmental samples. This technology relates to a number of projects that directly benefit the State of Utah as demonstrated in applications of RT-PCR techniques to:

  1. Provide quantitative analysis of specific organism numbers, gene copies, and/or gene expression using messenger RNA probes so that environmental responses to engineered perturbations (carbon donor addition, electron acceptor addition) can be quantitatively analyzed for improved contaminated site management throughout Utah.
  2. Provide quantitative analysis of microbial community composition in Utah reservoirs to investigate microbial sources of taste and odor and eutrophication problems.
  3. Evaluate differences in microbial communities within impacted trees at Hill AFB, an innovative application of molecular biology tools to phytoremediation sites in order to investigate the role microbial communities internal to trees (endophytes) play on the overall fate of TCE at contaminated sites.

4. Evaluate the presence and abundance of arsenic reducing bacteria in soil and groundwater surrounding the Logan City Landfill to isolate the landfill's influence on groundwater quality impairment.
5. Examine soil microbial community characteristics in soil collected from restoration plots typical of Eastern Utah and Western Colorado rangelands. Soil bacterial, fungal and arbuscular mycorrhizal fungal (AMF) communities were quantified in response to contrasting soil history and plant species dominance.

- Geographic Areas:

  Study Area: Various counties throughout Utah where soil, groundwater, reservoir, and plant samples have been collected for analysis, including Cache, Davis, Morgan, Salt Lake, Tooele, and Weber Counties.

  Areas Benefited: All counties in the state would potentially benefit from capabilities for microbial community analysis using these molecular tools on samples from natural, contaminated, or engineered sites.

- Accomplishments:

  Findings: At least five separate studies are currently underway utilizing this equipment as a significant part of the analyses to support system performance evaluation or remedial design. These quantitative molecular tools have been useful in tracking the progress of remediation and the growth and maintenance of remediation cultures applied at a chlorinated solvent site at Hill AFB; evaluating the molecular composition and diversity of groundwater plumes adjacent to Hill AFB; identifying the sources of algal blooms and surface water impacts in Pineview Reservoir; evaluating the presence and abundance of arsenic reducing species in soil and groundwater adjacent to the Logan City Landfill; assessing the composition and diversity of bacterial, archeal, and fungal communities associated with poplar plants in a phytoremediation study at Hill AFB; evaluating interactions among plants and soil bacterial, fungal, and AMF communities in western rangeland soils subjected to various reclamation techniques; and evaluating the presence, abundance, and expression of functional genes associated with TCE transformation in large-scale flow through column studies related to OU5 at Hill AFB.

  Results: Specific results generated from the use of this equipment are highlighted in the project summaries for these individual projects.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797-3227, E-mail: ryan.dupont@usu.edu.

Website: http://public.me.com/rdupo/UWRL Report Files/MicrobialDiversity_Study_Report_Files.

Remediation of Chlorinated Solvent Contamination of Groundwater

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Kathita Chittaladakorn (student)
Lindsay Stevens (student)
Suzy Smith (student)

Partners/Collaborators:
- ***Federal:*** *Kyle Gorder, Hill AFB, UT*
  Mark Roginske, Hill AFB, UT

Project Description

- Need and Purpose:

  All counties in Utah have groundwaters contaminated with TCE or PCE due to various industrial and dry cleaning operations. TCE and other chlorinated solvents are also common groundwater contaminants at military bases. An improved understanding of the biogeochemistry that influences the dechlorination of solvents will aid in the development of methods for evaluating sites and in the selection of bioremediation options for the successful reclamation of contaminated groundwaters.

  Biostimulation has been used at various contaminated sites to promote the reductive dechlorination of TCE, but the addition of a carbon donor also stimulates bacteria that use iron (III) as the terminal electron acceptor (TEA) in potential competition with dechlorination processes. Previous microcosm studies using TCE contaminated aquifer solids from Hill Air Force Base indicate that selection of a carbon donor for biostimulation in the remediation of chlorinated solvent impacted aquifers may greatly influence the extent of the reductive dissolution of iron minerals in direct competition with dechlorination processes.

- Benefits to the State:

  All counties in Utah would benefit from improved understanding and thus development of remediation strategies for dechlorination of TCE and other chlorinated solvents that are contaminating groundwater resources.

- Geographic Areas:

  Study Area: Hill Air Force Base, Davis and Weber Counties

  Areas Benefited: In addition to the specific areas above, this project will contribute to groundwater protection throughout the state.

- Accomplishments:

  Findings: Complete dechlorination of TCE to innocuous breakdown products will occur if the optimal biogeochemical conditions are promoted with the addition of a carbon source.

  Results: Columns packed with aquifer solids from HAFB were leached with TCE containing groundwater and one of three carbon sources for over seven-years. These columns were sampled in summer 2010 (Figure 1) by collecting three cores from each 6-inch layer within the column. Samples were analyzed for TCE and breakdown products, various geochemical parameters, and DNA and RNA. Complete dechlorination was observed only in columns treated with whey. The

addition of the two oil based carbon sources led to partial dechlorination. The microbial activity that led to dechlorination in all columns was limited to the top foot of the column. Conditions necessary for full dechlorination were depletion of Fe(III) minerals and sulfate reduction, both conditions indicative of highly reducing environments, and the presence of active dechlorinating bacteria, as determined through RNA analysis. Conditions conducive to dechlorination, however, were also favorable for arsenic solubilization. Elevated concentrations of arsenic were found in the pore water of all carbon treated columns and the arsenic had been transported throughout the column (Figure 3).

Work Plan FY11/FY12

Identify the microbial community structure, along with the biogeochemical conditions that support the optimal community structure, necessary for the complete dechlorination of TCE in groundwater systems.

Informational Resources

Contact: Ms. Joan McLean, (435) 797-3199, E-mail: joan.mclean@usu.edu.

Figure 1. Processing the six-foot columns packed with aquifer solids for Hill AFB. Groundwater with TCE plus various carbon sources has been passed through the columns for over six years. The columns are now being sampled to investigate the biogeochemical processes that are favorable to TCE degradation

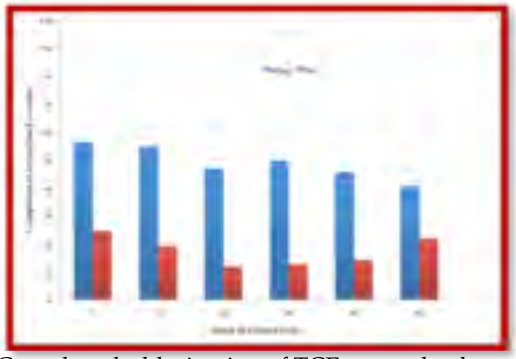


Figure 2. Complete dechlorination of TCE was only observed with the whey treatment where bioavailable Fe has been depleted. Iron minerals are, however, the storehouses for arsenic; microbial dissolution of Fe mineral increase solution phase arsenic

.

Figure 3. Arsenic concentration increases in the pore water down the column profile with the addition of carbon. The intent of biostimulation is the dechlorination of TCE into nontoxic by-products, but the reducing conditions imposed caused the solubilization and transport of arsenic

Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen

Partners/Collaborators:

- ***Federal:*** *Kyle Gorder, Environmental Management Directorate, Hill AFB*

Project Description

- Need and Purpose:

  Attempts to stimulate the bioremediation of TCE contaminated groundwater at Hill AFB, Operable Unit 5 (OU5) using relatively simple and inexpensive biostimulation technology were unsuccessful due to low population levels of native dechlorinating microorganisms and the apparent competition for added carbon by non-dechlorinating, iron-reducing bacteria found there in high concentrations. Laboratory scale studies indicated the need for bioaugmentation, along with a source of carbon, for successful reductive dechlorination of TCE in the OU5 aquifer.

  This project evaluates the limitations of biostimulation versus bioaugmentation under simulated field conditions from the laboratory microcosm scale to large-scale flow through column scale. It also develops molecular biology monitoring techniques to identify principal microbial community members in the dechlorinating inocula, and refines these methods to quantify the viability and mobility of organisms in the simulated field environment.

- Benefits to the State:

  This project benefits Utah in a number of ways including the following: (1) improving the reliability of source area treatment at OU5 so that TCE exposure and risk to adjacent property owners can be reduced over time in a cost-effective manner, (2) verifying molecular biology tools to provide Hill AFB and the Utah Department of Environmental Quality (DEQ) with cost-effective techniques to monitor the movement and viability of added microbes to ensure adequate control during site remediation, (3) collecting treatment and design data for the control and production of degradation products at OU2 so that complete site remediation can be ensured, and (4) providing cost-effective recovery of impacted water resources at two specific Hill sites and many more sites across the state with similar contamination.

- Geographic Areas:

  Study Area: Hill AFB in Weber County

  Areas Benefited: All locations in the state with TCE impacted groundwater sources would potentially benefit from the findings of this project as they improve the predictability and reliability of bioaugmentation for contaminated site remediation.

- Accomplishments:

  Findings: The spatial distribution of substrate and the microbial community have a significant impact on TCE transformation in OU5 soil. Unlike the small microcosm studies, partial dechlorination of TCE is observed in the flow-through columns with carbon donor addition without bioaugmentation. The column study confirmed whey as the optimal carbon source in terms of both the rate and extent of TCE transformation. In addition, whey produced the greatest

diversity of microbial metabolic pathways of all donors evaluated, supporting and maintaining a microbial community with full functional gene capability for reductive dechlorination of TCE over the cumulative 2,700 days of the study.

Results: Bioaugmentation was found to accelerate TCE Transformation as follows: (1) No change was found in the extent of transformation, but the rate of transformation increased with the addition of the BR Culture. (2) Bioaugmentation decreased the time to the onset of TCE transformation by 7 to 16 months. (3) Long-Term Transformation of TCE was supported using single dose Emulsified Oil treatments equivalent to 1,000 mg C/L. The initial Emulsified Oil dose (Day 490) supported reductive dechlorination for approximately 300 days, while a second dose (Day 1242) supported reductive dechlorination for more than 900 days.

Microbial community analysis indicated: (1) A high diversity of organisms exists even in the background soil. (2) The carbon source is the determining factor in the microbial community that develops over time. (3) The community extracted from the mobile groundwater is more indicative of TCE transformation potential than community composition determined from the soil phase. (4) All carbon sources support reductive dechlorination in the presence of high sulfate conditions. (5) Even after nearly 8 years of groundwater flow through the columns, complete TCE transformation and virtually all reductive dechlorination microbial activity was confined to the upper 7.5 cm of the columns, suggesting extremely high and extremely localized TCE transformation rates in bioaugmentation settings.

Work Plan FY11/FY12

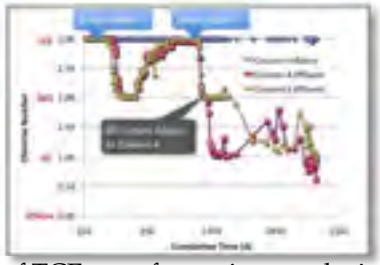
Incremental sampling of soil within the columns began in FY11 for molecular biology. Soil and water quality analyses will continue to assess the persistence, growth, and continued distribution of the dechlorinating inocula and the significance of sulfur metabolism throughout the pilot scale columns. Analysis and reporting of these data will occur throughout FY12.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.
Website: http://public.me.com/rdupo/UWRL Report Files/HillAFB_Study_Report_Files.

Flow through columns


Soil core sample collection from columns


Example of TCE transformation results in the form of chlorine number from emulsified oil columns

Risk Characterization Using Modified 3MRA at Biosolids Land Application Sites

Principal Investigators:
Michael J. McFarland

Partners/Collaborators:
- ***State:*** *Mark Schmitz, Utah Division of Water Quality*
- ***Local:*** *Karthik Kumarasamy, Utah State University*

Project Description

- **Need and Purpose:**

  Compliance with water quality standards and the increases in biosolids production has pushed the industry towards looking at a more sustainable solution such as biosolids land application. However, concerns about the presence of biosolids micro-constituents are requiring a revisit of risk the assessment to understand the impacts of land application.

- Benefits to the State:

  Biosolids land application practice is not only a sound economic solution, but it is an approach that takes advantage of the nutrients present in the material. This risk assessment can aid in the better management of this fertilizer resource and in strengthening the beneficial use practice.

- Geographic Areas:

  Study Area: Although the study areas are located in WA and UT, two counties in UT were considered for this study. The biosolids land application sites of Ensign Ranch site in Skull valley and Central Davis Sewer District farm sites were included in the risk assessment. A detailed study was performed at the Yakima County site in WA. Figure 1 shows the conceptual layout of the site in Yakima County, WA.

Figure 1. Conceptual layout of site

Areas Benefited: Two areas that directly benefited from this effort include disturbed and/or marginal agricultural land located in Tooele county where significant amounts of biosolids are being recycled. The other area was the farm land located around Central Davis Sewer District. Since extensive contaminant monitoring data is available at only few locations in the nation, and access to data was provided for the WA site, the WA site is being used to test the model. Once the validation is satisfactory, the results and the modeling platform will be used to test the two study sites being considered here in UT.

- **Accomplishments:**

A method has been developed to increase understanding of biosolids land application practice using computer based modeling. In order to fully characterize a site using the original modeling platform, over 900 variables are required. This study developed an approach to characterize the site using less than 50 variables to estimate a screening level risk assessment. This technique has the potential to allow screening level site specific characterization of risk.

Findings: The original modeling platform did not allow for easy characterization of a site. The Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) platform is based on extensively validated models; however, its use in biosolids management has been absent due to the software's limitation in adapting to other applications and the poor user interface. This study demonstrated this software's use for simulation biosolids land application practice.

Results: Preliminary findings indicate federal regulations are fully protective of biosolids land application practice. It has to be noted that certain sites have the potential for higher application rates.

Work Plan FY11/FY12

Complete the validation of the model for the Yakima site, and use the validated model to assess the impact of biosolids land application on sites in Utah.

Informational Resources

Contact: Dr. Michael J. McFarland (435) 797-3196, E-mail: farlandm@msn.com.

Study of Cache Valley's Vertical Ozone Profiles and Application to the Uintah Basin

Principal Investigators:
Randal S. Martin
Crystal (Viator) Wood (student)

Partners/Collaborators:
- ***Local:*** *Bear River Health Department*
- ***State:*** *Utah Division of Air Quality (UDAQ) & Air Monitoring Center (AMC), USURF's Energy Dynamic Laboratory*

Project Description

- **Need and Purpose:**

  In December of 2009, the Cache Valley, as well as most of Utah's Wasatch Front, was declared non-attainment for $PM_{2.5}$ (particulate matter less than 2½ µm in diameter) by the U.S. EPA. Past research determined that these wintertime pollutants are dominated by secondary (not directly emitted) compounds, primarily ammonium nitrate (NH_4NO_3). Further research has shown that the photochemical reactions necessary to form NH_4NO_3 are limited by the nitrate side of the compound, that is, the reactions to form atmospheric nitric acid (HNO_3) from precursor oxides of nitrogen emissions. Available ozone (O_3) drives the conversion of nitric oxide (NO) emitted from vehicles and other combustion sources to nitrogen dioxide (NO_2). Subsequently, O_3 is also involved in the formation of hydroxyl radicals (•OH), which convert the NO_2 to HNO_3. Previously, we preformed limited initial airplane studies on the vertical O_3 profile and found a strong positive O_3 gradient with elevated values extending through the inversion layer, suggesting that at least some of the O_3 may be regionally, rather than locally derived. However, these were only performed over two small plane flights (afternoon and morning). The goal of this project is to develop and test a light vertical O_3 system and examine the vertical ozone structure in the wintertime air in the Cache Valley. Additionally, the unexpected phenomenon of unacceptably high levels of wintertime O_3 has been recently observed in Utah's Uinta Basin and the need to understand both temporal and spatial O_3 formation, transport, and transformation behaviors provides a secondary opportunity to apply techniques developed under this project.

- Benefits to the State:

  Research into effective methodologies for understanding the vertical behavior of locally generated and regionally transported O_3 will be of key importance when developing remediation strategies for either secondary $PM_{2.5}$ (e.g. ammonium nitrate) or O_3 itself.

- Geographic Areas:

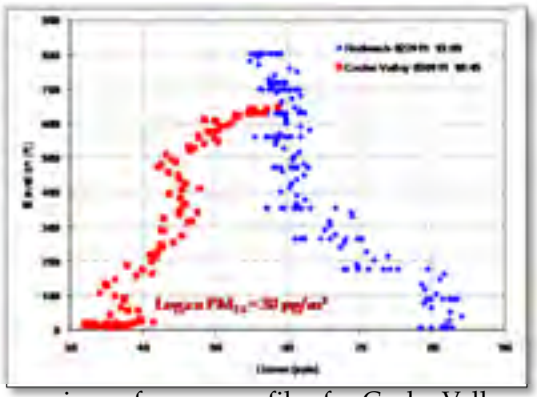
  Study Area: Cache Valley, UT (including the entire cross-border airshed) and Uinta Basin (Uintah and Duchesne counties) - system specifically tested at Red Wash (109 21′ 9.00″ W, 40 11′ 49.79″ N) in Uintah County.

  Areas Benefited: The Cache Valley airshed would receive the most pressing and immediate benefit owing to the current Federal $PM_{2.5}$ non-attainment status, but findings and future work could logically be extended to the Wasatch Front and other non-attainment areas. The preliminary results from the Uinta Basin examination have demonstrated the likelihood of local, ground level wintertime O_3 formation and should be instrumental in understanding the area's unique air quality issues and in the eventual development locally appropriate remediation approaches.

- **Accomplishments:**

Findings: A finalized, prototype strip-down version of a portable 2B Technologies Model 202 Ozone monitor was assembled, tested, and characterized in the laboratory under conditions expected for ambient wintertime conditions. The system was used on several days to examine the vertical O_3 profile in south central Cache Valley. Additionally, the system was incorporated into a separate project in Utah's Uinta Basin. The figure below shows the system attached to a tethered balloon as well a comparison of the sample O_3 profiles for the two sites. As can be seen, the Cache Valley site show higher concentrations at elevation, suggesting the possibility of regional transportation, while the Uinta Basin location, with higher ground level values suggests local O_3 sources/formation.

Portable ozone monitor attached to a tethered balloon



Comparison of ozone profiles for Cache Valley and Uintah Basin locations

Results: The commercially-purchased O_3 monitor was successfully adapted for deployment with the tethered balloon system and was successfully able to capture the vertical structure of O_3 with the boundary (inversion) layers in both the Cache Valley and at a single test site in the Uinta Basin.

Work Plan FY11/FY12

Work on developing protocols for economically and accurately measuring vertical ozone profiles will continue into FY11-FY12. Additional vertical O_3 profiling of the Cache Valley airshed will continue to more fully characterize the area under varying meteorological conditions. We also continue to pursue other funding opportunities to aid in the evolution of the system to a UAV-based instrument (e.g. UWRL's AggieAir^{TM}). It is further anticipated that either the tethered balloon system or the desired UAV system would also be deployed to 2011/2012 Uinta Basin wintertime O_3 studies.

Informational Resources

Contact: Dr. Randal S. Martin, (435) 797-1858, E-mail: randy.martin@usu.edu.

Uptake of Organic Contaminants from Groundwater and Transfer into Edible Plants: Species Differences

Principal Investigators:
William J. Doucette
Julie Chard
Naho Orita (student)

Partners/Collaborators:
- ***Local**: Kyle Gorder, Hill AFB, Utah*
  Erik Dettenmaier, Hill AFB, UT

Project Description

- Need and Purpose:

  Chlorinated solvents, fuel related compounds, explosives, pharmaceuticals and personal care products (PPCPs), and other organic chemicals have contaminated surface and groundwater at many locations in the State of Utah, including many communities surrounding Hill Air Force Base. Quantitative information regarding the uptake of organic contaminates by plants is needed for risk assessment, groundwater plume delineation, and phytoremediation applications. Unfortunately, relatively little experimental data is available due to the difficulty and expense involved with the generation of such data. Recently, Dettenmaier et al. (2009) reported a pressure chamber approach that can be used to rapidly and reproducibly determine the uptake potential of organic chemicals. Experimental data generated for soybean and tomato plants indicated that nonionizable highly water-soluble organic compounds are most likely to be taken up by plant roots and translocated to shoot tissue. While significant differences between soybean and tomato uptake were not observed, some literature suggest that species differences can have a significant influence on the uptake and transport of organic pollutants, especially for the plant family Curcurbitaceae. For example, studies have reported a nearly 10-fold difference between zucchini and cucumber. Determining the potential significance of species on the uptake of organic chemicals is critical, especially in risk assessment. However, because standard methods for quantifying the plant uptake of organic chemicals are not available, direct comparison of results from different studies is difficult and the reported differences may be associated more with experimental protocol than actual species differences. This study uses a pressure chamber technique to examine the uptake of organic contaminates in the Curcurbitaceae family and seeks to determine whether the reported species variability is real or an artifact of the experimental methods used.

- Benefits to the State:

  The potential uptake and transfer of organic chemicals into fruits and vegetables is a critical concern for residents living near Hill Air Force Base and other areas where groundwater is contaminated by organic chemicals. Results obtained from this study will benefit the State of Utah by providing baseline information that can be used in screening-level risk assessments.

- Geographic Areas: State of Utah.

  Study Area: Residential areas located around Hill AFB, UT and other areas where contaminated groundwater exists.

  Areas Benefited: Residential areas located around Hill AFB, UT and other residential areas within State of Utah located above shallow groundwater contaminated with organic chemicals.

- **Accomplishments**:

  Findings/Results: Plant uptake data generated to date for eight compounds, expressed as transpiration stream concentration factors (ratio of xylem to root zone solution concentrations), is provided in Table 1 below.

Table 1. Summary of plant uptake data expressed as TSCF

	Soybean			Zucchini		
Compound	**Number of Plants**	**Avg. TSCF**	**St. Dev (±)**	**Number of Plants**	**Avg. TSCF**	**St. Dev. (±)**
Tritiated water (^3H_2O)	6	1.02	0.12	3	1.00	0.06
Caffeine	3	0.57	0.06	3	0.60	0.06
Pyrene	2	0.14	0.035	0	-	
Triclorocarban (TCC)	1	0.03	N/A	0	-	
Fluoxetine	0	-		1	0.70	N/A
Carbamazepine	0	-		1	0.77	N/A
Tris (2chlorethyl) phosphate	0	-		1	0.87	N/A
Progesterone	0	-		1	0.0077	N/A
Sulfamethoxazole	0	--		1	0.0082	N/A

Work Plan FY11/FY12

Additional plant uptake experiments will be performed to complete Table 1.

Informational Resources

Contact: Dr. William J. Doucette, Phone (435) 797 3178, E-mail: william.doucette@usu.edu.

Pressure chamber system

Zucchini plant used in pressure chamber

Volatile Organic Compounds in Indoor Air: Source Identification, Emission Flux Determinations, and Model Development

Principal Investigators:
William J. Doucette
Dave Firmage (student)

Partners/Collaborators:
- ***Local:*** *Kyle Gorder, Hill AFB, UT*
  Erik Dettenmaier, Hill AFB, UT

Project Description

- Need and Purpose:

  Many consumer products contain volatile organic compounds (VOCs) that are also the focus of CERCLA (Superfund) soil and groundwater cleanups in the USA. The emissions of these VOCs from consumer products into indoor environments can lead to false assumptions during vapor intrusion (VI) investigations. The focus of this study was to determine the relationship between the emission rates of chlorinated volatile organic compounds (cVOCs) from common household products and their concentrations in indoor air.

- Benefits to the State:

  Distinguishing between external and internal sources of chlorinated solvents is critical in determining the most appropriate, cost effective remedial approach for residences located over shallow contaminated groundwater. The goal is to demonstrate that the laboratory measured emission rates of chlorinated solvents from consumer products can be used to predict indoor air concentrations and thus help to distinguish between internal and external sources of chlorinated solvents in residential homes.

- Geographic Areas:

  Study Area: Residential areas located around Hill AFB, UT.

  Areas Benefited: Residential areas located around Hill AFB, UT and other residential areas within State of Utah located above shallow groundwater contaminated with chlorinated solvents.

- Accomplishments:

  Findings: Emissions rates of volatile chlorinated solvents from an adhesive (PCE), a cleaning solvent (PCE and TCE), and a commercial permeation tube of known emission rate (1,2-DCA) were measured in the laboratory using a flow through chamber approach. Screening-level calculations indicated that the measured emission rates of these items could lead to indoor concentrations high enough to be of regulatory concern. A follow up indoor air monitoring study was performed to test the screening-level calculations. The three objects were placed in a single room on the second floor of a two-story residence with finished basement. Indoor air concentrations were measured using sorbent tubes/thermal desorption GC/MS and an onsite GC/MS over a three-day period, which was followed by an additional two-day period after source removal. After 24 hours, measured concentrations of PCE and TCE were as high as 100 ppvb within the source room on the second floor and 10 ppbv in rooms on the first floor. After

36 hours, PCE and TCE were also found within the basement at concentrations between 1 and 2 ppbv.

Work Plan FY11/FY12

Comparisons between measured and estimated indoor air concentrations will be evaluated relative to risk assessments and typical VI screening levels.

Informational Resources

Contact: Dr. William J. Doucette, Phone (435) 797-3178, E-mail: william.doucette@usu.edu.

Air monitoring in home

Consumer products in house

Emission chamber sampling of consumer product

Surface and Groundwater Quality and Quantity

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Surface and Groundwater Quality and Quantity

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
A Methodology for Improved Groundwater Recharge Estimation in Semi-Arid Regions	$22,443.53	$23,116.84	$23,810.34
A Three-Dimensional Hydrodynamic and Thermal Model of Cutler Reservoir	$2,339.51	$0.00	$0.00
Development of Technology for Streambed Thermal Property Instrument (SPI)	$24,020.32	$0.00	$0.00
Incorporation of Heat into Solute Models	$43,818.40	$45,132.95	$46,486.94
Investigating Stream Dissolved Organic Matter Dynamics in the Little Bear River Using Continuous Monitoring Data	$13,160.77	$13,555.59	$13,962.26
Investigating Turbidity and Sediment Transport Dynamics in the Little Bear River Using Continuous Monitoring Data	$16,338.19	$16,828.34	$17,333.19
Lab-on-a-Chip Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$93,631.54	$96,440.49	$99,333.70
Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support	$15,472.37	$15,936.54	$0.00
Optimizing Wet Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies	$111,598.46	$114,946.41	$0.00
Quantification and Management of Salt Production in the Desert Lake Watershed	$64,000.87	$25,000.00	$0.00
Release of Arsenic from Aquifer Solids Under Anaerobic Conditions	$96,452.91	$99,346.50	$102,326.89
Technical Support for Bear River System Data Acquisition	$51,094.02	$52,626.84	$0.00
Uptake and Release of PCPPs (Personal Care Products and Pharmaceuticals) and Other Organic Contaminants from Sediments, Soils, and Biosolids	$46,452.75	$47,846.33	$49,281.72
Water Allocation and Salinity Issues of the Sevier River Basin	$9,153.84	$9,428.46	$0.00
Weber Basin Decision Support System (DSS) Modernization	$15,472.37	$15,936.54	$0.00
Designated Projects		$450,141.70	$23,155.00
Undesignated Projects		$141,010.00	$0.00
Total	**$625,449.85**	**$1,167,293.53**	**$375,690.04**

A Methodology for Improved Groundwater Recharge Estimation in Semi-Arid Regions

Principal Investigators:
Jagath J. Kaluarachchi
Fathi Anayah (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  In agriculture dominated semi-arid river basins, more than 70% of the water use is for agriculture. In estimating water balance across a given river basin, accurate estimates of evapotranspiration (ET) are needed, given the large amount of land cover consisting of agricultural crops. Classical methods of estimating ET use significant amounts of data related to land use and land cover combined with hydrometeorological data. Given the time and cost of gathering such detailed data, estimation of water use and demand in river basins can lead to significant uncertainty. This project is to develop an improved approach, The Complementary Relationship Methodology, to estimate ET independent of land cover and land use that uses simple meteorological data such as temperature, wind speed, relative humidity, and dew point. The key advantages of the method are the simplicity of the data, the ability to gather metrological data relatively easily, and the ability to predict ET during both growing and non-growing seasons under all types of land cover. It can also combine with climate prediction models with the use of only meteorological data to predict regional ET as opposed to point estimates.

- Benefits to the State:

  Given the dominance of agriculture in Utah, especially in rural communities, accurate estimation of ET is important in water resources planning and management. The Complementary Relationship methodology proposed here is capable of making accurate estimates of ET with minimal data. This allows the planner to allocate existing water effectively and to estimate potential future water demands under climate change.

- Geographic Areas:

  Study Area: Applicable areas across Utah where meteorological data are gathered. At the present time, we are using data available from elsewhere, but the application will be conducted for Utah's Cache Valley in the next year.

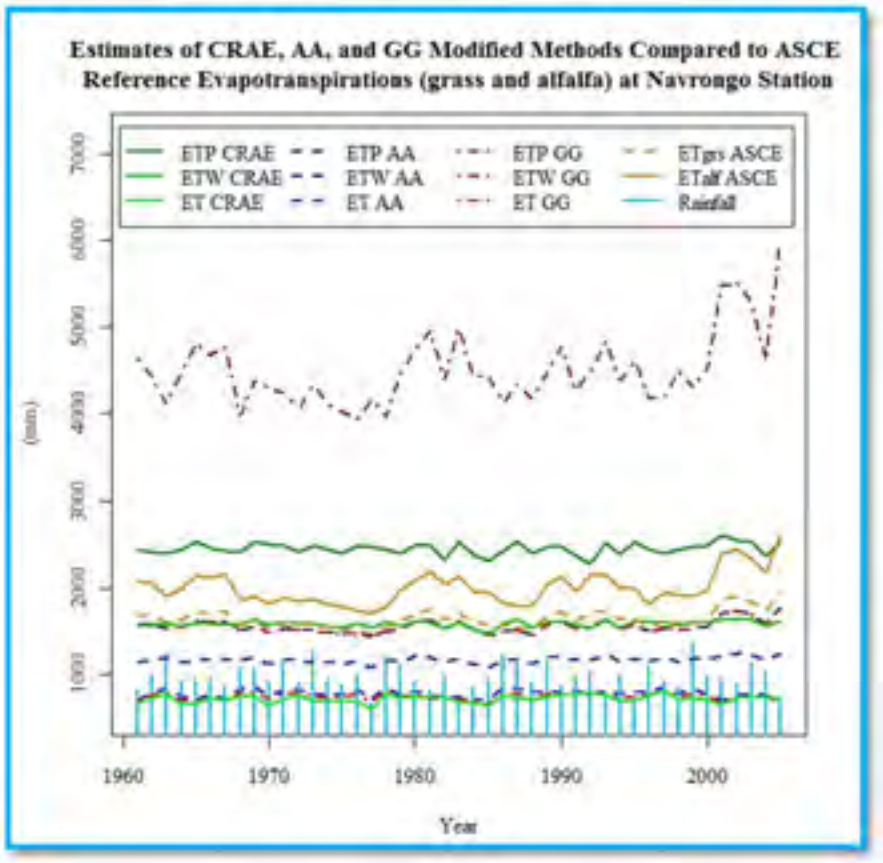
  Areas Benefited: Areas with limited water supply that have agricultural activities sustaining rural economies.

- Accomplishments:

  Findings: A complete survey of available complementary methods was conducted. Since prior studies on this topic have used mostly 1 to 2 sites with similar climatic conditions, this study used 34 geographic locations across the globe with contrastingly different climatic conditions. These sites contained measured ET data. Using the observed data, the applicability of three different complementary methods was evaluated, and based on the results, one modified form of the complementary method was proposed. The advantage of this approach was that a single method

was developed to accommodate a wide variety of climatic conditions while still using limited meteorological data to estimate ET at the regional scale.

Results: The results showed that the Complementary Method is as accurate as the classical methods consisting of the Penmen-Monteith or the Thornthwaite methods.



NOTE:
ET: actual evapotraspiration,
ETW: wet-environment evapotranspiration,
ETP: potential evapotranspiration,
ETgrs: grass-referenced evapotranspiration,
ETalf: alfalfa-referenced evapotranspiration,
CRAE: Complementary relationship areal evapotranspiration method (Morton, 1983),
AA: Aridity-Advection method (Brutsaert and Stricker, 1979),
GG: Granger and Gray method (Granger and Gray, 1989),
ASCE: the ASCE standardized reference evapotranspiration equation.

Work Plan FY11/FY12

We will now extend the work to estimate recharge using the classical water balance methods. Since ET is the major contributor in the water balance calculations for semi-arid regions, recharge can now be estimated reliably knowing ET estimates from the proposed complementary method.

Informational Resources

Contact: Dr. Jagath J. Kaluarachchi, (435) 797-3918, E-Mail: jagath.kaluarachchi@usu.edu.

A Three-Dimensional Hydrodynamic and Thermal Model of Cutler Reservoir

Principal Investigators:
Robert Spall

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Cutler Reservoir, located approximately six miles west of Logan, UT, is impacted by excessive nutrient loading that may result in the reservoir being classified as impaired. The excessive nutrient loading contributes to a dense growth of algae and other organisms that subsequently decay and deplete the shallow waters of available oxygen. The low levels of dissolved oxygen are of particular concern for the fish population in the reservoir. Although the reservoir is not impaired for temperature, levels above the maximum allowable 27 degrees C have been observed with some regularity during the summer months. To address these issues, a robust three-dimensional modeling procedure applicable to the reservoir is needed.

- Benefits to the State:

  The results of this project will determine the viability of three-dimensional thermal, hydraulic, and biogeochemical modeling of Cutler Reservoir. If proven successful, the model will serve as a valuable tool in the future management and restoration of Cutler reservoir and other similar reservoirs within the State.

- Geographic Areas:

  Study Area: Cache County.

  Areas Benefited: Cache County and other areas containing impacted reservoirs.

- Accomplishments:

  Findings: A numerical model has been constructed using the hydrodynamics code ELCOM to compute velocity and temperature distributions within a section of Cutler Reservoir (see Fig. 1). The relevant bathymetry north of Benson marina, which was used to define the reservoir topology, is plotted in Fig. 2. Experimental temperature distributions, shown in Fig. 3, were obtained to provide inlet boundary conditions and to validate the model.

  Results: Measured water temperatures at several locations within the reservoir through mid-September of 2010 are shown in Fig. 3. The results indicate a very uniform spatial temperature distribution, with temperatures exceeding 27 degrees C during the months of July and August. Computed temperature distributions over the reservoir at a depth of 1 meter are plotted in Fig. 4 for the Julian date 2010131 (May 10). A comparison with experimental data (Fig. 3) indicates good agreement with temperatures on the order of 13-14 degrees C. The conclusion of this research is that the three-dimensional numerical modeling represents a viable approach for thermal/hydraulic predictions of Cutler reservoir. Additional work would require the acquisition of a complete set of bathymetry data for the reservoir.

Figure 1. Cutler reservoir looking north from Benson marina.

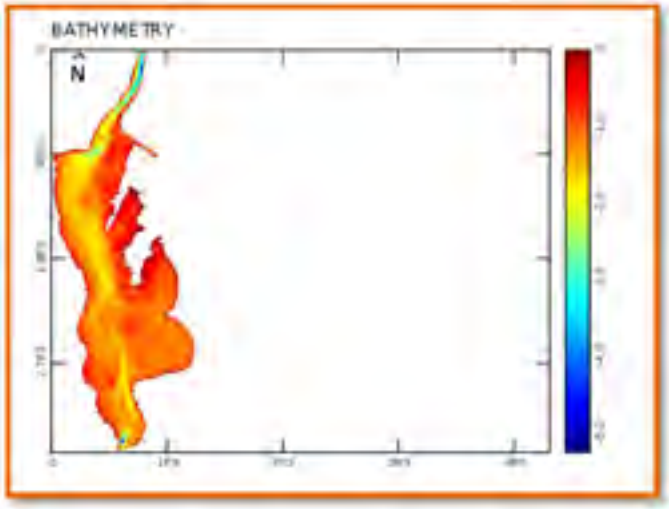


Figure 2. Bathymetry (water depth in meters) north of Benson marina (located at bottom of figure).

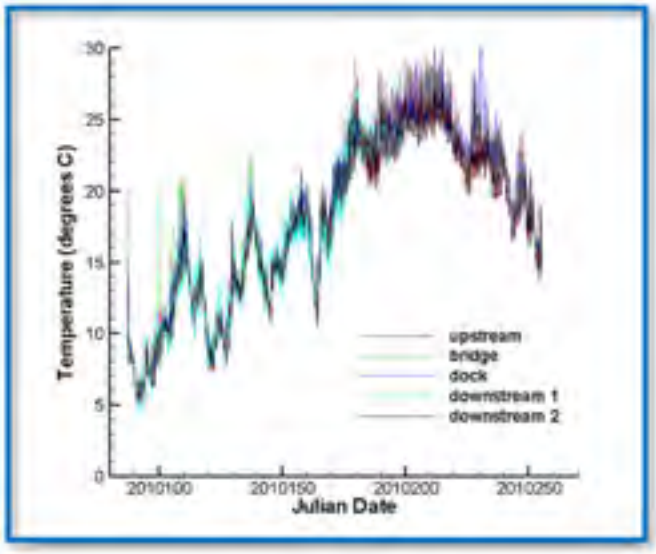


Figure 3. Measured water temperatures.

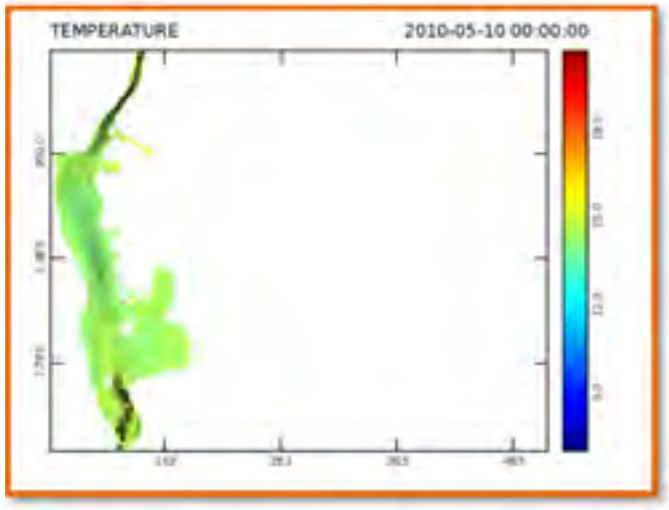


Figure 4. ELCOM predicted temperature distribution and velocity vectors at 1m depth.

Work Plan FY11/FY12

No additional work is planned for FY2011/FY2012.

Informational Resources

Contact: Dr. Robert Spall, (435) 797-2878, E-mail: spall@engineering.usu.edu.

Development of Technology for Streambed Thermal Property Instrument (SPI)

Principal Investigators:
Heng Ban
Bethany T. Neilson

Partners/Collaborators:
- ***State**: Dan Christensen, Utah Division of Wildlife Resources; Steve Meismer, Virgin River Program*

Project Description

- Need and Purpose:

  This project is developing a system to measure *in situ* streambed thermal properties (e.g., thermal diffusivity). The results will enable data gathering for more accurate predictions of stream temperature. Such a technology is not currently available in the market and can potentially result in intellectual property that can be applied in many similar applications.

- Benefits to the State:

  The State of Utah benefits from this project by having a more accurate means to predict instream temperatures and therefore understand the effects of management strategies on aquatic species. This is particularly important in areas like the Virgin River where the state is continually attempting to find the delicate balance between water demands and the needs of two endangered species that are unique to the Virgin River: Virgin River Chub (*Gila seminuda*) and woundfin (*Plagopterus argentissimus*). Both species suffer from instream temperature exceedances. Currently the Two-Zone Temperature and Solute (TZTS) model is being used in the Virgin River for real-time stream modeling and forecasting to assist in stream temperature management. If proven successful and accurate in the Virgin River, this approach to management for instream habitat can be implemented in other river systems in Utah that have temperature impairments. Since the TZTS model was developed, applied, and tested within a number of diverse rivers within Utah, the model results will be a useful decision-making tool within a large portion of the watersheds within the state. As new methods for estimating parameters associated with this model become available, the uncertainty in model predictions will decrease and the confidence in management strategies will increase.

- Geographic Area(s):

  Study Areas: Curtis Creek, Cache County, near Hyrum, UT; Virgin River, Washington County, near Hurricane and St. George, UT.

  Areas Benefited: This project will provide thermal property estimates in any river or stream; therefore, all counties could potentially benefit.

- Accomplishments:

  Findings: Practical streambed applications require robust, large-diameter thermal probes. Two unique, large-diameter probes have been built: one is an oversized penta-probe design for use in a flow cell that simulates a streambed, and the second is a much larger carbon fiber design intended for *in situ* testing. Both probes have thicker diameters than can be used with existing equations. To accommodate the dimensions of these probes, a computer model was built in

COMSOL to bridge the gap between the theory and the necessary diameter size. Using the COMSOL model, the diameter size can quickly be changed and the effects of diameter size quantified.

Results: Data from the penta-probe tests outline the importance of stabilizing the off-set needles of the penta-probe. Modifications have been made to hold the off-set needles in place. The data from these tests will be analyzed to determine the range and applicability of a large penta-probe for streambed use.

Because diameter size is readily changed in the COMSOL model and a dimensionless analysis has been performed, the model can be used as a guide for future large-diameter probe designs. The model has shown that property measurements can be in error of 20% or greater as far away as 1.5 probe diameters off the probe surface. Calibration curves must be used to accurately use a large-diameter probe. The COMSOL model will generate these calibration curves.

Informational Resources

Contact: Dr. Bethany Neilson, (435) 797-7369, E-mail: bethany.neilson@usu.edu.
Dr. Heng Ban, (435)-797-2098, E-mail: heng.ban@usu.edu.

Figure 1. Large-diameter carbon fiber probe. The probe has depths of 3, 9 and 20cm, and will be used to measure the change in streambed thermal properties as a function of depth. This probe is robust enough to be pounded into a cobble streambed.

Figure 2. (a) Temperature profile of a probe of diameter 6.27mm. The red points are where the temperature-time curves are generated and are used to measure the thermal properties of the streambed. (b) Flow cell setup with penta-probe inserted (see picture "c"). The elevated cups allow the flow rate to be reliably adjusted. (c) Robust penta-probe. The center probe provides heating as well as a temperature response, and the four off set probes record temperature. The tip of the center probe is inserted 7" horizontally into the flow cell.

Incorporation of Heat into Solute Models

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***Local:*** *Corey Cram, Washington County Water Conservancy District*
- ***State:*** *Dan Christensen/UDWR; Steve Meismer, Virgin River Program*
- ***Federal:*** *Rick Friedell, US Fish and Wildlife Service*

Project Description

- Need and Purpose:

  In many watersheds, exchanges between surface water and groundwater play an important role in understanding solute transport and transformations. Quantifying the relative magnitude and direction of these exchanges is important for understanding both the energy and the mass balances within streams and rivers. A number of different methods have been developed to assist in quantifying these interactions, including data collection techniques that use a variety of sensors and sampling procedures and a combination of data collection and modeling techniques. There are questions, however, as to the appropriateness and accuracy of these methods for different systems. This project analyzes the data resulting from the combination of several different data collection techniques as multiple lines of evidence toward quantifying the magnitude and direction of fluxes between surface water and groundwater using various modeling approaches.

- Benefits to the State:

  This area of research provides for a more complete understanding of the impacts of transient storage and surface water-groundwater interactions on streams in Utah and the Intermountain West. As methods are developed to measure and predict the fate and transport of constituents in stream and rivers, while simultaneously considering the impacts of surface water-groundwater interactions, the state of Utah will have the tools and methods necessary to complete these types of studies and better manage limited water sources.

- Geographic Areas:

  Study Area: Curtis Creek, Hardware Ranch, Cache County, Utah; Silver Creek, Summit County, Utah; and Virgin River, Washington County, Utah.

  Areas Benefited: The current applications of the modeling approach span desert and mountain watersheds. Therefore, the entire State of Utah could potentially benefit.

- Accomplishments:

  Findings: Data collection strategies and new approaches to model development have provided more accurate heat and solute fate and transport predictions through the main channel, dead zones, and the surface-groundwater interface of rivers and streams (referred to as two-zone transport models). Analytical solutions have been developed to describe these transport processes better than more traditional methods using numerical solutions. Additionally, the introduction of heat into solute transport models allows for more cost-effective data collection and predictions that cover larger time periods that are often limited when using solute alone. New techniques have also been developed to account for spatial variability in system characteristics using information extracted from aerial high resolution multispectral and thermal

infrared imagery (Figure 1). The analytical solutions combined with a convolution approach provide methods to incorporate spatially variable parameters and investigate increased data resolution on solute transport predictions.

Results: Analytical solutions of two-zone solute transport have been developed with the use of Laplace transforms and have been tested against observed solute data. These solutions allow parameters within the model to be treated as functions of space rather than having to transfer information from reach to reach. Figure 2 shows example predictions of the movement of a short duration pollutant spill through a river or stream.

Figure 1. Subset of aerial high resolution multispectral and thermal infrared imagery used to determine spatially variable characteristics of the system that are used within the modeling framework to improve predictions.

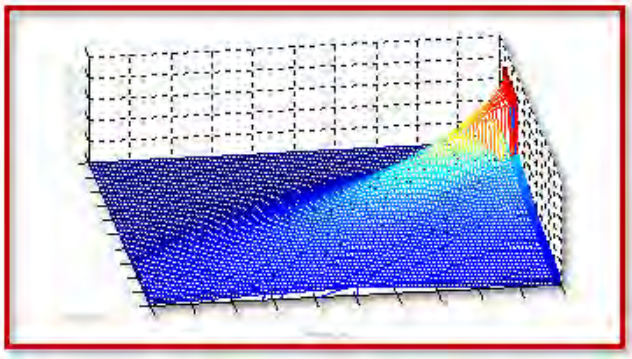


Figure 2. Example of using analytical solutions to predict the transport of a pollutant spill through a river or stream.

Work Plan FY10/FY11

The two-zone solute analytical solutions and temporal moments are complete and the heat transport equations have been partially solved analytically. Various data sets within rivers in Utah have been collected and we will work on testing the model solutions while incorporating surface water-groundwater interactions. The overall objective is to fully integrate heat into the solute model so predictions of both heat and solute can be made with minimal data collection efforts.

Informational Resources

Contact: Dr. Bethany T. Neilson, (435) 797-7369, E-mail: bethany.neilson@usu.edu.

Investigating Stream Dissolved Organic Matter Dynamics in the Little Bear River Using Continuous Monitoring Data

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Brant Whiting (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Dissolved organic matter (DOM) is ubiquitous in aquatic environments and plays a major role in the health of stream ecosystems. Riverine DOM is important in carbon dynamics and nutrient budgets because it participates in the complexation of trace metals and the mobilization of pollutants. It is also a key water quality constituent that affects the cost and efficacy of drinking water treatment as well as disinfection byproduct formation. Many processes from the local to regional scale, such as climate variability, artificial drainage, and land use change, are known to affect the flux and composition of riverine DOM. However, the usual, infrequent grab-sampling approaches have been inadequate to characterize the timing, magnitude, and composition of DOM transported within watersheds. Few studies have examined changes in DOM concentrations in streams over continuous time scales, thus leading to an incomplete understanding of the mechanisms affecting DOM dynamics. New optical sensors capable of measuring Chromophoric DOM (CDOM) as a surrogate for DOM concentrations with frequencies on the order of minutes are now becoming available for use in streams and rivers. This project will use high frequency CDOM monitoring within the Little Bear River Watershed of northern Utah, coupled with grab sampling and laboratory measurements of DOM. The objective is to determine the mechanisms controlling DOM dynamics in the Little Bear River.

- Benefits to the State:

  The hydrologic regimes of most of our rivers in Utah are driven by spring snowmelt. Many of our rivers are used as drinking water sources. Results from analyses of high frequency data collected in the Little Bear River indicate that approximately 50 – 60% of the annual sediment (and associated phosphorus) loading in the river occurs within a time period of about 2 – 3 weeks during the early spring snowmelt period. This short response period is poorly characterized by a few water quality grab samples, which provide no information at all about sources of sediment. The continuous monitoring techniques that we are developing will provide information about the timing, magnitude, and composition of the sources and flow paths of DOM. The research will aid the State of Utah Division of Water Quality, utilities providing drinking water to municipalities, and other water quality organizations in controlling the impact of DOM on water quality and aquatic environments.

- Geographic Areas:

  Study Area: Little Bear River in Cache County.

  Areas Benefited: The Little Bear River and other river systems state-wide.

- **Accomplishments:**

  Findings: Previous studies within the Little Bear River have shown that large percentages of the fluxes of sediment and phosphorus occur within a very short time window associated with spring snowmelt. Although this work is just beginning, we hope to examine the timing and magnitude of DOM fluxes to see if they have timing that is consistent with other major water quality constituents or whether CDOM fluxes are driven by different sources and flow paths.

  Results: Expected results include: 1) a demonstration of how new CDOM sensors can be deployed and used to make continuous estimates of DOM concentrations; 2) a demonstration of how continuous CDOM measurements can be integrated with the existing Little Bear River monitoring and telemetry system, and 3) an examination of the timing and magnitude of DOM fluxes in the Little Bear to examine potential sources and flow pathways.

Work Plan FY11/FY12

We will install new CDOM sensors and conduct high frequency monitoring at three different sites within the Little Bear River, coupled with much lower frequency grab sampling and laboratory measurement of DOM to investigate the mechanisms controlling DOM dynamics. We will integrate the new CDOM sensors with existing monitoring and telemetry equipment in the Little Bear and establish the necessary database and data processing protocols.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.

Website: http://littlebearriver.usu.edu.

Typical CDOM sensor
(Source: http://www.turnerdeisgns.com)

A continuous monitoring site on the Little Bear River

Investigating Turbidity and Sediment Transport Dynamics in the Little Bear River Using Continuous Monitoring Data

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Brant Whiting (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  In recent years, water managers have increasingly recognized the need to include sediment control strategies within watershed management plans. In many cases, suspended solids are regarded as a primary indicator of pollution. Information on the timing and sources of the sediment transported by a river is an important requirement for designing effective sediment control strategies. High concentrations of suspended sediment can limit light for aquatic vegetation growth, contribute to low dissolved oxygen levels, impact aquatic insects, damage fish gills, and impact fish spawning. Additionally, pollutants such as phosphorus are often associated with suspended sediment through complex binding effects. This can increase the time such pollutants are resident within a watershed because of repeated deposition with their sediment hosts. Turbidity, which is an optical measure of water clarity, is often used as a surrogate variable for suspended solids concentration because it is easy and inexpensive to measure. This project will use high-frequency turbidity monitoring at several different sites within the Little Bear River Watershed of northern Utah, coupled with much lower-frequency grab sampling of sediment concentrations to investigate methods to better quantify the sources, timing, and magnitude of sediment fluxes.

- Benefits to the State:

  Because the analysis and monitoring techniques that we are developing provide information about the timing, magnitude, and the source of sediment loading, they will be of interest to the State of Utah Division of Water Quality and other water quality organizations nationwide as a more effective way of quantifying TSS loading. Indeed, we have already begun coordinating with individuals within the Utah Division of Water Quality to share our experience and expertise.

- Geographic Areas:

  Study Area: Little Bear River in Cache County.

  Areas Benefited: The Little Bear River and other river systems state-wide.

- Accomplishments:

  Findings: Within the State of Utah, the hydrology of most rivers is driven by spring snowmelt. Results from analyses of data collected in the Little Bear River indicate that approximately 50-60% of the annual sediment (and associated phosphorus) loading within the Little Bear River occurs within a time period of about 2-3 weeks during the early spring snowmelt period. This short response period is poorly characterized by water quality grab sampling, which provides no information at all about sources of sediment.

  Results: We are developing robust methods for estimating suspended sediment concentrations and loads from continuous turbidity and streamflow data. Preliminary relationships between

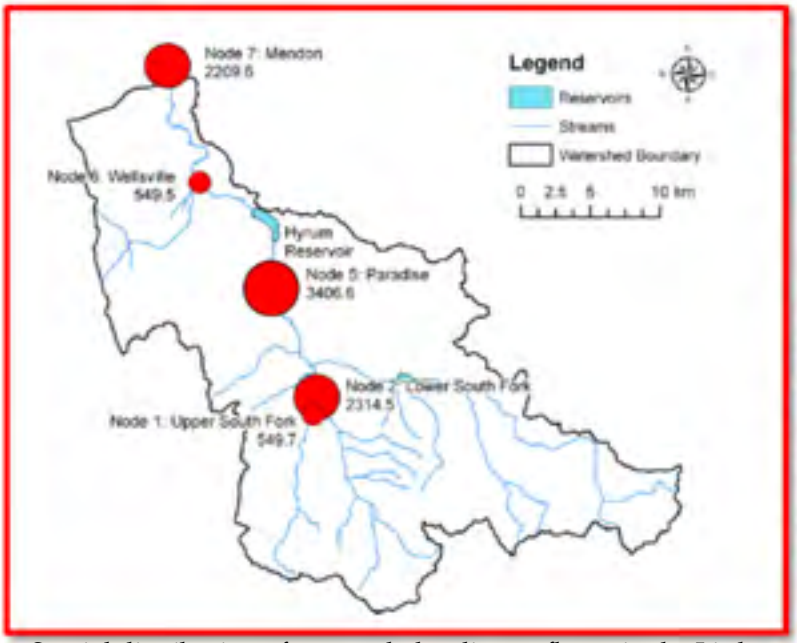
suspended sediment concentrations and turbidity have been established at each of the monitoring sites and a suspended sediment loading profile has been developed for the Little Bear River watershed. Continuous data collection is ongoing at 7 stream sites and 4 continuous weather stations.

Work Plan FY11/FY12

We will continue our work with ongoing data collection at several monitoring sites within the Little Bear River to assemble high frequency turbidity data as a surrogate for suspended sediment. We will refine our preliminary relationship between suspended sediment and turbidity and create high-frequency estimates of suspended sediment concentrations. We will collect new suspended sediment samples and examine the particle size distribution at different times of the year to provide more information about sources of suspended sediment and to examine the effects of particle size distribution on the relationship between suspended sediment and turbidity. We will use multiple techniques to measure suspended sediment concentrations in the stream. Additionally, we will examine new data from weather stations within the watershed for potential relationships between the timing of snowmelt and soil moisture dynamics and the timing of suspended sediment loads within the Little Bear. Finally, we will examine the utility of this combination of datasets for better quantifying the sources, timing, and magnitude of sediment fluxes in the Little Bear River.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.
Website: http://littlebearriver.usu.edu.



Spatial distribution of suspended sediment fluxes in the Little Bear River watershed. Sediment fluxes are expressed in metric tons and are for the year 2008

A typical continuous monitoring site on the Little Bear River

"Lab-on-a-Chip" – Miniaturized Salinity Sensor Arrays for Water Quality Monitoring

Principal Investigators:
Anhong Zhou

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Utah is one of seven western states in the United States (Arizona, New Mexico, California, Utah, Colorado, Wyoming, and Nevada) making up the Colorado River Basin Salinity Control Forum. The forum manages the problem of elevated salinity levels in the Colorado River. Salt in the Colorado River, aside from the natural sources, generally results from activities in support of irrigated agriculture in the Upper Colorado River, especially in drainages such as the Price and San Rafael Rivers in Utah. However, there is substantial uncertainty about the efficacy of salinity management in the basin due to the lack of a commercially available detection device to adequately measure salinity levels in the river. This project is aimed at developing a portable, reliable, affordable chemical sensor device capable of measuring the concentrations of individual salt ions in the field.

- Benefits to the State:

  The ability to detect the majority of salinity ions (Cl-, Na+, SO42-, Mg2+, Ca2+, and HCO3-) will help to better manage and control Utah's contribution to the Colorado River salinity problem. Benefits of this project include (1) ion sensor arrays that can be used to measure salt loading in critical Utah rivers, (2) a new portable detector not currently available for measuring the most significant salinity ions contributing to salinity from Utah and other states, and (3) help for farmers and Utah residents to improve the timing and efficiency of water quality monitoring and to track the salinity sources in the water system.

- Geographic Areas:

  Study Area: Price and San Rafael Rivers in Utah

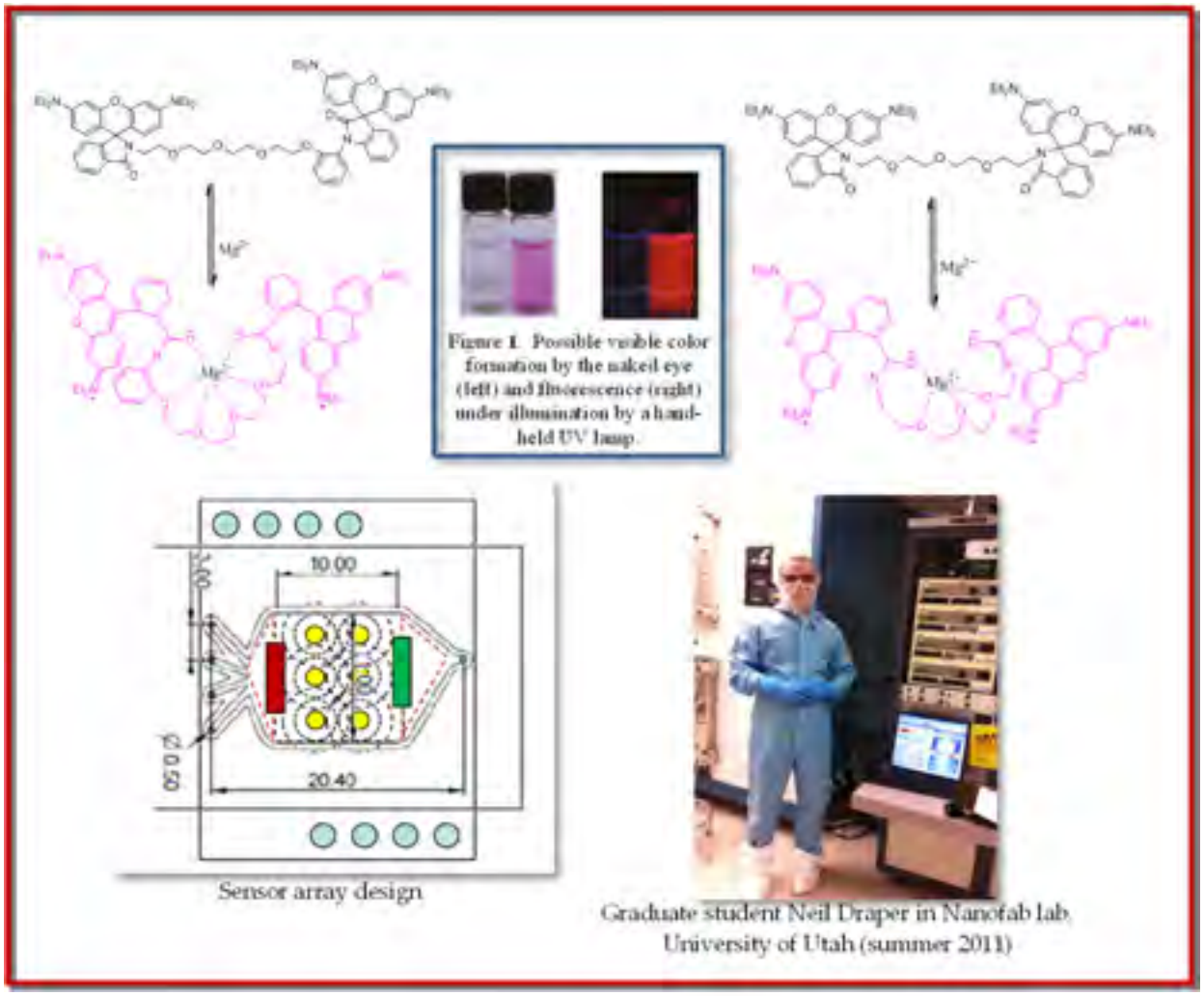
  Areas Benefited: Salinity concerns are statewide, so all counties in the state would potentially benefit from this project.

- Accomplishments:

  Findings: We have been working with USU Technology Commercialization Office on intellectual property protection for our ongoing research. In November 2010, our first patent in salinity ion detection was issued (U.S. Patent No. 7,842,174 B2). Our second provisional patent "Handheld Electrochemical Sensor" was also filed by USU TCO on Oct 5th, 2010. Meanwhile, we have started the synthesis of new ionophore for recognizing the Mg2+ ion. We have also worked on the design and fabrication of our microsensor-integrated lab-on-a-chip device.

  Results:
  1. Ionophore plays a critical role in the development of the ion selective sensor.
  2. One of synthesis approaches illustrated below uses the novel idea of synthesis of new compounds that can recognize ionophore molecules.
  3. NMR and MS characterization of the synthetic intermediates and final product to confirm the chemical structures of these new compounds.

4. Fabrication of the microsensor integrated sensor array device was completed in the Nanofab lab in University of Utah (see photo below).



Work Plan FY11/FY12

- Identification of the synthetic chemical structures by a variety of instrumental analysis techniques (NMR, MS, FTIR, XRD, etc.).
- Performance evaluation of our new Mg2+ sensor including selectivity, sensitivity and detection limit.
- Design, fabrication, and initial evaluation of lab-on-a-chip device that has the potential to detect multiple ions simultaneously.

Informational Resources

Contact: Dr. Anhong Zhou, Phone (435) 797 2863, E-mail: Anhong.Zhou@usu.edu.

Website: Dr. Zhou at Dept. of Biological Engineering, USU: http://www.be.usu.edu.

Salinity probe project at UWRL, USU:
http://uwrl.usu.edu/researchareas/surfacewaterquality/labonachip.html.

Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support

Principal Investigators:
David K. Stevens
R. Ryan Dupont
Darwin L. Sorensen
Joan E. McLean
Ana Ovalle (student)
Ruba Mohamed (student)
James Milleson

Partners/Collaborators:
- ***Local:***
  Issa Hamud, City of Logan
  Jim Harps, City of Logan
  Wynn Cardon, land owner, producer
  Jason Fuhriman, producer

Project Description

- Need and Purpose:

This project provides water quality monitoring in eight rivers that drain into Cutler Reservoir. Water quality is also monitored at five locations in the reservoir itself, at 15 wastewater reuse sites, and at 15 wastewater collection system sites. Measurements include the nutrient loading, suspended sediments, and general water quality as measured by temperature, dissolved oxygen, turbidity, and total dissolved solids. Heavy metals are also monitored at the wastewater reuse and collection system sites. Additional data related to nutrient and oxygen fluxes from the sediments into the overlying water were also obtained in several of the tributaries. These data are used to estimate the internal nutrient loading and corresponding oxygen demand under different environmental conditions.

Based on discussions with City of Logan Environmental Department personnel, a sampling program was carried out at the following locations to develop baseline information regarding nutrient loading and water quality in Cutler:

Map of sampling locations

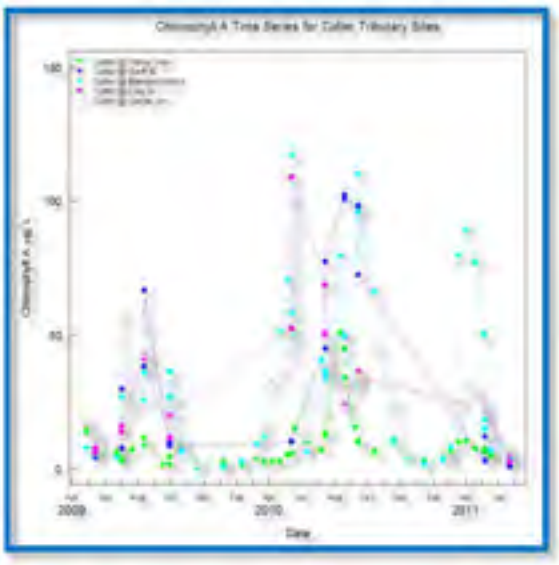
1) Spring Creek (at Mendon Road).
2) Logan River (near Mendon Road).
3) Little Bear River (at Mendon Road).
4) Swift Slough near Cutler (2 sites).
5) Clay Slough near Benson.
6) Blue Springs near Benson Road.
7) Bear River into Cutler.
8) Five locations within Cutler Reservoir.
9) Fifteen groundwater monitoring wells and four nesting lysimeters at 12, 24, and 36 inch depths in two pastures irrigated with treated wastewater from the City of Logan WWTP. These pastures border Benson Road (3200 W) on the east in Logan from the Valley View Highway north to Blue Springs.
10) Fifteen wastewater collection system sites Smithfield, Hyde Park, North Logan, Nibley, Providence, and River Heights trunk sewers, and a number of sites in the City of Logan).

The river and reservoir sampling locations have been sampled monthly beginning January 1, 2009 using grab samples, vertical profiles, and manual field and laboratory analyses to aid in

placement of continuous probe measurement stations. Flow estimates to determine load require a datum established at each location and the water surface elevation measured relative to that datum using a staff gauge. Rainfall events were also sampled over a 24-month period, as were in-reservoir diurnal monitoring. The well and lysimeter stations, and waste water collection system sites have been sampled since April 2010.

- **Benefits to the State:**

  Estimating a full accounting of total phosphorus loading into Cutler Reservoir shows how conditions in the reservoir respond to the total phosphorus loading. This supports State of Utah efforts to implement the total maximum daily load plan based on improvements to the City of Logan wastewater treatment plant to control phosphorus loads, and will identify additional sources of phosphorus entering the reservoir.



- **Geographic Areas:**

  Study Area: Bear River Basin, Cache County.

  Areas Benefited: City of Logan/Cutler Reservoir.

- **Accomplishments**:

  Findings: In addition to an existing monitoring station on the Little Bear River, we have installed three automated flow and water quality monitoring stations on the Logan River, Spring Creek, and the Bear River. Monthly field sampling at each station is ongoing at these sites and at five locations in Cutler Reservoir for nutrients (total and dissolved nitrogen and phosphorus, total suspended solids, and Chlorophyll A (in the reservoir only). In addition, the well and lysimeter sites have been monitored for nutrients, pH, dissolved oxygen, specific conductance, and turbidity since April 2010. Waste water collection system sites were sample for BOD5, suspended solids, nutrients, pH, dissolved oxygen, temperature, turbidity, and specific conductance. The data through June 2011 are available via a dedicated database housed at the UWRL.

  Results: The outcome of this project is a large and growing data set for public and research use. The data are currently accessible by contacting the PI. In the future, data will be made available to the public via the Bear River Watershed Information System (http://bearriverinfo.org).

Work Plan FY11/FY12

Data collection is complete. A final report will be filed in November 2011. The possibility exists for extension of the project with new funding into the future.

Informational Resources

Contact: Dr. David K Stevens, (435) 797 3229, E-mail: david.stevens@usu.edu.
Website: http://www.bearriverinfo.org.

Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Malgorzata Rycewicz-Borecki (student)
Amanda Goodwin (student)

Partners/Collaborators:
- ***Local:*** *Bill Young, Logan City Public Works Department*

Project Description

- Need and Purpose:

  The Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) water pollution control program mandates that municipalities across Utah install structural stormwater best management practices (BMP) as a means of reducing polluted runoff from major industrial facilities, city storm sewers, and construction sites that disturb 5 or more acres of land. Stormwater detention basins are often used in response to this federal mandate. This progressive program aims to minimize pollutants and discharge volumes from urbanized areas entering receiving water bodies and to address the growing problems of impacted water quality and increased flooding from urban and rural non-point sources.

  In the past, stormwater treatment in Logan City has mainly focused on water quantity. Logan City and its surrounding municipalities are only now beginning to address the issues of stormwater quality, and they need locally generated, quantitative research to accurately depict the effectiveness of vegetative species within stormwater management facilities.

  This study measures biomass production and water quality improvement effectiveness in a controlled laboratory environment and in a field demonstration site study. The laboratory scale study was designed to produce controlled, laboratory scale replicates of stormwater retention basins in which biomass production, total nutrient and metal removal. Water uptake can be quantified for seven individual vegetative species under simulated (frequency and duration) rainfall events. The field demonstration is designed to produce quantitative data for the water quality improvement effectiveness of three species and compare them with voluntary weed species and non-vegetated control plots. The field study site is an existing subdivision stormwater detention area in Logan, Utah. Data from the site will determine plant production and contaminant removal in response to periodic plant harvesting.

- Benefits to the State:

  This study will provide Utah municipalities with the stormwater nutrient and metal removal effectiveness of species found and planted locally. The data are specific to Utah's climate and geologic conditions. Logan City officials intend to utilize this information in the upcoming TMDL regulations that target reductions in the nutrient loading (particularly phosphorous) of discharges into Cutler Reservoir. Additionally, the quantitative results will prove critical to Utah's BMP designers and managers responsible for species selection under local/regional site conditions and nutrient and metal removal requirements.

- Geographic Areas:

  Study Area: Logan, Utah. Laboratory study at Utah State University Research Greenhouse, Field demonstration study: Green Meadows Subdivision detention basin, 600 S and 800 W.

Areas Benefited: All counties in the state would potentially benefit from quantitative data that could be utilized within their stormwater management systems.

- **Accomplishments**:

  Findings: Greenhouse studies initiated in late spring 2010 included planting and propagating a variety of species found in stormwater management systems in northern Utah. Simulated stormwater events accounting for storm intensity, duration, and frequency were carried out, and intense monitoring of soil leachate, surface and rhizosphere soil, and plant tissue was completed between October 2010 and April 2011. Final construction and planting of the field demonstration site at Green Meadows was completed the end of fall 2010, and site and plant maintenance were continued through the end of FY10 in preparation for field monitoring and plant harvesting initiated during the summer/fall season of FY11.

  Results: Seven plant species were successfully propagated and grown under simulated stormwater wetting and drying cycles in the USU greenhouse facility, and plant and soil harvesting was completed by the end of FY10. Plant and soil extractions and analysis for nutrients and metal uptake were begun, and data are being analyzed to quantify nutrient, solids, and metal removal potential as a function of species type.

  Operation procedures for the field demonstration site are being finalized. Plant production data are being collected. Preliminary water quality sampling is being conducted for the storm events taking place during the end of FY10. Standard field sampling and monitoring protocols will be finalized based on experience gained during the spring/summer of 2011.

Work Plan FY11/FY12

Final data analysis and reporting will be carried out during FY 12 for the nutrient and metal removal data collected in the lab greenhouse study. Operation of the field demonstration site will continue through FY12 to capture runoff input and contaminant removal performance data during the summer and fall of 2011. Field plant harvesting and soil sampling will be carried out at the end of the growing season in late fall 2011 to develop background data on nutrient and metal uptake and partitioning in the four plant species and invasive plants grown during the first year of operation of the demonstration site. Reporting of nutrient and metal uptake potential in these systems will be carried out during the latter half of FY12.

Informational Resources

Contact: Contact: Dr. R. Ryan Dupont, Phone (435) 797-3227, E-mail: ryan.dupont@usu.edu.
Website: http://public.me.com/rdupo/UWRL Report Files/Stormwater_Study_Report_Files.

Green Meadows stormwater BMP field demonstration site during high runoff event, late spring, 2011

Typical plant crop harvested from laboratory greenhouse simulated BMP study

Quantification and Management of Salt Production in the Desert Lake Watershed

Principal Investigators:
Lizzette Oman
Said Ghabayen
Mac McKee

Partners/Collaborators:
- ***Local:*** *Emery Water Conservancy District*
- ***Federal:*** *Nick Williams, Steve Noyes, Bureau of Reclamation; Colorado River Salinity Science Team*

Project Description

- Need and Purpose:

  Salt in the Colorado River has economic and environmental effects on the whole Colorado River Basin. As the water of the Colorado becomes more saline, upstream water users will come under greater scrutiny for methods to control salt in the river. To respond to this problem, Utah must have better estimates of salt loading to its tributaries to the Colorado River.

  Currently salt loading in Utah's streams is estimated from monthly water and stream flow samples averaged over time. This project is employing real-time monitoring information for both flow and water quality to estimate salt loading from runoff at Desert Lake in Emery County and is developing tools to identify the different sources of salt in the Desert Lake drainage, which will lead to better control of the salt produced by agriculture and natural sources.

- Benefits to the State:
  - Improved estimates of salt loading for the Desert Lake system.
  - Identification of individual contributions of salt to the Desert Lake system.
  - Evaluation of monitoring measures to improve the salt source and load estimation and reduce the uncertainty in the estimates.

- Geographic Areas:

  Study Area: Desert Lake Waterfowl Management Area and drainage basin. The system drains into the Price River, which flows to the Green River.

  Areas Benefited: Upper Colorado River basin and irrigated agriculture statewide. Potentially all areas of the State that have a salt load from natural and agriculture sources will benefit.

- Accomplishments:

  Findings: The hourly, daily, and monthly Bayesian Belief Model produces good results when the real-time input data are reliable. The model shows that Shoemaker Wash produces the smallest amount of salt to the system through surface water, while Desert Lake Wash and Timothy Wash produce the majority of the loading.

  There is a lag between irrigation and salt loading during the non-irrigation season. During winter, it is difficult to obtain a reliable estimate for salt loading because of freezing and the problems this poses for the real-time sensors that monitor salt concentrations and stream flow.

The groundwater model built during the project shows good results in identifying different salt sources using ionic ratios and shows a distinct, identifiable difference between natural and agricultural sources. The value of this work has been increased through the use of the data collected this year on boron and other isotopes in the surface and ground water.

Aerial imagery obtained through use of the unmanned aerial vehicles (UAVs) developed by the UWRL and deployed by the AggieAir™ Flying Circus (http://aggieair.usu.edu) has been used to demonstrate their application in estimation of evapotranspiration rates at Desert Lake as a part of the overall water balance calculations.

Results: Work this year using the isotopic data has shown that estimates of salt loading from the Desert Lake watershed can be refined to confidently distinguish between the salt that results from irrigated agriculture and other agriculturally related activity and the salt that comes from natural sources in the watershed. This will help to target salinity management operations in the area more precisely.

Work Plan FY11/FY12

- Prepare one or more scientific publications on salt loading quantification and salt source identification in the Desert Lake drainage.
- Extend the application of the UAVs for improved water balance estimation.

Informational Resources

Contact: Ms. Lizzette Oman, (435) 797-3159, E-mail: l.j.oman@aggiemail.usu.edu.

Aerial Imagery Obtained by Use of UAVs, Used to Estimate Evapotranspiration in the Desert Lake Area

Release of Arsenic from Aquifer Solids under Anaerobic Conditions

Principal Investigators:
Joan E. McLean
Wade Nicholas (student)
Xianyu Meng (student)
Suzy Smith (student)
Lindsey Stevens (student)

Partners/Collaborators:

- ***Local:*** *Issa Hamud, Director of Environmental Department, City of Logan*

Project Description

- Need and Purpose:

  Seventeen percent of the well water in Cache County, tested as part of a survey conducted by the Utah Geologic Survey, contained levels of arsenic that exceeded the drinking water limit. The USGS has also reported elevated concentrations of arsenic in well water in Salt Lake and Utah counties. Geologic formations throughout Utah contain arsenic. Many of these formations are stable and pose no threat to humans or the environment. In other locations, changes in aquifer conditions, in particular with the introduction of organic matter, either intentionally for remediation purposes or unintentionally, may lead to the release of arsenic to ground water resources. The overall objective of this study is to investigate conditions that lead to arsenic release to groundwater at sampling locations near the City of Logan landfill. This site has a network of groundwater wells that have been monitored for arsenic for over ten years.

- Benefits to the State:

  All counties in Utah will benefit from improved understanding of the biogeochemistry governing the behavior of arsenic in subsurface environments undergoing reducing conditions that may lead to groundwater contamination. Reducing conditions are imposed on subsurface systems as a remediation strategy for dechlorination of TCE and other chlorinated solvents. All counties have groundwater contaminated with TCE or PCE due to various industrial and dry cleaning operations. TCE and other chlorinated solvents are also common groundwater contaminants at military bases. Reducing conditions are also associated with municipal landfills where arsenic has been reported in monitoring wells. Most arsenic contamination of groundwater world-wide, however, is due to sources and processes that are natural. The counties most immediately benefiting from this research are Cache, Davis, and Weber.

- Geographic Areas:

  Study Areas: City of Logan Landfill, Cache County; Hill AFB, Weber-Davis County

  Areas Benefited: In addition to the specific areas above, this project will contribute to protection of groundwater throughout the state. Arsenic in groundwater is a worldwide problem.

- Accomplishments:

  Findings: Arsenic in groundwater comes from geologic sources. Arsenic occurs throughout the soil-sediment profile, from the soil surface to depth of groundwater.

  Results: We are exploring the mineralogy of As from the soil surface to the depth of the groundwater (Figure 1), in particular the role of carbonates, the effect of altering redox conditions in the transition zone, the microbial community development focusing on As reductase and

oxidase coding microbes coupled with specific mineralogies, and identification of the type and source of organic carbon driving microbial processes. We have evidence that As in the surface soils is associated with sulfides or crystalline Fe oxides. The proportion of 0.5 M HCl extractable As increased with depth, which indicates that As leached from the surface soils is retained by sorption or co-precipitation with carbonate minerals and amorphous Fe oxides (Figure 2). The adsorption and mobilization of As by Fe oxides fits the most popular hypothesis; whereas, the association between As and carbonate minerals under natural conditions has hardly been investigated. The accumulation of As in the saturation zone may be due to the reformation of As-sulfides or the retention by Fe-sulfides under sulfate-reducing conditions.

Work Plan FY11/FY12

We will continue to investigate the biogeochemical factors that lead to the release of arsenic to groundwater from native geologic materials. We are developing more sensitive techniques for identifying bacteria that are responsible for arsenic mobilization. With use of synchrotron advance x-ray absorption spectroscopy, we can directly examine how arsenic is associated with minerals. We have submitted a proposal to Brookhaven National Laboratory for this purpose.

Informational Resources

Contact: Ms. Joan E. McLean, (435) 797-3199, E-Mail: joan.mclean@usu.edu.

Figure 1. Collection of core material from the study site for evaluation of arsenic concentration through the profile and determining mineralogy of arsenic and biochemical processes of arsenic release to groundwater

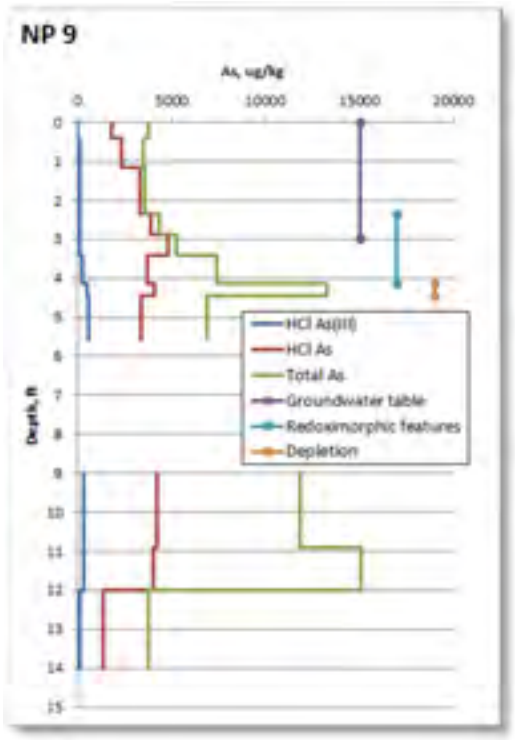


Figure 2. Profile of arsenic distribution from the soil surface to depth of groundwater

Technical Support for Bear River System Data Acquisition

Principal Investigators:
David K. Stevens
Bethany Neilson
Austin Jensen
Hussein Ali Batt (student)

Partners/Collaborators:
- ***Federal****: Annette de Knijf, USFWS*
- ***Private/Business****: Bear Lake Watch*

Project Description

- Need and Purpose:

  The focus of the project is to provide high-level technical support for development of alternative data acquisition networks for large-scale remote data gathering stations in watersheds, on rivers, and in lakes. We are investigating two potential data acquisition systems: (1) UAV aircraft to monitor sediment dynamics in lakes, and (2) fiber optic temperature data collection system for rivers and lakes, with field sampling to support relevance vector machine statistical learning methods.

- Benefits to the State:

  Specific benefits of the modeling work to the State of Utah include:

  1. Improved understanding of the temperature dynamics in the Bear River basin.
  2. Innovative data acquisition systems for remote areas.
  3. Investigation of the influence of ground/surface water exchange for improved understanding of energy fluxes in mountain rivers that will improve prediction of water column temperatures.
  4. A preliminary framework for understanding surface and groundwater temperature interactions and their impact on groundwater management.
  5. Data acquisition to assess dynamics of sediment transport in lakes.

- Geographic Areas:

  Study Area: Bear River Basin, Rich County, Cache County.

  Areas Benefited: Watersheds statewide.

- Accomplishments:

  Findings: Fiber optic temperature measurements have been collected in Curtis Creek (Cache County) for analysis of local scale high spatial and temporal resolution temperature dynamics to incorporate into temperature models of the hyporheic and dead zones in river channels.

  An inexpensive unmanned aerial vehicle (UAV) has been deployed with the capability to carry and control various types of remote sensing equipment and to gather remotely sensed data that can then be processed for distribution to researchers in Mud Lake, north of Bear Lake. Field vegetation mapping was collected in 2009/10/11.

Field monitoring in Mud Lake was carried out during summer 2011 to assess the transport of sediment into and out of Bear Lake from the Bear River. Hydrolab measurements were used to characterize the general water quality. Field measurements of flow velocity at 29 locations in Mud Lake were also obtained to help determine the direction and magnitude of water and sediment flow. These data will be used in conjunction with a statistical learning model known as relevance vector machines (RVM) to try to predict the sediment behavior in this shallow, vegetated lake. This will provide needed insight for sediment transport in the Bear River Basin, in other parts of Utah, and in the Intermountain West region.

Results:

- Programmable intelligence followed a pre-determined flight path to acquire and stored high-resolution images in the visual and near-infrared spectral bands.
- The remotely sensed images were processed to match the location of the images with respect to ground coordinates and transform the resulting images into GIS-compatible formats.
- The fiber optic temperature measurements included a spatial resolution of 1-2 cm and a temporal resolution of < 2 seconds.
- The field samples were analyzed for suspended solids.

Work Plan FY11/FY12

- Complete data analysis for remote sensing data and for Mud Lake monitoring campaign.
- Build, calibrate, and test Relevance Vector Machine model of sediment transport.

Informational Resources

Contact: Dr. David K. Stevens, Phone (435) 797 3229, E-mail: david.stevens@usu.edu.

Website: http://www.bearriverinfo.org.

Mosaic image of a portion of the Mud Lake refuge from UAV Data Collection.

Uptake and Release of PCPPs (Personal Care Products and Pharmaceuticals) and other Organic Contaminants from Sediments, Soils, and Biosolids

Principal Investigators:
William J. Doucette
Joe Stewart
Oksana Roth

Partners/Collaborators:

- ***Local****: Waste water treatment facilities in Brigham City, Spanish Fork, and Hyrum City, Utah,*

Project Description

- Need and Purpose:

  Pharmaceuticals and personal care products (PPCPs) are being increasingly identified in the environment. Concern over the potential ecological effects (i.e., hormone disruption, increased microbial resistance to antibiotics) attributed to some of these compounds has led to an increased interest in their environmental distribution and fate. Most PPCPs enter the environment by passing untreated or partially treated through wastewater treatment plants (WWTPs) or septic systems and during the land application of WWTP biosolids containing PPCPs. For example, nonylphenol, an endocrine disrupting metabolite of nonylphenol ethoxylate surfactants, was found in biosolids collected from a Northern Utah WWTP at concentrations as high as 1000 mg/kg on a dry weight basis during a recent project that is examining the environmental fate of nonylphenol.

  The main objective of this project is to investigate the effectiveness of three Utah WWTPs, each using different treatment technologies, in removing PPCPs. Ten specific PPCPs were selected for this study based on their wide range of chemical properties and reports of being found in WWTP effluent and biosolids. Removal effectiveness will be evaluated by measuring the concentrations of these PPCPs in wastewater influent, effluent, and biosolids samples collected several times during the year. The wastewater treatment technologies used by the three WWTPs are oxidation ditches, trickling filters, and membrane bioreactors (MBR) represented by Brigham City, Spanish Fork, and Hyrum City, Utah, respectively.

- Benefits to the State:

  Results from this study will contribute to our basic understanding of the fate of PPCPs in WWTPs and determine which treatment processes are more effective in removing PPCPs. Information on the PPCP concentrations in WWTP influents and biosolids will also help facilitate modeling efforts for the protection of surface water and groundwater resources from these compounds. An improved understanding of the fate of PPCPs in WWTP by regulatory agencies such as the Utah DEQ will also enable the more efficient expenditure of public dollars based on risk management prioritization that will be made possible by this information.

- Geographic Areas:

  Study Area: Brigham City (Box Elder county), Spanish Fork (Utah county), and Hyrum City (Cache County), Utah.

  Areas Benefited: Wastewater is generated statewide, so all counties in the state would potentially benefit.

- **Accomplishments**:

Findings/Results: Samples of wastewater influent, effluent, and biosolids were collected from Brigham City, Hyrum, and Spanish Fork WWTPs in May, July, and August of 2011. Influent and effluent samples were collected into four-liter amber glass bottles. Influent samples were collected prior to the headworks and effluent samples were obtained immediately before entering the receiving waters. Biosolids samples were collected from the drying beds in 500 mL wide-mouth clear glass jars wrapped in aluminum foil. The samples were stored in the dark at <4 C until analysis. Aqueous samples were concentrated using a solid phase extraction (SPE) procedure and subsequently analyzed by LC-MS and GC-MS. Biosolids were extracted using an accelerated solvent extractor (ASE) followed by solid-phase extraction (SPE) and analyzed by LC-MS and GC-MS. All samples were extracted within 14 days of collection and analyzed within 40 days of extraction following the general procedures outlined in EPA Method 1694. Example results from Hyrum City WWTP are presented below in Table 1. Preliminary results indicate that removals are compounds specific.

Table 1. Influent, effluent, and biosolids concentrations of 10 selected PCPPs collected from Hyrum WWTP in July 2011 (ND denotes not determined).

Compound	Hyrum influent conc (ug/L)	Hyrum effluent conc (ug/L)	Hyrum biosolids conc (mg/kg)	Brigham city influent conc (ug/L)	Brigham city effluent conc (ug/L)	Brigham city biosolids conc (mg/kg)	Spanish Fork influent conc (ug/L)	Spanish Fork effluent conc (ug/L)	Spanish Fork biosolids conc (mg/kg)
acetaminophen	7.852	0.003	0.003	12.569	0.001	0.000	12.312	0.007	0.001
caffeine	3.854	0.012	0.001	4.616	0.002	0.000	5.617	0.004	0.000
sulfamethoxazole	0.043	0.086	0.000	0.236	0.060	0.000	0.148	0.017	0.000
carbamazepine	0.003	0.021	0.000	0.009	0.021	0.000	0.040	0.051	0.001
tris(2-chloroethyl) phosphate	0.042	0.053	0.000	0.041	0.055	0.000	0.067	0.070	0.000
estrone	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005
progesterone	0.000	0.091	0.001	0.000	0.000	0.000	0.000	0.000	0.000
gemfibrozil	0.035	0.056	ND	0.093	0.010	ND	0.000	0.000	ND
4-n-nonylphenol	0.434	0.149	ND	0.189	0.077	ND	4.342	0.221	ND
bis(2-ethylhexyl) phthalate	1.793	0.867	ND	1.411	0.753	ND	1.751	0.848	ND

Work Plan FY11/FY12

Analysis and data processing of influent, effluent, and biosolids samples is continuing. Relationships between removal efficiencies and the physical and chemical properties of the compounds will be evaluated to determine if predictive models can be developed.

Informational Resources

Contact: William J. Doucette, Phone (435) 797-3178, E-mail: william.doucette@usu.edu.

LC/MS system for analysis of PCPPs

Extraction of water samples for PCPPs

Water Allocation and Salinity Issues of the Sevier River Basin

Principal Investigators:
Jagath J. Kaluarachchi
Daeha Kim (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  The majority of water in the Sevier River Basin is generated from snow and precipitation from the upper basin, while the major agricultural water demands occur in the lower basin. Water required for agriculture in spring and summer months is mostly available through Otter Creek, Piute, and Sevier Bridge reservoirs, with contributions from smaller regulating reservoirs such as Gunnison Bend, DMAD, and Fool Creek. Water allocation for irrigation is typically conducted in March based on reservoir storages and anticipated runoff. However, given the large uncertainty of anticipated water availability, reliable water allocation has been a concern. Therefore, a reliable estimate of available water in early spring is needed based on available storage volumes in reservoirs and snowfalls in the upper basin, salinity, and information related to true water needs based on existing land use and land cover data. At the present time, groundwater pumped from the basin at a substantial cost is used to dilute surface water flows in order to reduce salinity. The focus of this project, then, is to address the issues of reliably predicting water availability in early spring, identifying cost effective salinity management options in the lower basin, and predicting water needs in the basins based on existing land use and land cover.

- Benefits to the State:

  The Sevier River Basin is an important region of Utah that holds a large agricultural community. As with most other basins in semi-arid Utah, water allocation and salinity issues are affecting full productivity of the basin. A study that addresses water allocation issues in a reliable manner using locally observed hydrologic data can help local communities better plan their annual farming activities. In addition, minimizing salinity of surface water can help produce the full potential crop yield. The methodologies and results coming from this work can help local farming communities effectively and efficiently use available water in a given year.

- Geographic Areas:

  Study Area: Sevier River Basin, Utah.

  Areas Benefited: Similar river basins of Utah.

- Accomplishments:

  Findings: A complete survey of all available stream flow, groundwater, meteorological, land use, and land cover data was conducted. All literature review related to prior studies was also conducted. Based on this information, the work will be conducted in many phases. In Phase I, a simple lumped hydrologic model will be constructed to estimate water balance in a given year based on locally measured data and information. The goal is to use this simplified model to quickly estimate water availability in a given water year so that water allocations can be performed well. The literature review was recently completed and a conceptual model for the proposed hydrologic model was developed.

Results: A summary of available weather and water measurement locations is shown in Figure 1. The proposed conceptual model is shown in Figure 2.

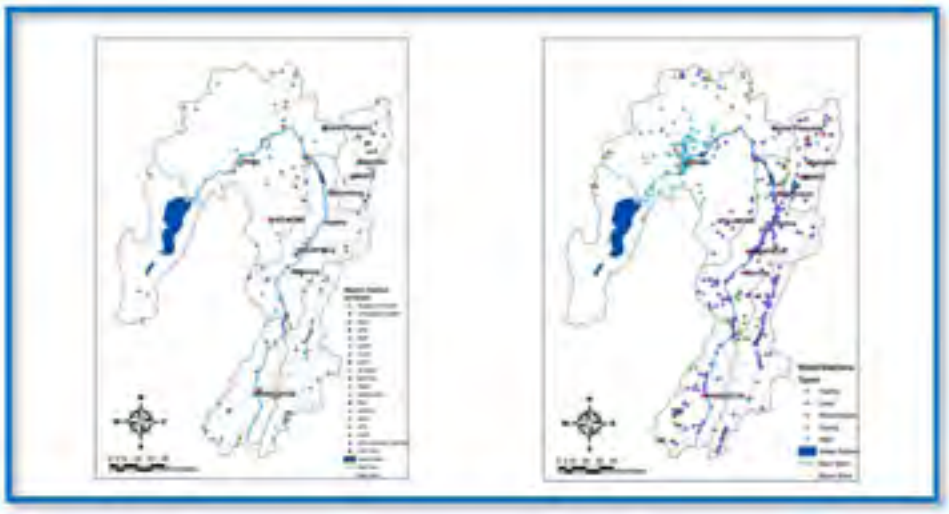


Figure 1. Locations of weather stations and water measurements in the Sevier River Basin.

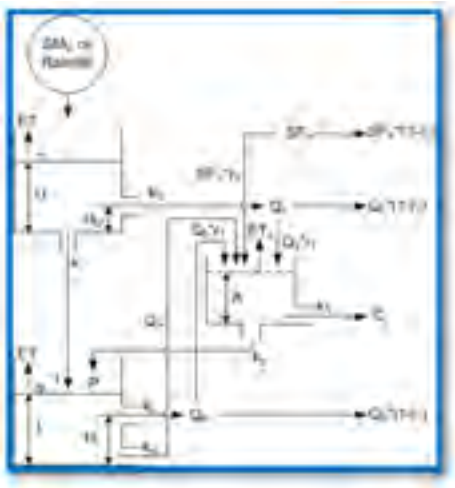


Figure 2. The proposed conceptual model of the lumped hydrologic model for the Sevier River Basin.

Work Plan FY11/FY12

We propose to complete the hydrologic model development and complete a set of scenarios to show model validation and verifications. These simulations will also include model sensitivity analysis to demonstrate the reliability of the proposed model with parameter uncertainty.

Informational Resources

Contact: Dr. Jagath J. Kaluarachchi, (435) 797-3918, E-Mail: jagath.kaluarachchi@usu.edu.

Weber Basin Decision Support System (DSS) Modernization

Principal Investigators:
David K. Stevens

Partners/Collaborators:
- ***Local:*** *Scott Paxman, Weber Basin Water Conservancy District*
- ***Private:*** *Christina Bandaragoda*
  Sanjaya Bandaragoda

Project Description

- Need and Purpose:

  The Weber Basin DSS is a GIS-based modeling and data analysis platform in MapWindow. The DSS is modular in nature and accommodates a variety of additional functional units in the form of plug-ins, which can be used with support from the GIS mapping. This project is redeveloping and modernizing the Weber Basin DSS to allow its continued viability into the future.

- Benefits to the State:

  Specific benefits of the Weber Basin Decision Support project to the State of Utah are:

  1. Modern extensible tools for assessment of watershed/river system flow and water quality.

  2. Improved ability to market software tools for new projects, both in Utah and outside of Utah.

  3. Improved installation protocols so that the software will be updated automatically using modern internet protocols.

- Geographic Areas:

  Study Area: Weber River Basin, Summit, Morgan, Weber, and Davis Counties.

  Areas Benefited: Watersheds statewide.

- Accomplishments:

  Findings:
  The following elements have been completed:

  - Build a distributed hydrology and river flow model for the Weber Basin to provide an alternative set of inputs for the water quality portion of the model (completed).

  - Convert the model interface to Visual C#.Net 2005. (completed).

  Significant progress has been made to:

  - Modify the Weber Basin mass balance model and database to include new flows into Park City from above Rockport (in progress).

Results:

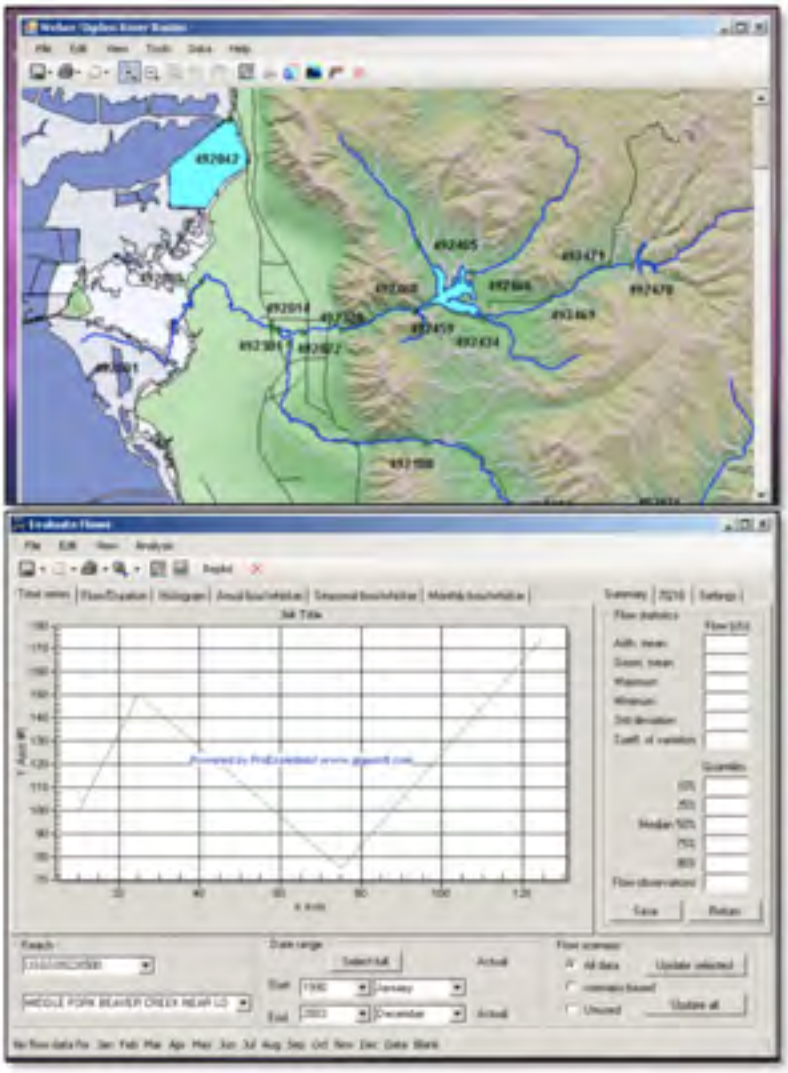
- A working prototype of the modernized Weber Basin DSS.
- A completed distributed hydrology model.

Work Plan FY11/FY12

Integrate the hydrology model and the water quality model into the Visual c# interface.

Informational Resources

Contact: Dr. David K. Stevens, (435) 797-3229, E-mail: david.stevens@usu.edu.



Example from modernized Weber Basin DSS

Water Conveyance, Distribution, and Control

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Conveyance, Distribution, and Control

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
Accuracy of In-Service Water Meters at Low and High Flow Rates	$39,563.51	$40,750.42	$21,972.00
Dam Failure Life-loss Estimation	$10,019.93	$0.00	$0.00
Dam Safety Risk Analysis Computations	$10,019.93	$0.00	$0.00
Dam Safety Risk Management	$10,019.92	$0.00	$0.00
Development of Flow Measurement Procedures for Pipe Installations with Non-Ideal Conditions	$22,261.72	$22,929.57	$0.00
Engineering Analysis of Sprinkler Irrigation Systems for Agriculture and Landscapes	$1,787.87	$0.00	$0.00
Hydraulic Structures for Flood Control and Flood Bypass	$16,747.86	$17,250.30	$0.00
Impact of Distributed Flow Measurement Using S&M Flumes on Irrigation System Water Management	$12,056.53	$15,486.47	$15,951.06
Labyrinth Weir Research	$85,787.11	$88,360.72	$0.00
Low Head Dam Dangers	$2,304.83	$57,373.00	$0.00
Open Channel and Closed Conduit Field Flow Measurement, Maintenance, and Upgrade for the State of Utah	$52,808.07	$54,392.31	$0.00
Open-Channel Unified Flume Calibrations	$20,919.44	$27,058.00	$0.00
Remote Control for the Crockett Canal Head Gates	$5,287.44	$5,285.09	$0.00
Sediment Management for Small Reservoirs: Logan First Dam Study	$9,251.32	$9,528.86	$9,814.73
The Transfer of Agricultural Water to Municipal and Industrial Uses	$16,528.77	$24,500.00	$0.00
Designated Projects		$187,277.69	$37,737.79
Undesignated Projects		$178,950.00	$10,000.00
Total	**$315,364.25**	**$729,142.43**	**$95,475.58**

Accuracy of In-Service Water Meters at Low and High Flow Rates

Principal Investigators:
Steven L. Barfuss
Michael C. Johnson

Partners/Collaborators:

- ***State/Local:*** *Fourteen utilities within the U.S. are formally participating on this project, including four from the State of Utah: Salt Lake City Department of Public Utilities, City of Logan Water and Wastewater Division, Ogden City Corporation Public Utilities Division and City of Orem Department of Public Works.*
- ***Business/Industry:*** *Water Research Foundation is the primary funding agency.*

Project Description

- Need and Purpose:

  This project has evaluated the accuracy of in-service flow meters (5/8- to 2-inch sizes) over a wider range of flow rates than is currently within AWWA standards. The project also investigated the accuracy of "pulled" meters and the accuracy of water meters in systems where particulates in the water may become lodged in the meter or cause meter wear. Nearly 1000 distinctly different new and "pulled" meters of varying type and size were accuracy-tested over the project period. In addition, both historical and current metering standards were researched and documented.

- Benefits to the State:

  Knowledge of the accuracy of in-service flow meters will help State utilities to better understand the capabilities of water meters currently in use in their systems. The data will also provide a foundation for a meter change-out program for each utility, thereby minimizing unmetered water costs and meter purchase costs.

- Geographic Areas:

  Study Area: This project included new commonly used residential water meters and "pulled" water meters from utilities representing the Utah cities of Logan, Mendon, Ogden, Salt Lake City, Orem, and Draper.

  Areas Benefited: Information from this project will benefit all water utilities that use residential water meters, including many cities throughout the State of Utah.

- Accomplishments:

  Findings/Results: Test results have clearly illustrated that a larger-than-expected number of new meters do not meet the AWWA flow registry standard applicable to the meter type. Of the technologies represented during this study, it is evident that not all meter types are created equal and that some manufacturers produce a superior product. Some meter types passed the AWWA registry standard tests more consistently than other meter types. Surprisingly, test results also clearly show that most manufacturers that publicize AWWA standard compliancy do not consistently meet AWWA metering standards. Test results also illustrated that some meter types were capable of accurately measuring flow at flow rates well below and well above the AWWA standard flow rates and that other meter types were not capable of measuring these same flows. The accuracy testing of the pulled meters (shipped to the UWRL from water utilities across the

United States) indicated that water quality (other than sand and other particulates) has a very small influence on the accuracy of meters. Surprisingly, most of the degradation trends for the pulled meter tests correlated very closely to the laboratory endurance degradation trends, with very few notable correlations between interior meter wear and indicated meter accuracy other than some extreme wear cases. Project results also indicated that a surprisingly high percentage of the subject meters passed the AWWA flow rate registry tests in spite of the fact that a relatively large slug of sand had been passed through them. Measurable degradation was noted, however, for the piston type meters at the AWWA minimum flow rate.

Work Plan FY11/12

- Project testing was completed in April 2010.
- Final report due Oct 2010 was re-submitted in its final form in February 2011.
- Publish the project results, including the following five journal papers have been written based on this research:
  - Apparent Losses Due to Water Meter Inaccuracies at Ultra-Low Flows, published in the Journal of American Water Works Association (May 2010).
  - Accuracies of Domestic Water Meters at Low Flows, to be submitted in the Journal of American Water Works Association.
  - Off-The-Shelf Accuracies of Residential Water Meters, accepted for publication in the Journal of American Water Works Association (September 2011).
  - Journal of American Water Works Association
  - Metering and Water Consumption, published in Drinking Water Research (Jul-Sep 2010).
- Final report will be published in Summer 2011.

Informational Resources

Contact: Mr. Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.

WRF Project Website: http://www.waterrf.org/search/detail.aspx?Type=1&PID=4028&OID=0.

Dam Failure Life-loss Estimation

Principal Investigators:
David S. Bowles

Partners/Collaborators:
- ***Federal:*** *USACE, USBR*

Project Description

- Need and Purpose:

  The objectives of this project are to strengthen the practical approaches and guidance for life-loss estimation and evacuation planning for natural and dam, levee, and canal embankment failure floods; to overcome the limitations of the empirical approaches while using readily-available data sources; and to require only a reasonable level of effort to implement.

- Benefits to the State:

  The improvements to dam failure life-loss estimation approaches are applicable to dams, levees and canal embankment in Utah. The use of dam safety risk assessment for dams in Utah can be expected to increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. Our research results are available for use by the Utah State Engineer's Office and practicing engineers in Utah. They are being applied by federal dam safety agencies such as the US Army Corps of Engineers, the US Bureau of Reclamation, the Department of Homeland Security and the Federal Energy Regulatory Commission.

- Geographic Areas:

  Study Area: Utah Water Research Laboratory/Utah State University.

  Areas Benefited: Any county with a dam or levee or that may be potentially impacted by dam, levee or canal embankment failure would benefit from of this project.

- Accomplishments:

  Findings: A spatially-distributed dynamic simulation approach for estimating potential life-loss for dam safety risk assessment has been developed. The LIFESim approach simulates the important processes that have been found to affect the magnitude of life-loss resulting from natural and dam-beach floods. This approach depends on readily-available data sources and requires only a reasonable level of effort for implementation. LIFESim internal modules are (1) Loss of Shelter, including prediction of building performance, (2) Warning and Evacuation, including a dynamic transportation model component, and (3) Loss of Life, including empirical fatality-rate probability distributions [developed by McClelland and Bowles (1999) in the first phase of this project] applied to the number of people estimated by LIFESim to remain in one of three homogeneous flood-lethality zones at the time of arrival of the flood wave. Estimated flood dynamics are obtained from a dam break-flood inundation model such as DAMBRK or HEC RAS and input to the LIFESim model in GIS form.

  Results: The Deterministic or Uncertainty Modes of LIFESim have been demonstrated and applied to a range of USACE dams under a wide range of warning times and conditions and for small and large downstream communities. LIFESim was applied for the Interagency

Performance Evaluation Team (IPET) to estimate pre- and post-Katrina potential life-loss for areas protected by the New Orleans Hurricane Protection System for Headquarters, US Army Corps of Engineers, Washington, D.C.

A simplified version of LIFESim has been developed by the USACE Hydrologic Engineering Center based on our design. The approach has been added to HEC-FIA and is being used in practice by USACE.

The USACE Hydrologic Engineering Center is also developing a user-friendly version of the full LIFESim software and applying it to a major USACE dam.

Work has focused on developing guidance for the assignments of values to parameters in LIFESim and other guidelines for setting up LIFESim applications. In addition, a cooperative comparison of alternative approaches is being planned with USACE, USBR and researchers in The Netherlands, Canada and the UK.

Work Plan FY 11/FY12

Project is complete.

Informational Resources

Contact: Dr. David S. Bowles, (435) 797-4010, E-mail: david.bowles@usu.edu.

Website: http://uwrl.usu.edu/people/faculty/bowles.html.

Dam Safety Risk Analysis Computations

Principal Investigators:
David S. Bowles
Anurag Srivastava (student)

Partners/Collaborators:
- ***State:*** *Matt Lindon, State Engineer's Office*
- ***Federal:*** *USACE*

Project Description

- Need and Purpose:

  The overall objective of this ongoing research is to provide an efficient computational tool for performing dam safety risk analysis computations.

  Proprietary software developed for business risk analysis applications is ill-suited for use in dam safety risk assessment. In response to this need, a generalized dam safety risk analysis model has been developed and is being improved. The eventual goal is to make the model widely available to dam safety professionals to perform dam safety risk analysis computations in a flexible and user-friendly way.

- Benefits to the State:

  The approaches to dam safety risk analysis being developed under this project are applicable to dams in Utah. It is expected that their use for dams in Utah will increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. The research results from this project are available for use by the Utah State Engineer's Office and practicing engineers in Utah. They are being applied by federal dam safety agencies such as the US Army Corps of Engineers (USACE) and the US Bureau of Reclamation. Benefits are expected to include improved understanding, prioritization, and justification of dam safety risk reduction measures.

- Geographic Areas:

  Study Area: Utah Water Research Laboratory/Utah State University.

  Areas Benefited: Any county with a dam or potentially impacted by dam, levee, or canal failure is a beneficiary of this project.

- Accomplishments:

  Findings: Software for efficient, flexible, and generalized event tree analysis called DAMRAE (DAM safety Risk Analysis Engine) has been developed. DAMRAE is now being used by the USACE while development continues. DAMRAE is designed to overcome the limitations of existing business-oriented risk analysis software.

  DAMRAE includes a graphical user interface (GUI) for developing and populating event tree inputs and a generalized algorithm for calculating and post-processing results. It provides estimates of the probabilities of various failure modes and their associated consequences for an existing dam. The post-processing step allows the user to combine results for various loading types (e.g. flood and earthquake) and to make comparisons against tolerable risk guidelines. A

flexible capability exists for obtaining tabular and graphical presentations of estimated risks at different levels of detail.

A generic dam project framework provides the functionality to analyze structural and non-structural risk reduction measures, considered as alternatives or staged measures, to obtain estimates of the risk reduction and the cost effectiveness of risk reduction. Applications made for a dam in a specific safety state can be readily updated by modifying the event tree structure and revising inputs for loading or system response probabilities (SRPs), dam failure consequences, risk reduction cost estimates, and other inputs such as state functions for stage-discharge relationships to represent changes to spillways.

The effects of changes in the event tree structure or changes to probability, state function relationships, or risk estimates consequences can be explored using sensitivity analysis incorporated in DAMRAE. In addition to individual dam applications, DAMRAE can serve as a core engine in a portfolio risk assessment and management system through a linked database. The capability to include the increased probability of failure for a long dam has been included in a special modification of DAMRAE.

Results: Recent work has led to improvements in user interface features and computational and post-processing functions. Development and verification of the database capabilities of DAMRAE facilitate an expansion of functionality in the following ways:

- Continues to increase the maximum dimension of event tree that can be analyzed to account for a wider range of failure modes, complex loading cases, and a wider range of exposure and consequences scenarios.
- Further increases the computation rates.
- Links to a portfolio risk management system.
- Generalizes the applicability to long dams, levees, or canal embankments.
- Provides uncertainty analysis.
- Automates verification of software changes.

Work Plan FY11/FY12

DAMRAE is undergoing continuous improvement of user interface features and computational and post-processing functions. Proposed improvements in the next fiscal year will focus on completing an uncertainty analysis capability and developing a capability for automated verification of software changes.

Informational Resources

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Dam Safety Risk Management

Principal Investigators:
David S. Bowles

Partners/Collaborators:
- ***Federal:*** *USACE, USBR, FERC*

Project Description

- Need and Purpose:

  The overall objective of this ongoing research is to improve the availability and capability of practical risk-informed approaches to dam safety risk management.

- Benefits to the State:

  The approaches to dam safety risk management being developed under this project are applicable to dams in Utah. It is expected that their use for dams in Utah will increase as a direct result of National Dam Safety Program initiatives in both risk ranking and potential failure modes analysis. The research results are available for use by the Utah State Engineer's Office and practicing engineers in Utah. They are being applied by federal dam safety agencies such as the US Army Corps of Engineers, the US Bureau of Reclamation, the Department of Homeland Security and the Federal Energy Regulatory Commission. Benefits include improved understanding, prioritization, justification of dam safety risk reduction measures and portfolio risk management for dam safety.

- Geographic Areas:

  Study Area: Utah Water Research Laboratory/Utah State University.

  Areas Benefited: Any county that is potentially impacted by dam, levee or canal failure is a potential beneficiary of this project.

- Accomplishments:

  Findings: For almost three decades, Utah State University researchers have developed procedures that explicitly consider the risks associated with the performance of dams. They have also applied these procedures to about 750 dams in Utah, in other parts of the United States (including dams owned by the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers and some regulated by the Federal Energy Regulatory Commission), and in Australia, Spain and England.

  Results: Information obtained from these applications has been used to support many decisions that improve the safety of existing dams. Applications have provided an opportunity to field-test procedures resulting from research and have lead to the identification of additional research needs. Training programs have been given on six continents to the major dam safety professional organizations and to federal agencies with dam safety responsibilities. This research has contributed to international guidelines, and we have assisted with the development and review of national, regulatory, and federal agency guidelines.

  Some specific areas of focus in the past year have included the following:

1. Portfolio Risk Management: Development of a scalable screening procedure for large portfolios in which screening is an initial step in establishing a portfolio risk management process. Development of a qualitative risk assessment process for owners and regulators that have limited resources, such as those regulated by the states.

2. Tolerable Risk Evaluation: Continued work on developing practical approaches to using information from tolerable risk evaluation to make dam safety decisions on individual dams and portfolios of dams. Topics includes justifying tolerable risk limits, investigating the ALARP (as low as reasonably practicable) and disproportionality principles, setting guidelines for progressive risk reduction, establishing a basis for when short-term or interim risk reduction is justified, and establishing the role of shared responsibility for risk management, including emergency management agencies and local planning entities.

3. Uncertainty Analysis: Dams exist in an environment of risk and uncertainty. This work addresses the following areas:
   a. Characterizing uncertainties associated with extreme floods and earthquakes.
   b. Developing practical approaches for uncertainties in dam safety risk analysis.
   c. Evaluating the significance of uncertainties in risk analysis and risk evaluation results and assessing their implications for dam safety decision-making.
   d. Guiding decision makers regarding interpretation of the uncertainties in risk assessment outcomes.

Work Plan FY11/FY12

No work planned - Project completed.

Informational Resources

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Development of Flow Measurement Procedures for Pipe Installations with Non-Ideal Conditions

Principal Investigators:
Steven L. Barfuss
Devin Stoker

Partners/Collaborators:
- ***State:*** *Utah Department of Natural Resources, Division of Water Rights*
- ***Business/Industry:*** *Terry Henderson, FloSonics*

Project Description

- Need and Purpose:

This project is developing procedures to improve flow measurements where clamp-on ultrasonic flow meters are used to measure flow in non-ideal piping configurations. The State of Utah promotes the proper allocation of water rights and is interested in information that improves the accuracy of flow measurements.

Field technicians who make a career of measuring flow rates for irrigation companies, power companies, and municipalities have indicated that this type of research has great value to them. Only a very small percentage of all field piping has adequate lengths of straight pipe between the metering location and disturbance sources such as valves, pipe elbows, or pumps to accurately measure flow. Because flow meter manufacturers do not have procedures for non-ideal applications, the field technicians are left to their own expertise to "tweak" or "estimate" the flow rate from the flow indicated by reading the meter.

An example of a poor approach condition is shown in Figure 1, a photograph of a pump on the Lower Bear River, located in Northern Utah. As seen in the photograph, the ultrasonic meter was placed just inches downstream from a 90-degree bend and is extremely close to the pump intake.

Figure 1. Bullen Farms Pump #43 (Courtesy: Utah Division of Water Rights)

- **Benefits to the State:**

  The improved accuracy of flow measurements resulting from this study will ultimately improve water rights allocation, system management, and water conservation in the State of Utah.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah, with application to all states in the U.S.

- **Accomplishments**:

  Findings: Laboratory experiments and numerical CFD simulations confirmed that the distorted velocity profiles downstream of a single 90-degree elbow adversely affect ultrasonic flow measurement accuracy. The numerical models were verified to match the physical measurements to a reasonable level of confidence. The trends observed in the measured velocity profiles and in the CFD simulations coincide with the recommendations of straight pipe lengths and installation instructions given by ultrasonic flow meter manufacturers.

  Results: The results of the physical scenario studied show that the ultrasonic flow meter always under-predicted the true flow rate when installed in non-ideal piping. By integrating the velocity profile of the fluid across the ultrasonic signal path and comparing the resulting total velocity to the same velocity for a fully-developed and symmetric velocity profile, the numerical models that were solved can potentially be used as a tool to apply corrections to ultrasonic flow meter measurements. For the physical scenario of a single 90-degree elbow, flow measurement error was reduced by nearly 90% by applying a developed correction equation.

Work Plan FY11/FY12

- Conduct field velocity profile measurements downstream of a selected number of flow disturbing devices to better understand the magnitude and the degree of disturbances associated with these setups and to validate the laboratory measurements.
- Investigate the large number of possible non-ideal installation scenarios that could be studied more in-depth using CFD.
- Using CFD and the known range of non-ideal flow conditions, generally apply other simulated non-ideal piping scenarios to the application of ultrasonic metering use.
- Develop and apply similar correctional adjustments to new data using the integrated velocity profile procedure for other piping configurations.
- Determine potential cost savings for applications where ultrasonic flow measurement is used in non-ideal piping scenarios.
- Continue to develop procedures for installation or flow measurement correction.

Informational Resources

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Engineering Analysis of Sprinkler Irrigation Systems for Agriculture and Landscapes

Principal Investigators:
Gary P. Merkley
Zhang Lin (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  In Utah's arid climate, both crop production and maintenance of residential landscapes and gardens depend on irrigation. This project's goal was to improve the efficiency and uniformity of water delivery in drip and sprinkler irrigation systems design and operation. This required hydraulic measurements and analysis of data for characterizing some components of irrigation systems and sprinklers. This study provides a better capability to advise farmers about irrigation operations and to provide higher-quality technical designs (and re-designs) of irrigation systems in Utah. The same information for irrigated lawns and landscapes can lead to improved water management in the state. We tested only sprinklers that are commonly used in Utah for agriculture and for landscapes.

- Benefits to the State:

  Sprinkler irrigation is prevalent in agriculture throughout the state, but there are many examples of systems operating with low water application uniformity. Through this study, we can provide better advice to farmers in the use and operation of periodic-move sprinklers for irrigation, as well as better technical analysis for re-designs of existing systems and for new designs. We can also provide the same for some sprinklers that are used to water lawns and landscapes in Utah.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Most of the State of Utah wherever periodic-move sprinklers are used or will be used in the future and landscapes that are watered with fixed sprinklers.

- Accomplishments:

  Findings: The data collected over spring and summer 2010, and the subsequent data analysis and model development, indicated that sprinkler water application uniformity can be predicted for field-scale systems. Results also indicated that maintaining the correct average pressure was more important than pressure variations due to topography and friction losses.

  Results: Two papers were published that show how the research can be used to predict water application uniformity with sprinkler irrigation.

Testing a Rainbird sprinkler at the Utah Water Research Laboratory

Setting up a no-splash barrier at the Utah Water Research Laboratory

Work Plan FY11/FY12

This project was completed in November 2010.

Informational Resources

Contact: Dr. Gary P. Merkley (435) 797-1139, E-mail: gary.merkley@usu.edu.

Website: http://www.neng.usu.edu/bie/faculty/merkley/.

References:

Zhang, L., G.P. Merkley (2011). Relationships between common irrigation application uniformity indicators. *Irrig. Sci.* (published online January 28, 2011). DOI 10.1007/s00271-011-0264-6.

Zhang, L., G.P. Merkley, K. Pinthong (2011), Assessing whole-field sprinkler irrigation application uniformity. *Irrig Sci.* (published online July 7, 2011). DOI 10.1007/s00271-011-0294-0.

Hydraulic Structures for Flood Control and Flood Bypass

Principal Investigators:
William J. Rahmeyer

Partners/Collaborators:
- ***Local:*** *Utah County and cities*
- ***Federal:*** *U.S. Army Corps of Engineers, U.S. Bureau of Reclamation*

Project Description

- Need and Purpose:

  Flood control has become even more of a critical issue for the State of Utah for several reasons, one of which is development along and within floodplains. Urban growth not only contributes to larger floods, but also reduces the size and ability of our flood ways and channels to convey major flows. Research for this project was conducted on three new and innovative concepts in hydraulic structures that will have a direct impact and benefit for Utah communities.

  The retrofit of dams and reservoirs for increased storage is an important issue. Such projects involve a unique design of a spillway and control structure that can both raise the pool elevation of the reservoir and also increase the outflow capacity of the spillway. Many of the dams and spillway structures in the Western United States are located in the diversion channels that were used to construct the reservoirs and dams. Widening and excavating the channels to increase flow capacity is too expensive, so new ideas and designs for the spillway crest control sections are being researched. The effects of road crossing and bridges also have a significant effect on flood control and flood bypass.

- Benefits to the State:

  The knowledge and methodology gained from this research in the retrofit of dams, hydraulic structures, and road crossings will directly benefit almost all of the cities and counties in the State of Utah by providing a better understanding of the need to retrofit or rehabilitate dams and hydraulic structures, as well as the costs and design parameters associated with the rehabilitation. Utah will be better prepared to respond to issues of flood control, emergency response, and flood and storm water management. The understanding gained from this research and how it applies to Utah will positively impact federal guidelines and requirements of flood and storm water control for Utah.

- Geographic Areas:

  Study Area: Entire State of Utah.

  Areas Benefited: All counties and cities in Utah.

- Accomplishments:

  Findings: The concepts that were researched this year focused on the remediation of a dam and spillway for both an increase in reservoir capacity and an increase in the outflow hydrograph of different storm events (i.e. 100-yr, 500-yr, and PMF). The use of standard ogee crests and broad crested weirs were investigated with different lengths, rotations, and the addition of notched weirs. However, the most significant accomplishment of this year's work was conducting the study by incorporating both numerical (CFD) modeling and physical modeling. A paper was

presented that discussed the new application of combining physical and numerical models into a composite model. This paper was based on the ogee and broad crested weirs from this year's studies.

A second area of study focused on the transport of bedload sediment in culverts. Culvert bedload transport is a significant cause of culvert and road crossing failures in Utah. A laboratory experiment was conducted on sediment transport in culverts, and a paper and a conference presentation were then made in the 34th IAHR World Conference.

A third area of study focused on the problem of adding bridge columns in a waterway for the widening of a bridge. For a bridge crossing in Idaho, it was found that increasing the length of the column rows could cause flow oscillation and waves in the waterway. The types of wave oscillations were highly erosive and damaging to both bridge abutments and channel banks and levees. A conference presentation was made on this work.

Results: Work was completed and information prepared on:

- Eliminating Wave Oscillations for the I-84 Bridge Crossing of the New York Canal, Boise, Idaho.
- Physical Modeling and Numerical Modeling of the Success Dam.
- Impact of culvert design on flood control and bypass, since sediment deposits in culverts limit the flow capacity of the culverts and the road crossings that incorporate them.
- Use of UAV's for floodplain assessment and the impact of culvert sedimentation on floodplains.

Work Plan FY11/FY12

- Participate with the Utah Floodplain and Storm Water Management Association and the Utah Office of Homeland Security in developing a series of joint workshops on flooding and floodplain problems.
- Continue research related to flood routing, management, and planning; retro-fitting dams for drought control and storage; rehabilitation and retro-fitting of spillway control structures; and eliminating wave oscillation from bridge columns.

Informational Resources

Contact: Dr. William J. Rahmeyer, Phone (435) 797 2938, E-mail: william.rahmeyer@usu.edu.

References:

Barfuss, S., W.J. Rahmeyer, and B. Savage (2011). Benefits and Limitations of Composite Modeling of Hydraulic Structures. *IAHR 34th World Congress 2011, Conference Presentation*.

Goodridge, W. and W.J. Rahmeyer (2011). Culvert Design for Flood Routing Considering Sediment Transport. *IAHR 34th World Congress 2011, Conference Presentation.*

Clegg, J., W.J. Rahmeyer, and B. Foote (2011). Modeling of Wave Oscillations from the I-84 Bridge Crossing of the New York Canal in Boise, Idaho. *2011 Project Development Conference*, Boise, ID. April.

Impact of Distributed Flow Measurement Using S&M Flumes on Irrigation System Water Management

Principal Investigators:
Blake P. Tullis
Travis Hollingshead (student)

Partners/Collaborators:
- ***State:*** *Lee Sim, State of Utah, Division of Water Rights*

Project Description

- **Need and Purpose:**

  Accurate flow measurement in water distribution systems is essential for developing and monitoring best water management practices. Many water distribution systems in the State of Utah have a very limited number of flow measurement structures, if any, and in many cases the accuracy of the data is suspect. One of the primary reasons for the limited number of flow measurement structures is the cost associated with such structures, since most water distribution systems have limited operating capital.

  The S-M flume, however, represents a relatively low-cost alternative for open channel flow measurement. The S-M flume consists of a rectangular channel section (inserts can be fabricated for installation in natural, trapezoidal, or other channel shapes) and vertical half cylinders installed on the sidewalls opposite one another. The half cylinders are comprised of PVC pipe cut in half longitudinally. The half cylinders create a local flow acceleration region where a critical section can occur, creating a control point and a unique head-discharge relationship. The upstream water depth is typically measured inside the PVC pipe, with a hole drilled through the sidewall of the pipe to create a hydraulic connection. In some cases, these flumes can be designed as semi-portable (i.e., the insert-type would be portable; however, the flume would likely need to have additional upstream guide walls installed upstream to transition the flow in to the measurement flume).

  Some research has been previously performed on S-M flumes. The objectives of this study would be to design two S-M flumes for installation in the water distribution system of the Hyde Park Irrigation Company, verify the head-discharge relationship of the flumes at the Utah Water Research Laboratory, and install the flumes in Hyde Park. This project will also evaluate the durability, longevity, and long-term accuracy of the flumes and determine the impact of the flow measurement data on the water resources management program of the Irrigation Company. Observations regarding ease of installation, public perception, and maintenance issues will also be provided.

  The scope of work associated with this project is summarized as follows:
  - Coordinate activities with the Hyde Park Irrigation Company, who have expressed their support for the project.
  - Identify approximately two different canal locations in the water distribution system where flow measurement structures are needed.
  - Design an S-M flume for each location based on flow requirements and canal size using published data in the literature.
  - Construct and test a lab-scale version of each S-M flume (if the prototype scale is too large) at the UWRL.
  - Construct and install prototype S-M flumes in the field, and perform a field calibration for verification.

- Develop a discharge monitoring system, collect discharge data, and determine how the data can be used to benefit the water management practices of the Irrigation Company.

- **Benefits to the State:**

  Quantifying the flow rates of irrigation water is important to the Division of Water Rights, the agency responsible for issuing, managing, and reallocating water rights and usage in the State of Utah. State distribution systems and local irrigation water companies have the responsibility of insuring that the appropriate water quantities are provided to the individual water users. This pilot-study will help to determine the practicality and potential usefulness of using the relatively inexpensive S-M flumes as open channel flow measurement devices in Utah. As more flow data become available, the ability to manage the water resources in the State of Utah will improve. Aaron Hunt and Lee Sim (Utah Division of Water Rights) are key supporters of this study.

- **Geographic Areas:**

  Study Area: All work will be completed in the Hydraulics Lab at the Utah Water Research Laboratory (UWRL) at Utah State University.

  Areas Benefited: Irrigation systems Statewide.

- **Accomplishments:**

  Findings/Results: This project began half way through FY10-11. Three S&M flumes were fabricated (8-ft, 1-ft, and 1-ft) and installed at different locations in the canal system supplying water to Hyde Park distribution system and at local diversion points in the Hyde Park distribution system. A fair amount of troubleshooting was required in order to solve problems associated with installing a flow measurement structure in a channel with an earthen invert (primarily scour issues). Flow measurement data are being collected during the 2011 irrigation season for analysis.

Work Plan FY11/FY12

Because of the late start of the 2011 irrigation season (late June), the majority of the data collection and data analysis will occur in FY11-12. Issues identified during the field study will potentially be investigated in the laboratory (UWRL) in an effort to develop a better understanding of S&M flume design, operation, and troubleshooting. The flow data will be used to identify possible discrepancies between amount of water allotted to an end user and the amount of water actually consumed by the end user in a system where local flow measurement has not been previously implemented.

Informational Resources

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Labyrinth Weir Research

Principal Investigator(s):
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Brian Crookston (student)
Ricky Anderson (student)
Sam Tingey (student)
Nathan Christensen (student)
Mitch Dabling (student)

Partners/Collaborators:

- ***Local**: Everett Taylor, DNR-Water Rights*

Project Description

- Need and Purpose:

  With revisions of probable maximum flood flows and greater emphasis on dam safety, many spillways require rehabilitation or replacement. Labyrinth weirs are often a favorable design option as these 'folded linear weirs' facilitate flood routing and increase base-flow reservoir storage capacity. However, the many geometric design parameters and the distinct hydraulic behaviors of these structures can make engineering an optimal weir design difficult. Also, current information and data available for labyrinth weir design and evaluation are incomplete.

  The study objectives include improving the design and analyses of labyrinth weir spillways by consolidating available data sets and information, assimilating and expanding current design methodologies, and utilizing physical models to investigate areas in need of research. Two variations of the labyrinth weir design, the piano key weir and the oblique weir were also evaluated in this study.

  - Piano key (PK) weirs represent a modified version of a traditional labyrinth weir that was developed specifically to increase discharge capacity of spillways with a limited footprint that sit atop narrow concrete gravity dams.

  - Oblique weirs can be installed in canals as flow measurement or flow diversion structures. Traditional linear weirs are installed normal to the flow direction, while oblique weirs are installed as angle to achieve a longer weir length and higher discharge capacity for a given upstream flow depth.

- Benefits to the State:

  The results of this study may increase the sustainability of existing dam with undersized spillways. Labyrinth weirs are a commonly used alternative for increasing the spillway capacity over a linear weir without increasing the width of the spillway apron. PK and oblique weirs represent other alternative weir designs that could be beneficial water control structures in Utah.

- Geographic Areas:

  Study Area: All work will be completed in the Hydraulics Lab at the Utah Water Research Laboratory (UWRL) at Utah State University.

  Areas Benefited: Surface spill flow control structures are common to nearly all dams, so the application of the study results could extend to all counties.

- **Accomplishments:**

  As part of this study, two separate experimental studies were carried out in FY10-11, which include a labyrinth weir study and a piano key weir study.

  Findings/Results: Approximately 40 different laboratory-scale physical models of various labyrinth weir geometries (sidewall angle and crest shape) were evaluated for discharge coefficients, nappe stability and aeration characteristics, and local submergence effects. Labyrinth weirs were tested for both channel and reservoir applications (i.e., some flow control structures installed in discharge channels, others in or directly adjacent to the reservoir). Tests on geometrically similar and geometrically dissimilar weird with 6-, 12-, and 36-inch weir heights were conducted to investigate the possibility of size-scale effects in labyrinth weir head-discharge relationships.

  The standard PK weir design was evaluated in the laboratory relative to a rectangular labyrinth weir with the same crest layout (different footprints). The PK weir proved to have a larger discharge capacity than the rectangular labyrinth weir. The influence of a number of PK weir geometric variation were also evaluated experimentally, including variations in the inlet to outlet apex width ratio. Bullnoses were added to the upstream abutments, and a parapet wall was added on top of the weir that featured an improved crest shape (half-round).

  The oblique weir research was completed in FY10.

Work Plan FY11/FY12

The arced labyrinth weirs study and the PK weir study of reservoir vs. channel applications and submergence will be completed in FY 11-12. The results of these studies will be presented in journal publication submissions in FY11/FY12. Work will continue on disseminating the results of the oblique weir study.

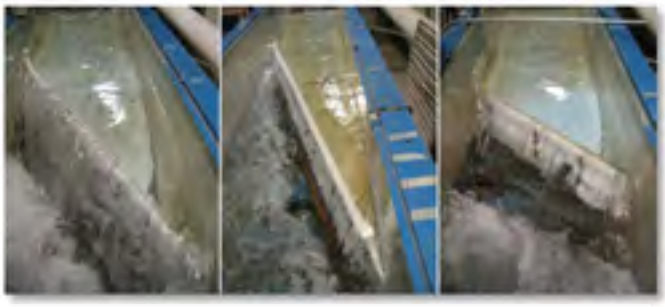
Informational Resources

Contact: Dr. Blake P. Tullis, (435) 797 3194, E-mail: blake.tullis@usu.edu.

Website: http://uwrl.usu.edu/people/faculty/tullisb.html.

Labyrinth Weir Study (UWRL)

Piano Key Weir Study (UWRL)



Oblique Weir Study (UWRL)

Low Head Dam Dangers

Principal Investigators:
Michael C. Johnson
Riley J. Olsen

Partners/Collaborators:
- ***State:*** *Mike Suflita, Utah DWR; Utah Division of Parks and Recreation; Utah Division of Forestry and State Lands*
- ***Local:*** *Salt Lake County Parks and Recreation; Unified Fire Authority*

Project Description

- Need and Purpose:

Low-head dams are small dams, usually no taller than 5 to 10 feet that can be found on rivers throughout Utah and the United States. They run from bank to bank across a river with the purpose of impounding small amounts of water to be used for irrigation, municipalities, industry, and recreation. Many people drown at low-head dams each year due to a dangerous countercurrent known as a "hydraulic" that is created as water flows over the dam. In fact, two kayakers drowned at a low-head dam on the Jordan River in Murray in August 2010. Because of this deadly flow pattern, low-head dams have been nicknamed "drowning machines" by paddling enthusiasts as well as water safety experts. The purpose of this study is to identify possible solutions that could be used to eliminate the deadly current at low-head dams.

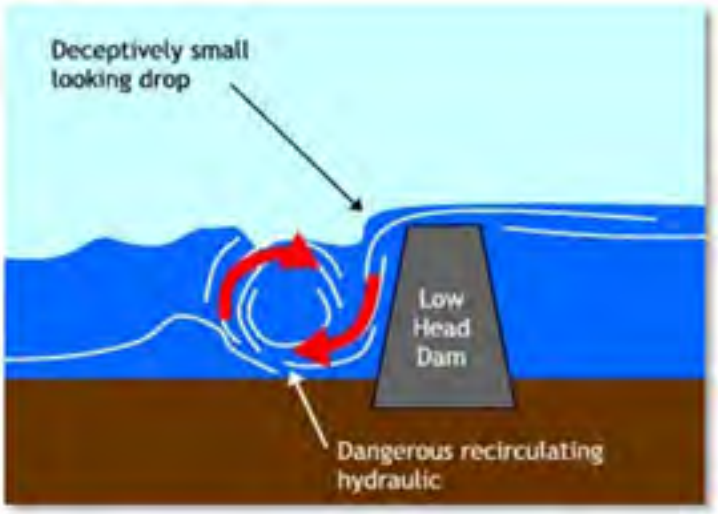


Figure 1: The countercurrent, or "hydraulic," created when water flows over a low-head dam.

- Benefits to the State:

The intent of this project is to identify possible solutions to make low head dams safer. If the low-head dams can be made safer by altering the flow, a benefit would be a reduction in the number of drownings caused by low-head dams in the State of Utah and world-wide. Informing the public of the dangers present at these structures, as well as possible remediation options that dam owners could implement, would make for safer water related recreation. Also, because many low-head dams are owned by the State of Utah, liability could be reduced at dams where a solution can be implemented.

- Geographic Areas:

  Study Area: The Winchester Crossing dam site on the Jordan River in Murray, as well as several other low-head dam sites throughout the state that are to be determined as research continues.

  Areas Benefited: The results of this project should be applicable to dams similar in size and shape of those studied, and to low-head dams throughout Utah, the United States, and even the World.

- Accomplishments:

  Findings: The hydraulic processes present at low-head dams have been studied in depth by hydraulic engineers for decades, but surprisingly, very few studies have been done with the purpose of improving public safety at these structures. Some solutions have been found, such as the complete removal of the dam or the addition of steps to the downstream side of the dam that break up the countercurrent, but these solutions are often impractical because of the large costs associated with implementation. Also, if the dam still serves a purpose, complete removal of the structure is obviously not a possibility.

  Results: Because this project is still in the early stages of research, no results have been published as of yet. Upon completion, the results of this study will help to identify means to enhance public safety at low head dams. The results could also be published in the *Journal of Hydraulic Engineering*, and in whitewater and other recreational publications.

Work Plan FY11/FY12

Continue literature review of low-head dams, implement the Flow 3D software to model the low-head dams, and identify potential remedies for making the low-head dams safer.

Informational Resources

Contact: Dr. Michael C. Johnson, (435) 797-3176, E-mail: michael.johnson@usu.edu.
Mr. Riley J. Olsen, (435) 797-3152, E-mail: riley.jay.olsen@aggiemail.usu.edu.

Open Channel and Closed Conduit Field Flow Measurement, Maintenance, and Upgrade for the State of Utah

Principal Investigators:
Steven L. Barfuss
Devan Shields

Partners/Collaborators:
- ***State:*** *James Greer, Utah DWR*
  Gertrudys Adkins, Utah DWR

Project Description

- Need and Purpose:

  Limited and depleted water resources have become an issue of increased concern, especially in Utah where the arid land requires irrigation to produce ample crops. As a result, water distribution systems have realized the importance of accurately measuring water used in their systems. Understanding the available methods and measurement devices and their specified accuracies is vital to ensuring that the best achievable distribution and use of water is occurring.

  Initial investigations showed that a large number of flow measurement devices throughout the State of Utah were not measuring flow at the accuracy design manufacturer specifications claim. The purpose of this project has been to determine major contributors to flow measurement errors and to assess the devices that exhibit these errors in an attempt to provide direction for reducing these measurement errors.

- Benefits to the State:

  Improved accuracy of flow measurements throughout the State of Utah will ultimately improve the allocation of water rights. Over time, small errors in flow measurement can add up to very large errors in the allocation of water rights. This project is generating a database of information to determine which flow measurement structures have the greatest need for remediation, repair, or recalibration.

- Geographic Areas:

  Study Area: Entire State of Utah.

  Areas Benefited: All irrigated areas of Utah.

- Accomplishments:

  Findings: 163 flow measurement device assessments have been performed as of July 29, 2011. These devices include 107 Parshall flumes, fifteen ramp flumes, one cutthroat flume, thirteen weirs, fourteen rated sections, three sluice gates, seven ultrasonic meters and five magnetic meters. Only thirty-one percent of the tested devices measured flow within manufacturer design specifications. The remaining sixty-nine percent exhibited flow measurement errors in excess of the design specifications. Some of the major contributing factors to inaccuracies were uneven settlement, sediment and moss buildup in and around the structure, corrosion or damage to the device, and uneven flow where head measurements are taken. These factors create incorrect measurements that prevent water users from receiving their true water allocations.

Results:

- A list of all visited sites and their locations, measurement device types, accuracies, and problems were sent to the Utah Division of Water Rights.
- Verification certificates for each site visited were created and sent to the measurement device operator, the Utah Division of Water Rights, and any other interested party.
- Five journal papers have been written and submitted to peer-reviewed journals.

Work Plan FY 11-12

- Continue to locate flow measurement devices throughout the State of Utah.
- Visit flow measurement device sites, perform verification tests to determine the accuracy of the flow measurement devices, and document concerns for error associated with each structure.
- Continue to report findings to the Utah Division of Water Rights and encourage the improvement and maintenance of degraded or inaccurate flow measurement devices.

Informational Resources

Contact: M. Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Devan J. Shields (435) 797 3231, Email: dev.j.shields@aggiemail.usu.edu.
Mr. Jesse Pope (435) 797 3231, Email: jesse.pope@aggiemail.usu.edu.

Examples of Flow Measurement Devices Tested in Utah

Open Channel Unified Flume Calibrations

Principal Investigators:
Gary P. Merkley
Sathaporn Temeepattanapongsa

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Over the long term, water shortages and water quality issues in Utah will continue to increase and will become more severe in the future. Good water management requires the ability to measure flow rates, yet the capacity to measure discharges in canals is very limited in most open-channel conveyance and distribution systems in Utah. For example, free-flow calibrations are often used when flumes operate under submerged-flow conditions, which results in large measurement errors due to a lack of understanding of the flow regimes in flumes. Laboratory experiments showed that there is no single value of transition submergence for each flume size, even though this has been the assumption and practice for several decades.

  Previous work using UWRL experimental data showed how a single equation could be used for a 3-ft Cutthroat flume. Since Cutthroat, Parshall, and many other flume geometries use the same calibration equations, the findings can logically be extended to those flume types.

  This project will generate calibration data over a range of submergences, and analyze those results to come up with unified (free and submerged) calibration equations for each standard flume size, and for all Cutthroat flume sizes (standard or not), if possible. The results will be verified using existing experimental data, especially for free-flow conditions. Finally, the results will be applied to flumes in irrigation canals in Utah and elsewhere, eliminating the confusion and errors associated with distinctions between free and submerged flow, and will improve calibrations by eliminating the need to determine transition submergence.

- Benefits to the State:

  The State of Utah will benefit through an improved ability to calibrate Parshall and Cutthroat flumes in irrigation and other canals. The new calibrations will combine free and submerged flow regimes into a single equation, thereby improving the ability to correctly measure discharges in irrigation and other canals for purposes of water management, water rights, and water quality analyses.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Most of the State of Utah.

- Accomplishments:

  Findings: Several hundred 3-D hydraulic simulations have been completed and the results have been compared with laboratory and field data. Results indicate that mathematical relationships can be defined for free flow conditions in all sizes of Cutthroat flumes.

Results: Standardized relationships have been developed for free-flow conditions for any size of Cutthroat flume.

Work Plan FY11/FY12

Some additional simulations will be run to fill in some missing data points. The data will continue to be analyzed to develop unified calibrations for submerged-flow conditions. Two refereed publications on the work will be prepared, and the project will be completed by late spring 2012.

Informational Resources

Contact: Dr. Gary P. Merkley (435) 797 1139, E-mail: gary.merkley@usu.edu.

Website: http://www.neng.usu.edu/bie/faculty/merkley/.

Remote Control for the Crockett Canal Head Gates

Principal Investigators:
Gary P. Merkley
Tyler Richards

Partners/Collaborators:
- ***Local: City of*** *Logan*
- ***Business/Industry:*** *Logan canal companies*

Project Description

- Need and Purpose:

  The objective of this project is to provide design and installation services to the affected canal companies for remote control of the Crockett Canal head gates, thereby permitting faster closing of the gates when rain begins to fall during the irrigation season. When a sudden rain occurs, it is imperative that the gates be closed as quickly as possible to discontinue Logan River water from entering the canal. This will increase the capacity of the canal to accept storm-water runoff and avoid canal overtopping and subsequent water damage to adjacent properties. This is difficult to do when the water masters or other canal company personnel are far from the head gates. For years, the canal companies have asked for assistance with the design and installation of a remote-control system for these gates, facilitating their timely closing at the onset of a precipitation event during the irrigation season (April to October each year).

- Benefits to the State:

  The proposed work will lead directly to improved water management in several of the most important Cache Valley, Utah irrigation canals and will greatly help alleviate storm-water runoff issues on properties near the canals. This will benefit all of the canal water users, as well as the City of Logan and other neighboring cities through the improved capability to deal with storm water runoff.

- Geographic Areas:

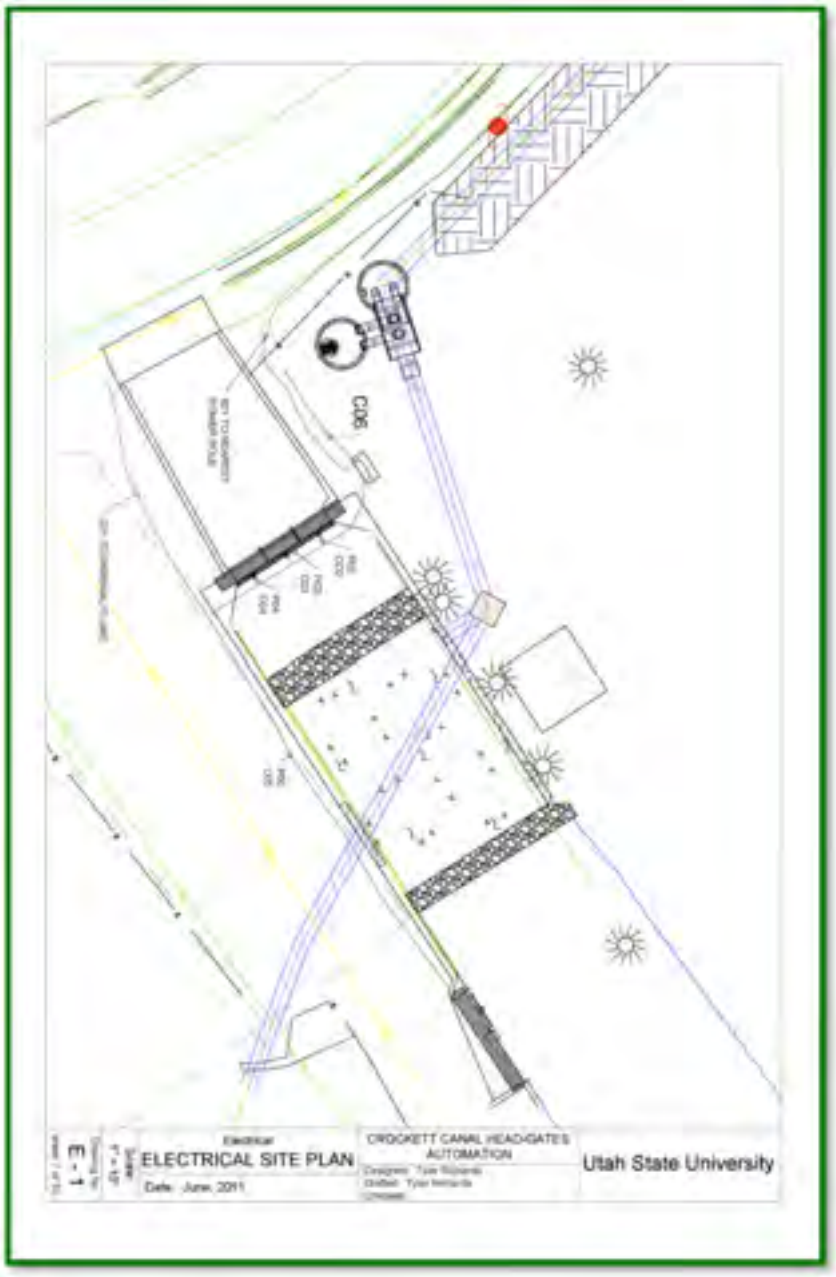
  Study Area: Cache Valley, Utah.

  Areas Benefited: Cache Valley, Utah.

- Accomplishments:

  Findings: We have worked closely with Logan canal company representatives and made many site visits. The project has developed alternative designs and budgets. The canal companies have approved the recommended design and will purchase the equipment with their own funds.

  Results: Thus far, the systems have been designed for gate automation and remote control and monitoring. Currently, Logan City approval of the designs is pending, and then procurement will begin.



Work Plan FY11/FY12

After the designs are approved by the City Engineer for Logan City, the procurement of the equipment and materials will begin, and installation is expected to occur after the 2011 irrigation season, in the fall of 2011. The project will be completed by December 31, 2011, and a report will be prepared about the project accomplishments.

Informational Resources

Contact: Dr. Gary P. Merkley (435) 797 1139, E-mail: gary.merkley@usu.edu.
Website: http://www.neng.usu.edu/bie/faculty/merkley/.

Sediment Management for Small Reservoirs: Logan First Dam Study

Principal Investigators:
Lizzette Oman
Mac McKee

Partners/Collaborators:
- ***Local:*** *Ben Barrett, Utah StateUniversity Facilities*
  Stan Kane, Utah StateUniversity Facilities
  Reid Olsen, Utah StateUniversity Facilities
- ***State:*** *Mike Rickert, Utah Department of Environmental Quality*

Project Description

- Need and Purpose:

  Sediment eventually fills reservoirs, quickly in some cases, but usually not for many years. In percentage terms, the highest rates for loss of storage are found in the smallest reservoirs, while the lowest rates are in the largest reservoirs. The life span of a reservoir is determined by the rate at which sediments reduce the storage capacity. One way to preserve reservoir storage is to flush or sluice sediments through outlet works within the dam. When this is done, however, severe damage can be done to valuable downstream fisheries and fish habitat.

  Research on sediment management methods has focused almost exclusively on maintaining reservoir capacity and extending the economic lifespan of the dam. Little work has been done to understand the downstream consequences that flushing or sluicing might have on biotic resources. This project is creating a set of guidelines intended to help develop sediment management plans for small run-of-river reservoirs in Utah. The objective of such plans is to minimize the negative consequences of sediment flushing or sluicing on downstream aquatic resources and water quality.

- Benefits to the State:

  The state will benefit from the state guidelines that will be made available for all managers of run-of-river reservoirs in Utah. Properly applied, the guidelines will help reservoir operators minimize the negative consequence of sediment flushing or sluicing on downstream aquatic resources, water quality, and other water users. It will also allow water managers to extend the life of the run-of-river reservoirs in Utah.

- Geographic Areas:

  Study Area: First Dam on the Logan River and the Logan River Basin above First Dam.

  Areas Benefited: Small run-of-river reservoirs throughout the State of Utah, so the potential benefit is statewide.

- Accomplishments:

  Findings: We have learned several things from the flushing experiments conducted on First Dam:

  - Monitoring must happen during flushing/sluicing events in order to evaluate the performance of the event and to control the flushing/sluicing procedures during the event.

- River flow is the main factor in terms of planning for a flushing experiment.
- During a flushing event, close attention must be given to flow data from real-time sites in order to verify that the hydraulic conditions required by the reservoir outlets are being met by the prevailing flow levels into the reservoir.
- For the several days that a flushing/sluicing event is conducted, available river flow forecasts must be periodically examined to better anticipate future flow conditions and regulate hydraulic operations at the dam.
- Outflows from the hydraulic structures on the dam must be monitored during flushing/sluicing events to ensure that the required hydraulic conditions are being met and maintained.
- During a flushing/sluicing event, estimates of the load entering and leaving the reservoir should be made in order to evaluate the performance of the procedures that were followed during the event.

Results: Mean annual sedimentation rates at First Dam have been quantified to be about 0.5 acft/yr. Sluicing during high runoff periods in the spring has been shown to reduce the amount of sediment that stays in the reservoir and the amount of fine sediment that is deposited against the dam and in the area near the outlet works. Most importantly, the project has shown that, when properly monitored, sediment sluicing at First Dam can be conducted without jeopardizing downstream aquatic resources.

Sediment management guidelines for small reservoirs have been provided to the Utah Department of Environmental Quality for application in the state, and a sediment management plan has been developed for use by the managers of First Dam.

Work Plan FY11/FY12

Researchers at the UWRL will assist the operators of First Dam in conducting a sluicing event during spring runoff in 2012 and in providing records of these activities to the Utah Department of Environmental Quality. UWRL researchers will also work with UDEQ personnel to distribute the Sediment Management Guidelines more broadly across the state and to examine water quality policies to identify better regulatory approaches to sediment management.

Informational Resources

Contact: Dr. Mac McKee, (435) 797-3157, E-mail: mac.mckee@usu.edu.

The Transfer of Agricultural Water to Municipal and Industrial Uses

Principal Investigators:
Michael C. Johnson
Dallin Stephens

Partners/Collaborators:
- ***State**: Department of Water Resources, State of Utah*

Project Description

- Need and Purpose:

  The Department of Water Resources (DWR) has interest in identifying methods of tracking water as the agricultural land to which the water is tied is sold and developed for municipal and industrial (M&I) uses. Their interest also includes determining the accuracy of the tracking system that currently exists.

  This project was designed to research specific case sites across the state where land has been developed for M&I uses. Water rights that are connected to each case site are identified and analyzed to determine how they have changed with the development of the land.

- Benefits to the State:

  The results of this study provided information regarding the accuracy of the existing water rights recording system. The study identified water rights that were inaccurate or that did not have up-to-date information. The study demonstrated that the State is doing a very good job of tracking water rights and managing the available water.

- Geographic Areas:

  Study Area: Major cities across the State of Utah.

  Areas Benefited: Same major cities.

- Accomplishments:

  Findings:

  - A survey was sent to eighty major cities in Utah to identify municipal behavior associated with obtaining and using water rights in the city. Thirty-six of eighty cities (45%) responded.
  - This study has also identified several locations that have recently been developed (within the last ten years) from agricultural to M&I that could be considered for case study locations.
  - Each of the 212 case sites was categorized as to the type of development: residential, commercial, educational, religious, or municipal buildings.
  - A number of case sites were investigated in-depth to determine the condition of the water rights associated with the site studied.

Results: The following is a list of the conclusions reached from the case sites that were evaluated.

- While the great majority of water right transfers are recorded accurately through Reports of Conveyance and Change Applications, there are a number of transfers regarding rights that consist of small flows (less than 0.1 cfs) that have not been correctly documented. The summation of these small quantity inaccuracies may add up to significant errors in the State's water rights information.

- The State's recordkeeping processes are an efficient system for tracking water rights transfers. However, unless the proper documents are submitted, the condition of the water right in question remains uncertain. Much of the burden of the reporting is the responsibility of the water right holder. Laws are in effect to facilitate the timely process of reporting changes to water rights.

- The majority of water rights' transfers are documented properly, and the state has up-to-date information on the rights. A small number of rights, however, have not been correctly documented.

- While some existing water right records are not up-to-date, no appreciable changes to the record-keeping system are recommended. We recommend that the State properly educate those users who have not provided up-to-date information on their water rights on how to do so.

- The lack of information on water shares provides, perhaps, the greatest uncertainty in tracking water through transfers. Decision-makers should realize that the use of water in water shares may be inaccurate and that further research into this process may be needed.

- Several rights (or shares) may have become dormant through the process of being transferred to a municipality and then stockpiled, legally, under the statute of Utah Code 73-1-4.

- A final report was submitted to Utah State Department of Water Resources.

Work Plan FY11/FY12

This project was finalized in June 2011.

Informational Resources

Contact: Dr. Michael C. Johnson, (435) 797 3176, E-mail: michael.johnson@usu.edu.

Water Education and Technology Transfer

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Education and Technology Transfer

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
Agricultural Water Resources Management Training	$14,523.52	$11,378.13	$0.00
Development and Maintenance of the Bear River Watershed Information System	$0.00	$5,000.00	$6,000.00
Enhancement of Septic System Educational Programs in Utah with Advanced Training Systems	$19,763.46	$20,356.36	$20,967.05
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$1,029.14	$1,060.01	$0.00
Salt Lake Valley Solid Waste Management Council	$6,330.95	$6,520.88	$6,716.50
State of Utah Solid Waste Control Board	$6,330.95	$6,520.88	$6,716.50
Support for State Watershed Modeling and TMDL Plans	$33,992.64	$35,012.42	$0.00
UAV Development for UDOT Applications	$8,371.60	$8,622.75	$0.00
Utah On-Site Wastewater Treatment Training Program	$20,225.67	$20,832.44	$21,457.41
Utah Water Education Project	$9,585.31	$9,872.87	$0.00
Designated Projects		$25,420.87	$10,000.00
Undesignated Projects		$7,500.00	$0.00
Total	**$120,153.24**	**$158,097.61**	**$71,857.46**

Agricultural Water Resources Management Training

Principal Investigators:
Gary P. Merkley
Mohammed Shaban

Partners/Collaborators:
- ***Business/Industry:*** *Utah farmers, Utah irrigators*

Project Description

- Need and Purpose:

  Utah has experienced water shortages that, in the long term, tend to become increasingly problematic. Water quality problems are also becoming more prominent. Much of the emphasis in dealing with water scarcity and quality problems has been directed toward infrastructure and technological improvements. Little has been done with regard to improved training tools that can be used to promote more complete understanding of the problems faced by farmers and the difficult operational decisions they face with respect to water management. In fact, many of the problems related to water delivery design and operation for agricultural irrigation are due to a lack of understanding of agricultural irrigation by policy makers, administrators, and others.

  Intelligent and heuristic simulation tools in the form of a game can simulate field experience and show the effects of decisions for a variety of situations. This understanding can lead directly to improvements in delivery system operation, design of delivery systems, and on-farm water management.

- Benefits to the State:

  The State of Utah will benefit through an improved capability to deliver effective training in the form of short-term workshops and seminars. The attendees will receive an in-depth understanding of the problems and decisions faced by irrigators and farmers. This improved understanding is expected to lead to improvements in the management of water for agricultural irrigation.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Irrigated agriculture is found statewide, so all counties in the state would potentially benefit.

- Accomplishments:

  Findings: The model has shown an ability to determine the best irrigation management for a simulated growing season, and work continues at present.

  Results: There are no results to show yet, except for the publication of the model design from 2010.

Work Plan FY11/FY12

The last major part of the research will involve the development of a heuristic algorithm to guide the simulations according to user interactions to make the simulations more realistic. The study will complete in the spring of 2012.

Informational Resources

Contact: Dr. Gary P. Merkley (435) 797 1139, E-mail: gary.merkley@usu.edu.

Website: http://www.neng.usu.edu/bie/faculty/merkley/

References:

Marjang, N., G.P. Merkley, and M. Shaban. (2011). Center-Pivot Uniformity Analysis with Variable Container Spacing. *Irrig. Sci.* (published on-line March 3, 2011). DOI 10.1007/s00271-011-0272-6.

Shaban, M.Z. and G.P. Merkley (2010). Training tool for on-farm water management using heuristic simulation software. *Paper presented at the USCID Sept 28-Oct 1*. Ft Collins, CO.

Development and Maintenance of the Bear River Watershed Information System

Principal Investigators:
Jeffery S. Horsburgh
Ben Morris (student)

Partners/Collaborators:

- ***Local:*** *Jim Bowcutt, USU Extension/Bear River Watershed Coordinator*
- ***State:*** *Mike Allred, Utah DWQ*
  Lynn Van Every, Idaho DEQ
  Don Newton, Wyoming DEQ
- ***Federal:*** *Jack Barnett, Bear River Commission*

Project Description

- Need and Purpose:

  As part of a USEPA Targeted Watersheds Grant in the Bear River Basin (Utah, Idaho, Wyoming), USU developed an Internet Based Watershed Information System (WIS) for the Bear River (http://www.bearriverinfo.org). The WIS is a central location where users can get data and information related to water quality and other watershed related issues in the Bear River Basin. This project provides ongoing support to and development of the Bear River WIS and is being matched by funding from the states of Utah and Idaho. The WIS has proved to be a great benefit to water quality managers in three states, and has been used in water quality educational programs at various levels. This project is continuing to support the partnerships and collaborations that have resulted in the current WIS.

- Benefits to the State:

  Continued support of the Bear River WIS is benefiting several efforts ongoing in the State of Utah:

  1. The Water Quality Committee (WQC) of the Bear River Commission is a tri-state committee that focuses on water quality issues in the Bear River Basin. The Bear River WIS supports the efforts of the WQC and many other water quality related organizations.
  2. The Bear River WIS has been an important outlet for water quality related outreach and education materials to be made available to teachers, students, and researchers throughout the State of Utah.
  3. The Bear River WIS was the development platform for many of the tools that are supporting efforts to (1) establish an environmental observatory in the Great Salt Lake Basin, (2) establish a national cyber-infrastructure for environmental observatories, and (3) improve hydrologic science. A new information system for the Great Salt Lake (http://www.greatsaltlakeinfo.org) has been created based on the WIS.

- Geographic Areas:

  Study Area: Bear River Basin, including Cache, Rich, and Box Elder counties.

  Areas Benefited: Primarily the Bear River Basin; however, the WIS can be implemented for any watershed.

- Accomplishments:

  Findings: The Bear River WIS provides unprecedented access to data in the Bear River Basin. The combination of informational resources, data resources, data visualization and analysis tools, and outreach and educational components make the Bear River WIS a unique system for promoting water quality awareness and improvement in the Bear River Basin.

Results: The Bear River WIS is a fully functional watershed information system that includes the following components:

- Informational watershed descriptive profiles that detail the Bear River Basin.
- Support for outreach and educational opportunities related to Bear River water quality.
- A wealth of geographic information systems (GIS) datasets and water quality, hydrology, weather, and climate monitoring datasets for the Bear River Basin.
- A variety of tools for data visualization and analysis.
- A resource guide that details the people, organizations, and projects in the watershed.
- A calendar of water quality related events and news.

The source code from the Bear River WIS has been used to develop a new information system for the Great Salt Lake under funding from the State of Utah Division of Forestry, Fire, and State Lands (http://www.greatsaltlakeinfo.org).

Work Plan FY11/FY12

In the coming year, we will continue to work with the Bear River WIS steering committee to maintain the current functionality of the Bear River WIS and will add additional datasets as they become available. We are now migrating the WIS to a standardized content management system to simplify its maintenance, to ensure its sustainability, and to open up opportunities for collaborators and contributors outside of USU.

Informational Resources

Contact: Dr. Jeffery S. Horsburgh, Phone (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.

Website: http://www.bearriverinfo.org

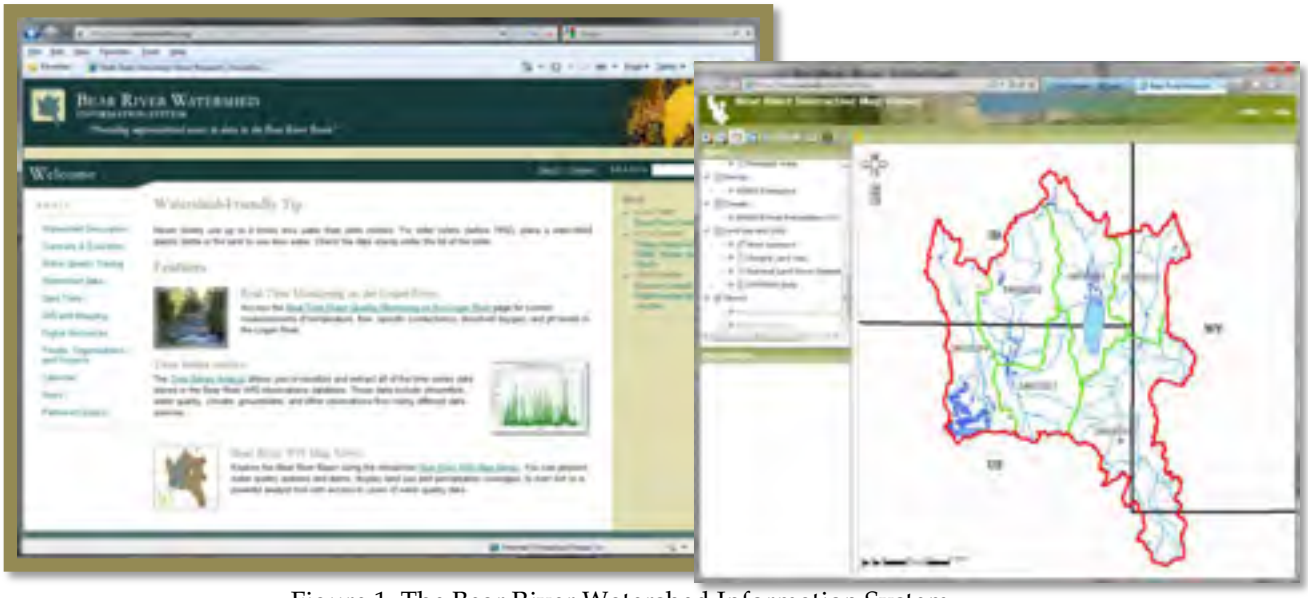


Figure 1. The Bear River Watershed Information System

Enhancement of Septic System Educational Programs in Utah with Advanced Training

Principal Investigators:
Judith L. Sims
Brian Cowan
Margaret Cashell

Partners/Collaborators:
- ***State:*** *David Snyder, Division of Water Quality, Utah Department of Environmental Quality*
- ***Local:*** *Utah Health Departments*

Project Description

- Need and Purpose:

  The 2000 Utah Nonpoint Source Management Plan emphasized that education, awareness, and training are important tools in reducing nonpoint source (NPS) pollution of surface water, ground water, and soils. The Plan also identified management of on-site wastewater disposal systems as one of Utah's nine priority non-point source pollution programs. The lack of education concerning appropriate siting of systems as well as operation and maintenance of systems contributes substantially to misuse and failure of on-site wastewater treatment systems.

  Since site and soil evaluations create the foundation for a working septic system, these evaluations should be correct and thorough, and potential limitations need to be properly assessed. For example, without training, soil textural differences may not be accurately distinguished, the hydraulic capacity of the soil may not be accurately determined or taken into account appropriately during the design phase, surface drainage may not be diverted as required from the drain field area, slope and landscape positions may be disregarded, or systems may be installed in saturated and/or poorly drained clay soils where conventional systems should not be constructed. It is also important that the gathered information accurately reflects the condition of the site and that the information is accurately recorded.

  Onsite professionals in Utah receive basic training in soils in the Level 1: Site and Soil Evaluation and Percolation Testing certification class. However, as regulations in Utah change such that soil and site properties will be utilized to a greater extent, advanced training that includes extensive field experiences is necessary.

  Utah Administrative Code R317-4, Onsite Wastewater Systems, mandates periodic inspections of alternative onsite wastewater treatment systems and R317-5, Large Underground Wastewater Disposal Systems, mandates periodic inspections of and the use of operating permits for larger onsite systems. There is also a requirement for periodic performance monitoring (sampling and analysis of effluent samples) for packed bed systems used in both large and small systems. In addition, there is a need to develop appropriate O&M procedures for systems that may accept wastewater that is different from typical residential wastewater, such as wastewater from restaurants. These systems that have higher organic or hydraulic loadings need to be addressed.

- Benefits to the State:

  Expected benefits to Utah watersheds include protection from the harmful effects of nitrogen, phosphorus, suspended solids, pathogens, and excessive organic loadings. Another benefit of the training programs will be an extension in the expected design lives of on-site wastewater treatment systems.

- **Geographic Areas:**

  Study Area: Workshops will be held in the Southwest Utah Department in Cedar City, the TriCounty Health Department in Vernal, and in the Weber-Morgan Health Department in Ogden.

  Areas Benefited: all 29 counties.

- **Accomplishments:**

  Findings: Information at this time is not readily available in Utah regarding advanced site evaluation techniques nor operation & maintenance of alternative, complex on-site wastewater treatment systems that address soil and site limitations.

  Results: Workshops have been developed addressing advanced site and site techniques and operation & maintenance of alternative systems.

Work Plan FY11/FY12

During FY11/FY12, we will deliver the workshops at selected locations around the state.

Informational Resources

Contact: Ms. Judith L. Sims (435) 797 3230, E-mail: judith.sims@usu.edu.

Website: http://uwrl.usu.edu/partnerships/training/classes.html.

Workshop field and classroom training

Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee

Principal Investigators:
Laurie S. McNeill

Partners/Collaborators:
- ***State**: Intermountain Section American Water Works Association*

Project Description

- Need and Purpose:

  The drinking water industry is facing a wave of retirements and needs to recruit new engineers to join the field. This is particularly true in Utah.

- Benefits to the State:

  This committee provides scholarships to students who will benefit the field of water quality, supply, and treatment in the Intermountain West (Utah and southern Idaho). Currently there are four scholarships: undergraduate ($1,000), 2 graduate ($1,500 each), and diversity ($1,000). The committee is also working to integrate water topics into the Utah K-12 education curriculum.

- Geographic Areas:

  Study Area: Statewide.

  Areas Benefited: Statewide – students at any college or university in Utah or southern Idaho are eligible.

- Accomplishments:

  Findings/Results: Three students (two undergraduate and one graduate) were awarded scholarships totaling $3,500 to study water quality and treatment during the Fall 2010 semester. These students are from Utah State University, the University of Utah, and Utah Valley University. The committee developed a significant fund-raising plan to increase funding, and already one additional scholarship has been endowed (increasing the number from 3 to 4 scholarships).

Work Plan FY 11-12

Participation in IMS-AWWA meetings and activities will continue. At least four scholarships will be awarded in Fall Semester 2011. Work will also begin on integrating water treatment topics into the State of Utah education curriculum; possible ties with the Utah Water Research Laboratory's International Office of Water Education will be considered.

Informational Resources

Contact: Dr. Laurie S. McNeill, (435) 797-1522, E-mail: Laurie.McNeill@usu.edu.

Website: http://www.ims-awwa.org/scholarships/Scholarship_Win.html.

Salt Lake Valley Solid Waste Management Council

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***Local:*** *Patrick Leary, Salt Lake County Public Works*
  Rick Graham, Salt Lake City Public Works
  Brian Bennion, Salt Lake County Health Department
  Russ Willardson, Council of Governments; Staff, Salt Lake County Solid Waste Management Facility
  Dwayne Wooley, Trans Jordan Landfill
- ***State:*** *Scott T. Anderson, Director, Division of Solid and Hazardous Waste*

Project Description

- **Need and Purpose:**

  The goal of the Salt Lake Valley Solid Waste Management Facility (SLVSWMF) is to provide environmental stewardship, financial integrity, safety, recycling education, and quality service to benefit the environment, residents, businesses, and employees of Salt Lake County for the long term.

  The SLVSWMF operates a transfer station and landfill and is involved with the collection, transportation, and disposal of municipal and commercial solid waste within the Salt Lake City and Salt Lake County boundaries. The landfill facility operates a citizen's unloading facility, provides recycling for various commodities including household hazardous waste, collects landfill-generated methane for electricity production, runs a green waste compost production operation, and is involved in land reclamation. The Facility is also proactively involved in education of the public in areas related to waste reduction, recycling, and composting and provides informational tours of the landfill and transfer station facility and their operations.

  The SLVSWMF operates on the financial principle of an enterprise fund, and is supported by gate fees, rather than by tax revenues. The SLVSWMF Council is tasked with oversight of operations at the facility, and makes recommendations to the owners of the facility (Salt Lake City and Salt Lake County) regarding operational issues and policies, the fee structure for services provided to the public, and other regulatory and management issues that arise during the course of running the enterprise.

- Benefits to the State:

  Membership on the SLVSWMF Council provides service to the citizens of Salt Lake City and Salt Lake County, the Utah DEQ, and the regulated community by providing technical overview and expertise in solid waste management to the operating staff of the Facility. The PI attends monthly meetings of the SLVSWMF Council, provides comments and input on solid and hazardous waste issues that arise, and has responded to special requests from the Council or Facility staff regarding technical issues affecting operation at the Facility. An example of this special project request is detailed in a separate report related to (1) investigating the impact on the SLVSWMF carbon and energy footprint of mandating green waste recycling on a County-wide basis and implementing food waste composting in Salt Lake City, and (2) evaluating the cost and environmental impact of providing additional recycling for West Valley City.

- Geographic Areas:

  Study Area: Salt Lake City, West Valley City, and Salt Lake County.

  Areas Benefited: Salt Lake City, West Valley City, and Salt Lake County.

- Accomplishments:

  Findings/Results: The PI attended all regularly scheduled SLVSWM Council meetings throughout FY11 and provided review and comment on all Council items relevant to his area of expertise, being heavily involved in analysis and development of recommendations regarding implementation of mandatory green waste recycling, food waste recycling, and increased municipal solid waste recycling throughout Salt Lake City, West Valley City and Salt Lake County.

Work Plan FY11/FY12

Continue involvement in decision-making through attendance at monthly SLVSWMF Council meetings and responding to special project requests as they arise to support the SLVSWMF's mission and goals.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797-3227, E-mail: ryan.dupont@usu.edu.

Website: http://www.slvlandfill.slco.org/
http://public.me.com/rdupo/UWRL Report Files/SLCounty_Green_Waste_Study_Report_Files.

State of Utah Solid Waste Control Board

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***State:*** *Scott T. Anderson, Director, Division of Solid and Hazardous Waste*

Project Description

- Need and Purpose:

  Under the Utah Solid and Hazardous Waste Act (the Act), responsibility for overseeing solid and hazardous waste disposal rests with Utah Department of environmental Quality (DEQ) and the Utah Solid and Hazardous Waste Control Board (Waste Control Board). The Waste Control Board has the authority to issue orders implementing the Act as well as to ensure compliance with the Act's provisions. Jurisdiction of the Waste Control Board covers public and private solid waste management units, hazardous waste storage, treatment and disposal facilities, including the various Federal chemical demilitarization facilities, and private hazardous and low-level nuclear waste disposal facilities located in Utah's West Desert region.

  In addition, Utah has enacted the Underground Storage Tank Act to regulate underground storage tanks. The Underground Storage Tank Act applies to all tanks covered by the Federal Resource Conservation and Recovery Act and specifically includes petroleum storage tanks. The Waste Control Board has the power to make rules regarding certification of tank installers, inspectors, testers, removers, and environmental consultants, as well as requiring the registration of underground tanks and management of the remediation of underground tank releases. Each owner or operator of an underground tank must register the tank with the Executive Secretary of the Waste Control Board.

- Benefits to the State:

  Membership on the Solid Waste Control Board provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by providing technical overview and expertise in solid and hazardous waste management to the Division of Solid and Hazardous Waste in their rulemaking, facility inspections and reviews, policy implementation, and conflict resolution. The PI attends monthly meetings of the Waste Control Board held throughout the State, and provides comments and input on solid and hazardous waste issues that arise during the course of the Division's implementation of Federal and State solid and hazardous waste management laws.

- Geographic Areas:

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- Accomplishments:

  Findings/Results: The PI attended all regularly scheduled Waste Control Board meetings and facility tours throughout FY10-11 and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY11/FY12

Continue involvement in decision-making through attendance at monthly Waste Control Board meetings and associated facility tours, and provide technical input and program review for relevant State Solid and Hazardous Waste programs.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.

Website:
http://www.hazardouswaste.utah.gov/Board/UtahSolidandHazardousWasteControlBoard.htm.

Support for State Watershed Modeling and TMDL Plans

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***Local:*** *Jenni Oman, Salt Lake County; Florence Reynolds, Salt Lake City*
- ***State:*** *Hilary Arens, UDEQ John Whitehead, UDEQ*
- ***Business/Industry:*** *Theron Miller, Jordan River POTWs; Nick VonStackeberg, Stantec Consultants; Eric Duffin, Cirrus Consultants*

Project Description

- Need and Purpose:

  The Clean Water Act (CWA) requires total maximum daily load (TMDL) development for impaired water bodies. The requirements associated with the TMDL process include the quantification of loads from both point and nonpoint pollution sources, reallocation of these loads to meet instream water quality standards, and implementation plans. Many local governments also create watershed management plans. In order to complete these steps, some sort of watershed and/or instream water quality model is necessary.

- Benefits to the State:

  States are tasked with developing the TMDL plans, but often lack the expertise necessary to conduct the modeling studies. Additionally, they may lack the understanding necessary to design the monitoring studies to support the modeling efforts. These efforts provide guidance to the Utah Department of Environmental Quality (DEQ) and their consultants in making decisions and prioritizing investments.

- Geographic Areas:

  Study Area: Salt Lake and Weber Counties, State of Utah.

  Areas Benefited: Jordan River Basin, Great Salt Lake, Salt Lake County Drainages, State of Utah.

- Accomplishments:

  Findings:

  Jordan River TMDL Modeling Review: Based on work last year with Utah DWQ, a conference presentation and paper were developed to communicate effective methods of model calibration for use within the TMDL program. Additionally, a journal article was submitted based on this work.

  Salt Lake County Watershed Modeling: Work was finalized for the Watershed Model that is being developed for Salt Lake County with Stantec as the expert reviewer. While the Jordan River TMDL and the Salt Lake County watershed modeling studies are independent efforts, the conclusions and resulting management decisions will need to be interrelated.

  Jordan River Temperature Modeling: Work continues with the Utah DWQ and South Valley Water Reclamation Facility to complete the instream temperature modeling, which will assist in determining whether a site specific temperature standard is necessary for the upper portion of the Jordan River.

Statewide Wasteload Allocation Study: Efforts have continued under a contract with Utah DWQ to complete the QUAL2KW modeling portion of a larger project that is (1) investigating the need for numeric nutrient criteria and (2) providing guidance regarding data collection to develop site specific nutrient criteria.

Results:

Jordan River TMDL Model Review Presentations/Publications:

von Stackelberg, N.O., B.T. Neilson, H.N. Arens (2010). Collaborative Calibration of a Water Quality Model of an Urbanized River. *ASABE TMDL 2010: Watershed Management to Improve Water Quality Conference*. Baltimore, MD. November.
von Stackelberg, N.O. and B.T. Neilson (In review). Collaborative Calibration of a Water Quality Model of an Urbanized River. *Transactions of American Society of Agricultural and Biological Engineers*.

Salt Lake County Watershed Modeling: The BASINS/HSPF model has been calibrated for hydrology and water quality, and this project is now complete. Salt Lake County can now use this model to make decisions regarding stormwater and flood control, as well as establish the impacts of development on instream water quality.

Jordan River Temperature Modeling and Statewide Wasteload Allocation Study: We continue to collect data in streams below various wastewater treatment plants throughout the state and have completed a significant amount of the modeling work. These models will be used within the context of developing nutrient criteria for the state of Utah and are currently being used in development of waste load allocations for various water reclamation facilities.

Work Plan FY10/FY11

Over the next year, we will continue technical support to the State of Utah through the Jordan River Temperature Modeling and Statewide Wasteload Allocation studies.

Informational Resources

Contact: Dr. Bethany T. Neilson, (435) 797-7369, E-mail: bethany.neilson@usu.edu.

UAV Development for UDOT Applications

Principal Investigators:
Steven L. Barfuss
Austin Jensen

Partners/Collaborators:
- ***State:*** *Utah Department of Transportation*

Project Description

- Need and Purpose:

  The purpose of this project is to further develop existing Unmanned Aerial Vehicle (UAV) technologies as they apply to State Departments of Transportation. Specifically, the research objective focuses on critical State highway and road issues where high resolution imagery from UAV systems is most appropriate. The project focuses have included:

  1. Monitoring wetland areas and regions of invasive plant species that are located along known DOT corridors.
  2. Photographing highway construction projects before, during and after for safety, design, and decision-making purposes.
  3. Locating highway structures required for UDOT inventories.

- Benefits to the State:

  This project is providing UDOT with additional tools for inventorying, evaluating, and monitoring highway corridor wetlands, construction, and associated roadway structures. The project provides UDOT with high resolution images from the UAV that can be imported to UDOT GIS databases, avoiding the long intervals associated with standard aerial imagery updates. Using USU-developed software, the high resolution images can specifically be used to determine the extent of different wetland species within UDOT highway corridors so that much more economical wetland mitigation decisions can be made. The high resolution images also allow new highway construction areas to be viewed before construction begins, during the construction, and then again when it is completed. This process of acquiring multiple images at different times during construction projects allows UDOT officials to monitor construction projects for efficiency and safety, while also producing a historical record of the project.

- Geographic Areas:

  Study Area: Southern Parkway Freeway construction project (located south of St. George, Utah) and the proposed Vineyard highway alignment (located between I-15 and Utah Lake).

  Areas Benefited: State of Utah, with application to all states in the U.S.

- Accomplishments:

  Findings: As expected, the new construction phase of this project was extremely successful. The full length of the Southern Parkway was flown prior to construction, in the middle of construction, and then again after the construction of the freeway segment was completed. The Southern Parkway, located near St. George, Utah starts at the I-15 interchange and ends at the new St. George airport. For each flight, the set of images was stitched together in a single geo-referenced image that could be placed in Google earth or used as a UDOT GIS overlay.

The flights for the proposed Vineyard highway alignment near Utah Lake have been somewhat delayed because wet weather has flooded the study area, and it is preferable that the area dry out before the ground samples and aerial images are taken. This phase of the study is expected to be completed by the end of summer 2011.

Results: The Aggie-Air UAV appears to be an effective tool for highway construction and wetland mitigation. For example, when UDOT submits wetland mitigation applications to the USACE, the data is expected to be much more accurate (using the UAV high resolution images), which will reduce the mitigation acreage ratio required and the associated cost to UDOT when a new highway is constructed in a wetlands area.

Southern Parkway Flight Takeoff (note camera ports on bottom of plane)

Work Plan FY11/FY12

- The three Southern Parkway flights in St. George, Utah have been completed.
- The Vineyard highway alignment flight near Utah Lake is expected to take place in late summer 2011. Post processing of the wetland images to geographically quantify several wetland species within the proposed highway corridor will occur during the weeks following the flight.

Informational Resources

Contact: Mr. Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Austin Jensen (435) 797 3315, Email: Austin.Jensen@aggiemail.usu.edu.

Utah On-Site Wastewater Treatment Training Program

Principal Investigators:
Judith L. Sims
Margaret Cashell
Brian Cowan
Richard Jex

Partners/Collaborators:

- ***Local:*** *Utah's 12 Local Health Departments; Utah On-Site Wastewater Association (UOWA)*
- ***State:*** *Division of Water Quality, Utah Department of Environmental Quality; Council of Local Environmental Health Directors (CLEHA)*

Project Description

- Need and Purpose:

  The Utah On-Site Wastewater Treatment Training Program was established in January 1998 in cooperation with the Utah Department of Environmental Quality (DEQ) and the twelve Utah local health departments. It provides classroom and field (hands-on) training to Utah homeowners, regulators, designers, installers, pumpers, and other stakeholders in on-site wastewater treatment systems.

  Adequately protecting environmental health and enhancing user satisfaction are achieved through knowledgeable selection, competent design, correct installation, and proper operation of on-site systems. Applying the right technology in the right place requires accurate information and up-to-date training. Landowners, homeowners, developers, lenders, installers, regulators, planners, municipal authorities, and elected authorities are all stakeholders in Utah on-site issues and must have current information and training to address these matters responsibly.

  Utah will continue to grow, and as housing developments continue to expand into current open space, such developments may include areas of groundwater recharge, shallow soils, or shallow ground water. Current Utah rules allow the use of conventional septic tank systems, as well as eight alternative treatment systems that may be installed in areas where soils are unsuitable for conventional systems. Training those involved in the use of both conventional and alternative systems will ensure that these systems will work correctly.

- Benefits to the State:

  Continued population growth, with associated housing developments, creates an increased need for accurate and thorough information regarding on-site wastewater treatment technologies. The Utah On-Site Wastewater Treatment Training Program addresses these challenges through such means as workshops and participation in educational conferences. Many of the soils in Utah are marginal or unacceptable for the use of conventional soil absorption systems due to high or fluctuating water tables, slowly permeable or highly permeable soil horizons, and extreme slopes, thus requiring the use of more advanced alternative systems. The On-Site Training Program provides the necessary education to utilize conventional and alternative systems in an effective manner that will protect both public health and the environment.

- Geographic Areas:

  Study Area: Entire State of Utah

  Areas Benefited: The entire state (29 counties and 12 local health departments).

- Accomplishments:

Findings: A state legislative initiative introduced and passed as House Bill 14s during the 2001 Legislative Session mandated a certification program for persons involved in siting, designing, operating, and maintaining both conventional and alternative on-site systems. The certification program, administered by the Division of Water Quality in the Utah DEQ, involves mandatory training provided by the Utah On-Site Wastewater Treatment Training Program.

The certification program includes three levels, each of which requires workshops and testing provided through the Utah Training Program: (1) Level 1: Soil Evaluation and Percolation Testing, (2) Level 2: Design, Inspection, and Maintenance of Conventional Systems, and (3) Level 3: Design, Operation, and Maintenance of Alternative Systems.

Workshops are also provided for renewal of certification, as Level 1 and Level 2 certifications expire after 5 years and Level 3 certification expires after two years.

Results: During FY 2010-2011, two Level 1 workshops, two Level 2 workshops, and two Level 3 workshops were taught at various locations around the State of Utah, as well as two Level 1 renewal workshops, two Level 2 renewal workshops, and two Level 3 renewal workshops.

In cooperation with the Utah On-Site Wastewater Association, we co-sponsored an education training opportunity on the use of pumps and pressurized distribution systems in on-site wastewater systems in Salt Lake City on June 16, 2011. At that meeting, we introduced the training manual that we developed in accordance with the Division of Water Quality, Utah Division of Water Quality, Utah Pressure Design Manual, December, 2010.

Work Plan FY 11-12

We will continue to provide workshops in support of the mandatory State of Utah certification program for on-site wastewater professionals.

Informational Resources

Contact: Ms. Judith L. Sims, (435) 797-3230, E-mail: judith.sims@usu.edu.
Website: http://uwrl.usu.edu/partnerships/training.

References:

Sims, J.L., Cashell, M., Cowan, B., and R.Jex (2010, 2011). *Course Manuals for Levels 1, 2, and 3 Certification*. Utah Water Research Laboratory, Utah State University, Logan, UT.

Sims, J.L. and R. Jex, R. (2010). Pressure Distribution Systems: Utah Guidance for Performance, Application, Design, Operation & Maintenance: Guidance Manual in Support of Utah Administrative Code R317-4: Onsite Wastewater Treatment. Utah On-Site Wastewater Treatment Training Program, Utah State University, Logan, UT, and Division of Water Quality, Utah Department of Environmental Quality, Salt Lake City, UT).

Workshop field and classroom training

Utah Water Education Project

Principal Investigators:
Steven L. Barfuss
Michael Budge
Jesse Pope

Partners/Collaborators:
- ***State:*** *Division of Water Resources*

Project Description

- Need and Purpose:

  Utah is one of the fastest growing states in the nation. As the population increases, the demand on water resources will also increase. Because Utah is the second driest state in the country, its limited water supply will always be a top priority.

  In a focused effort to educate the public about the state's water supply, as well as how to conserve its water supply and what is required to provide water to its citizens, a digital photograph computer screensaver is being prepared. Upon project completion, this computer screen saver is intended to be widely distributed to school districts, colleges and universities, and government agencies, as well as made available to the general public. The screensaver will include over 1000 carefully selected Utah water-related photos and each photo will include a brief descriptive and educational caption. The captions will provide snippets of information and instruction about Utah's water resources and the proper use of the resources without burdening the reader with large amounts of text.

  The purpose of the project is to incrementally educate a diverse public about ways Utah's water is used, specifics regarding water conservation, and information about the state's streams, rivers, and lakes and the animals and people that rely on this resource. The selected photographs will be high quality, interesting, and beautiful so that the reader will be naturally encouraged to read the caption. The photographs will all include some aspect of Utah's water resources, water infrastructure, or some aspect of Utah's water use, and they will be strategically selected so that all 26 counties within the State of Utah will be represented in the screensaver.

- Benefits to the State:

  Utah is second only to Nevada in gallons of water used per person. Few Utahans would argue against the need to conserve water; however, most people will not change water-use behaviors unless they understand the importance of conservation and the need to be stewards of the resource. The intent is that viewers of the photos in this screen saver project will be naturally encouraged to change personal behaviors in water use through incremental education. The end benefit to the State of Utah, of course, will be a reduction in per capita water use and preservation of the state's water resource.

- Geographic Areas:

  Study Area: Entire State of Utah.

  Areas Benefited: Entire State of Utah.

- Accomplishments:

Findings: Project has recently started.

Results: Over 80 photos have been selected for use in the project to date. University students are performing significant research to insure that short photo captions are accurate as well as educational. The photograph below is an example of one photo that will be used in the screen saver.

Piute Dam, Utah

Work Plan FY11/FY12

- Continue literature reviews to research water-use patterns and water resources in each county.
- Continue to collect water-related photos that meet the project criteria to help educate people about water in Utah. Photos are provided by donations and freelance photographers.
- Determine the most appropriate means for distributing the screen saver to the citizens of Utah. Specific target groups will be schools and public offices.
- Develop the most effective means for displaying the photos on individual computers.

Informational Resources

Contact: Mr. Steven L. Barfuss (435) 797-3214, E-mail: steve.barfuss@usu.edu.

Water Resources Planning and Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Resources Planning and Management

Project Name	FY2011 Actual Expenditures	FY2012 Budgeted Expenditures	FY2013 Planned Expenditures
Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake (Extended to Include Utah Climatic Analysis Using Atmospheric-Oceanic Oscillations)	$23,249.01	$23,946.48	$0.00
Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties	$48,074.50	$931.74	$0.00
ASR Optimization Protocol and Decision Support	$4,232.68	$40,000.00	$40,000.00
Curtis Creek: A 3-Dimensional Flow and Contaminant Transport Model to Estimate Stream and Groundwater Exchange and Water Quality Changes	$68,112.99	$5,201.91	$0.00
Development of Flood Emergency Response Capability Using UAV's	$18,297.00	$0.00	$0.00
Effects of Rotenone Treatment for Removal of Non-Native Fish on the Macroinvertebrate Assemblage of Boulder Creek, Utah	$3,652.08	$3,500.00	$0.00
Eliminating the Division Between Ecosystem Engineers and Biologists	$13,740.98	$0.00	$0.00
Estimating Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated Systems at Different Spatial Scales	$17,141.90	$4,012.92	$0.00
Finding Appropriate Complexity for Distributed Hydrologic Model	$55,134.55	$56,788.59	$0.00
Flood Potential Due to 100-Year Storm Events for Small Utah Cities	$6,493.28	$6,688.08	$0.00
Habitat Monitoring of the Bear River	$37,914.93	$0.00	$0.00
Improving Hydrologic Model Predictions for the Effects of Land Use and Climate Change	$25,336.83	$0.00	$0.00
Interstate Movement of Bonneville Cutthroat Trout	$119,872.98	$123,469.17	$0.00
Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration EstimatesEstimates	$1,505.28	$20,000.00	$20,000.00
Low Cost Vertical Take Off and Landing Personal Remote Sensing Systems for Water Engineering	$30,547.46	$31,463.88	$35,000.00
Multispectral Image Processing for Water Management and Other Agricultural Applications	$10,282.05	$7,199.16	$0.00
Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment	$80,944.00	$83,372.32	$90,000.00
Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology	$196,129.87	$20,000.00	$0.00
Quantifying the Flow Field in Baffled Fish Culverts	$29,662.92	$184.79	$0.00
Real-Time Management of Irrigation Systems in the Sevier River Basin	$144,974.25	$160,000.00	$170,000.00
Restoration of Interstate Migration Routes for Bonneville Cutthroat Trout	$5,235.60	$5,000.00	$0.00
Statewide Water Resources Modeling for Utah	$9,961.92	$10,260.78	$0.00
Stream Restoration in Boulder Creek, Utah: Effects of Increased Stream Discharge and Non-Native Fish Removal	$1,208.15	$10,000.00	$15,000.00
Treated Wastewater Use in Agricultural Irrigation	$15,838.82	$92.03	$0.00
UAV Remote Sensing Service Center	$142,074.37	$150,000.00	$150,000.00
Water Conservation and Managing Water Shortages	$30,837.74	$31,762.87	$31,762.87
Water Resources Modeling for Utah's Cache Valley	$17,912.20	$18,449.57	$18,449.57
Dedignated Projects		$576,774.16	$51,537.12
Undesignated Projects		$156,700.00	$0.00
Total	**$1,158,368.34**	**$1,545,798.45**	**$621,749.56**

Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake (Extended to Include Utah Climatic Analysis Using Atmospheric-Oceanic Oscillations)

Principal Investigators:
Gilberto E. Urroz
Mac McKee
Niroj Shrestra

Partners/Collaborators:
- ***State:*** *Utah Division of Water Resources*

Project Description

- Need and Purpose:

  Accurate prediction of Great Salt Lake (GSL) levels may improve water resources management in the GSL basin. Statistical Learning Techniques utilize computer models for predicting GSL water levels, and have been extended to the study of the relative influence of oceanic-atmospheric oscillations in Utah climate as reflected in streamflow in Utah rivers.

- Benefits to the State:

  Accurate prediction of Great Salt Lake (GSL) levels would help GSL shareholders, such as the Utah Division of Water Resources and the municipal and county governments in the counties of the Great Salt Lake, as well as industries in the shoreline, in terms of planning, development, and emergency response. The analysis of Utah's climate improves understand of climatic patterns in the state of Utah in relation to water flows in major rivers in the state. This information is useful for river basin stakeholders.

- Geographic Areas:

  Study Area: Great Salt Lake, Weber River, Sevier River, and Western Colorado River basins

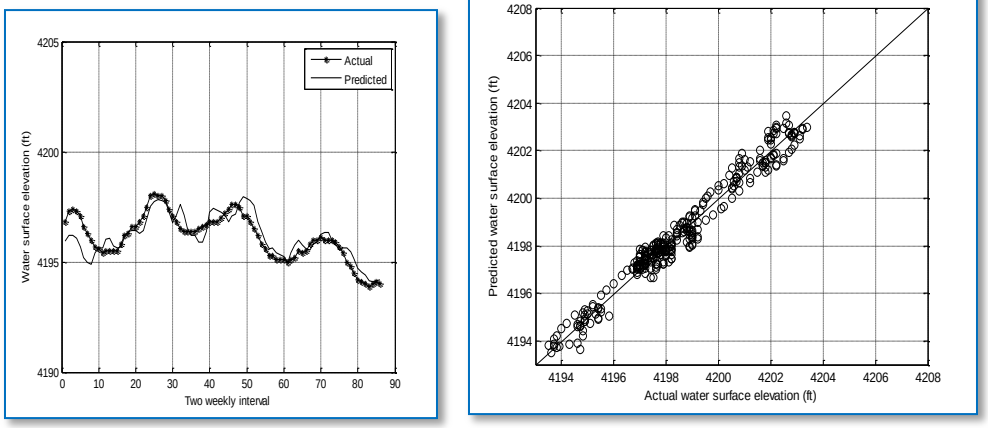
  Areas Benefited: Great Salt Lake basin, Box Elder, Weber, Davis, Salt Lake, and Tooele counties, along with counties in the Weber River, Sevier River, and Western Colorado River basins.

- Accomplishments:

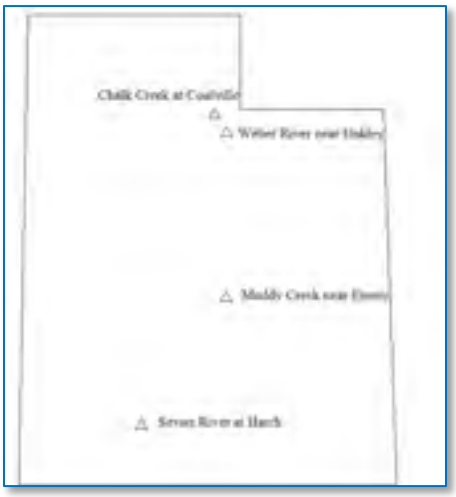
  Findings:

  - Statistical techniques were used to predict GSL levels by "training" computer programs using existing data provided by the Utah Division of Water Resources. While earlier applications used Artificial Neural Networks (ANN), Support Vector Machines (SVM), and Relevance Vector Machines (RVM), the FY 10-11 work concentrated on Multivariate Relevance Vector Machines (MVRVM). The following graphs illustrate the results of MVRVM applications for predicting Salt Lake Levels by comparing predicted to actual levels for selected periods of time.

  - Both graphs show that the predictions follow the general trend of the observed water levels, thus indicating that Statistical Learning Techniques such as MVRVM can be used for predicting Great Salt Lake levels with a high level of confidence.



- MVRVM techniques were also applied to the analysis of the effects of atmospheric-oceanic oscillations on Utah climate. This portion of the project was accomplished by studying the streamflow in four major rivers in Utah shown in the map below. The streams chosen were Chalk Creek at Coalville, the Weber River near Oakley, Muddy Creek near Emery, and the Sevier River at Hatch. Four common ocean-atmospheric oscillation indices were used as predictor variables for Utah river streamflows. This part of the study is still in progress.



Work Plan FY11/FY12

- Publish a journal paper demonstrating the use of MVRVM for GSL level prediction.
- Complete the analysis of streamflow in Utah rivers as affected by atmospheric-oceanic oscillations using Statistical Learning Techniques.
- Publish a journal paper demonstrating the use of MVRVM for predicting streamflow in selected Utah rivers based on data for atmospheric-oceanic oscillations.
- Publish work demonstrating the use of Statistical Learning Techniques, specifically the MVRVM technology, in hydrological applications in Utah.

Informational Resources

Contact: Dr. Gilberto E. Urroz (435) 797-3379, E-mail: gilberto.urroz@usu.edu.

References:

Shrestra, N. (2011). *Statistical Learning Machines Applied to Hydrological Analyses in Utah*. Ph.D. Dissertation, Utah State University, Logan, UT.

Shrestra, N., M. McKee, and G. Urroz (In progress). Bayesian machine learning regression approach for long-term streamflow forecasting and identifying relative influence of oceanic-atmospheric oscillation modes in Utah. *Water Resources Research*. (Paper 2).

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Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties

Principal Investigators:

David E. Rosenberg
Karin M. Kettenring
Christopher M.U. Neale
Omar Alminagorta
Melina Santos Vanderlinder

Partners/Collaborators:

- ***Local:*** *Al Trout, Friends of Bear River Refuge*
- ***Federal:*** *Bob Barrett, U.S. Fish and Wildlife Service*
  Sharon Vaughn, U.S. Fish and Wildlife Service
  Howard Browers, U.S. Fish and Wildlife Service

Project Description

- Need and Purpose:

  Wetlands, particularly along the Great Salt Lake, provide critical wildlife habitat, resting grounds for migratory birds along the Pacific Flyway, and social and economic services including water purification, storm water retention, and recreation for hunters. Water is necessary for wetlands, but in the western U.S. and Utah, water is typically scarce and not sufficiently available to flood and maintain habitats that can support wetland functions. Scarce water challenges wetland managers on how to best allocate limited water to and within wetlands to improve ecosystem functions and services. Water allocation decisions are further complicated because desired ecological responses, such as area covered by native plant species or number of individuals of a key indicator bird species, are often variable or uncertain. This project is extending systems modeling and ecological experiments underway at and for the Bear River Migratory Bird Refuge (BRMBR). Part I is focused on building a deterministic wetland systems (optimization) model to identify water and vegetation management actions that BRMBR mangers can take to improve wetland performance under existing water, budget, staff time, and other constraints. Part II aims to quantify the response to wetland water and salinity levels of *Phragmites australis* (common reed, hereafter *Phragmites*), a non-native, invasive grass. We are using old and new aerial photographs and satellite images to inventory *Phragmites* coverage at the BRMBR over the past 20 years.

- Benefits to the State:

  The project is benefiting Utah in several direct and indirect ways. First, the project is helping Utah wetland managers to better manage and allocate their scarce water, personnel, and budget resources to achieve their wetland objectives. The project is also contributing new information on the water and salinity levels that both encourage and discourage *Phragmites* spread. The project is also demonstrating how to use this information and the uncertainties contained within it to manage water to reduce *Phragmites* spread. Ultimately, this understanding will help Utah wetland managers to better manage wetlands to support the hunting, birding, and recreation that are vital to the Utah communities that border the Great Salt Lake. Finally, the project is integrating systems modeling, ecology, invasion ecology, and remote sensing and showcases Utah as taking a new approach to natural resource management.

- Geographic Areas:

  Study Area: Bear River Migratory Bird Refuge, north shore of the Great Salt Lake, Box Elder County, Utah.

  Areas Benefited: Wetlands throughout the State of Utah.

- **Accomplishments:**

Findings:

- Classified vegetation coverage at the refuge from multispectral aerial imagery taken in April 2010 (Figure 1).
- Debugged systems model and articulated species habitat suitability indices that represent wetland manager preferences for habitat conditions (Figure 2).
- Began classifying 1992 aerial imagery to identify vegetation change over time. Initial results suggest little *Phragmites* present at the Refuge in 1992.
- Made a meta-analysis of 155 wetland studies; identified relationships between water depth, duration, frequency, vegetation biomass, coverage vegetation, species richness, and germination.
- Presented vegetation classification and coverage results at Utah State University Spring Runoff Conference (March 29-30, 2011).
- Submitted $838,000 proposal to National Science Foundation (NSF) Dynamics of Coupled Natural and Human Systems (CNH) program to extend work to ecological uncertainties.

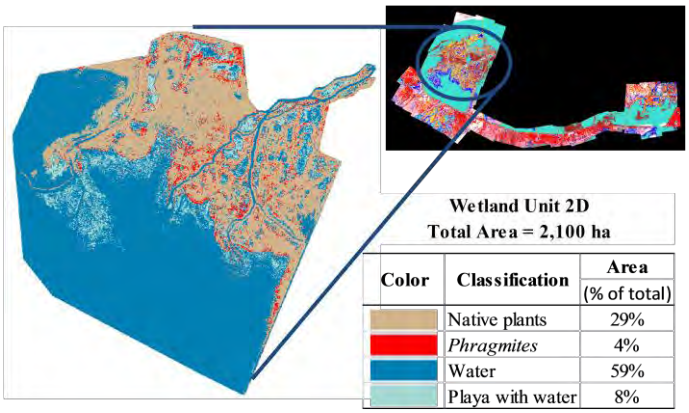


Figure 1. Vegetation classification at the Bear River Migratory Bird Refuge, Utah (April 2010).

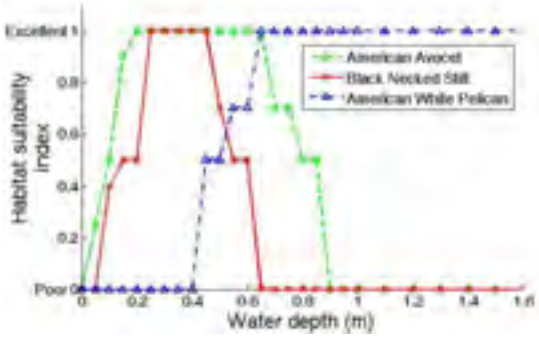


Figure 2. Habitat suitability indices as a function of wetland water depth for key bird species.

Work Plan FY11/FY12

- Finish developing the systems optimization model for the BRMBR and conduct sensitivity analysis—identify ecological parameters to which model results are most sensitive.
- Report recommended water allocations and work collaboratively with BRMBR managers to verify that model recommendations are reasonable.
- Finish classifying 1992 imagery, compare with 2010 vegetation coverage, and pair vegetation and water level changes over the time period.
- Submit wetland meta-analysis paper for publication.
- Revise and resubmit proposal to NSF CNH program.
- Submit CAREER proposal to NSF Environmental Engineering program to extend work to consider multiple wetland and riparian areas in the lower Bear River watershed.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.
Website: http://www.engr.usu.edu/cee/faculty/derosenberg/projects.htm.
Website: http://dx.doi.org/10.1061/41114(371)264.

ASR Optimization Protocol and Decision Support

Principal Investigators:
Richard C. Peralta
Ali Forghani

Partners/Collaborators:

- ***Local:*** Richard Bay, Jordan Valley Water Conservancy District

Project Description

- Need and Purpose:

  The Jordan Valley Water Conservancy District (JVWCD) began operating a full-scale Aquifer Storage and Recovery (ASR) system in 2002. Currently the system has 18 extraction/injection wells. The JVWCD wishes to optimize management of the ASR system. This includes considering economics and the amount of credit received from the State Engineer for the water that the JVWCD injects (injectate). The State Engineer allows multiple-year carryover credit of injectate, subject to the condition that 10% of the injectate is lost per year of carryover storage after the first 12 months from injection. This loss assumedly represents the escape of groundwater that has flowed laterally, rather than directly toward extracting ASR wells. JVWCD thinks they are physically able to recover more injectate than they receive credit for, and wishes to know more accurately how much injectate they can physically recover. They want to know how best to inject and extract with time. Fully addressing the problem involves more accurately quantifying the amount of injectate that is recovered, and optimizing the timing of injections and extractions, subject to projected temporally varying water availability, water need, and cost. Ssoftware to facilitate use of the ASR optimization protocol is also desireable.

- Benefits to the State:

  To best integrate use of available water resources, Utah water managers increasingly consider applying aquifer recharge (AR) and aquifer storage and recovery (ASR) techniques. Usually river water is treated and used to recharge (injected into) aquifers in the spring season. Groundwater is extracted (pumped out) later in the year when surface flow is low. ASR should be optimized with respect to cost, reliability, and related issues. Considerations are (1) how much injectate the recharging organization can physically recover, and how much credit the State Engineer might give to the recharging organization and (2) cost (considering energy use and well clogging) and timing of water need and availability. Although optimal ASR strategies are site- and management-specific, the procedure for developing them is transferable to other situations. This project will enhance the ability of the JVWCD to use Provo River water. As water manager confidence increases in their ability to recover more water and receive credit for it, the procedure will encourage ASR use by other organizations.

  Geographic Areas:

  Study Area: The new methodology will be developed and tested for the Jordan River Valley within Salt Lake County.

  Areas Benefited: This project will benefit all water providers that wish to intentionally recharge their aquifers thru wells and later extract the water for use. It will be applicable for sites worldwide. It is especially appropriate where the timing of surface water availability does not coincide with water need.

- **Accomplishments:**

  The primary work began in August 2011. Thus far, the following work has been performed:

  - A computer model that simulates groundwater quality changes has been modified to output the contaminant mass or water quality coming from each screened interval of a well. This is needed to optimize injection and extraction rates from ASR systems having multiple wells.
  - An existing above-ground water distribution system software (WEAP) has been partially evaluated to determine how best to link it with the groundwater flow simulation model. Specifically, its reported ability to prepare groundwater simulation model input files was tested.
  - Computer files and a report describing the above-ground water distribution system were requested from the Jordan Valley Water Conservancy District

  Findings: Errors in WEAP processing were reported to the developer (Stockholm Research Institute).

Work Plan FY11/FY12

- Acquire existing calibrated groundwater flow and transport simulation model(s) for the area.
- Select an existing flow and transport model to be used for this project and perform baseline simulations to demonstrate how the system currently responds to management.
- Meet with Jordan Valley Conservancy District to discuss optimization problem formulation.
- Prepare a preliminary optimization problem formulation.
- Prepare a representative hypothetical system for optimization model development and testing.
- Perform preliminary optimizations using existing simulation-optimization model, and determine whether and how to further modify the model.
- Report results to Jordan Valley Conservancy District.

Informational Resources

Contact: Dr. Richard C. Peralta, (435) 797-2786, E-mail: richard.peralta@usu.edu.

Curtis Creek: A 3-Dimensional Flow and Contaminant Transport Model to Estimate Stream and Groundwater Exchange and Water Quality Changes

Principal Investigators:
Said Ghabayen

Partners/Collaborators:
- ***State:*** *Dan Christensen, Utah Division of Water Resources*

Project Description

- Need and Purpose:

  Groundwater-surface water exchanges in mountain streams are widely recognized as affecting the geochemical processes, aquatic ecology, and water quality of the river system. A better understanding of these processes leads to appropriate management practices for the protection of water resources. Curtis Creek, UT was used as a case study to develop methodologies for linking groundwater modeling with an existing two-zone surface water temperature model in order to quantify and predict groundwater-surface water interactions for a better understanding of the impacts on geochemical processes, aquatic ecology, and water quality.

- Benefits to the State:

  Most of the water resources in Utah originate from mountain streams. Hence, better understanding of groundwater-surface water exchanges in a typical Utah mountain stream leads to better water resources management practices at the state level, and will ultimately lead to more effective management and protection of Utah water resources.

- Geographic Areas:

  Study Area: Curtis Creek, Hardware Ranch, and Cache County, Utah.

  Areas Benefited: The entire State of Utah could potentially benefit.

- Accomplishments:

  Findings: Different models and methods were applied to estimate the groundwater-surface water interactions. Application of groundwater modeling for the data collected through 2008 and 2009 showed that Curtis Creek has complex surface water-groundwater interactions. Gains and losses were quantified and shown to be significant in most of the sub-reaches (Figure 1).

  Results:

  - For Curtis Creek, gains and losses can be as large as 10% of the upstream flow and depend on the scale of the experiment.
  - Results from the groundwater model and from the dilution gauging method were consistent in terms of flow direction, but they were different by one order of magnitude in estimating gains and losses due to different uncertainties such as heterogeneity of the physical system; the existence of numerous flow paths, including long surface-groundwater exchanges that are not captured by MODFLOW but are very well-estimated by dilution gauging; and model discretization (cell size and layers).

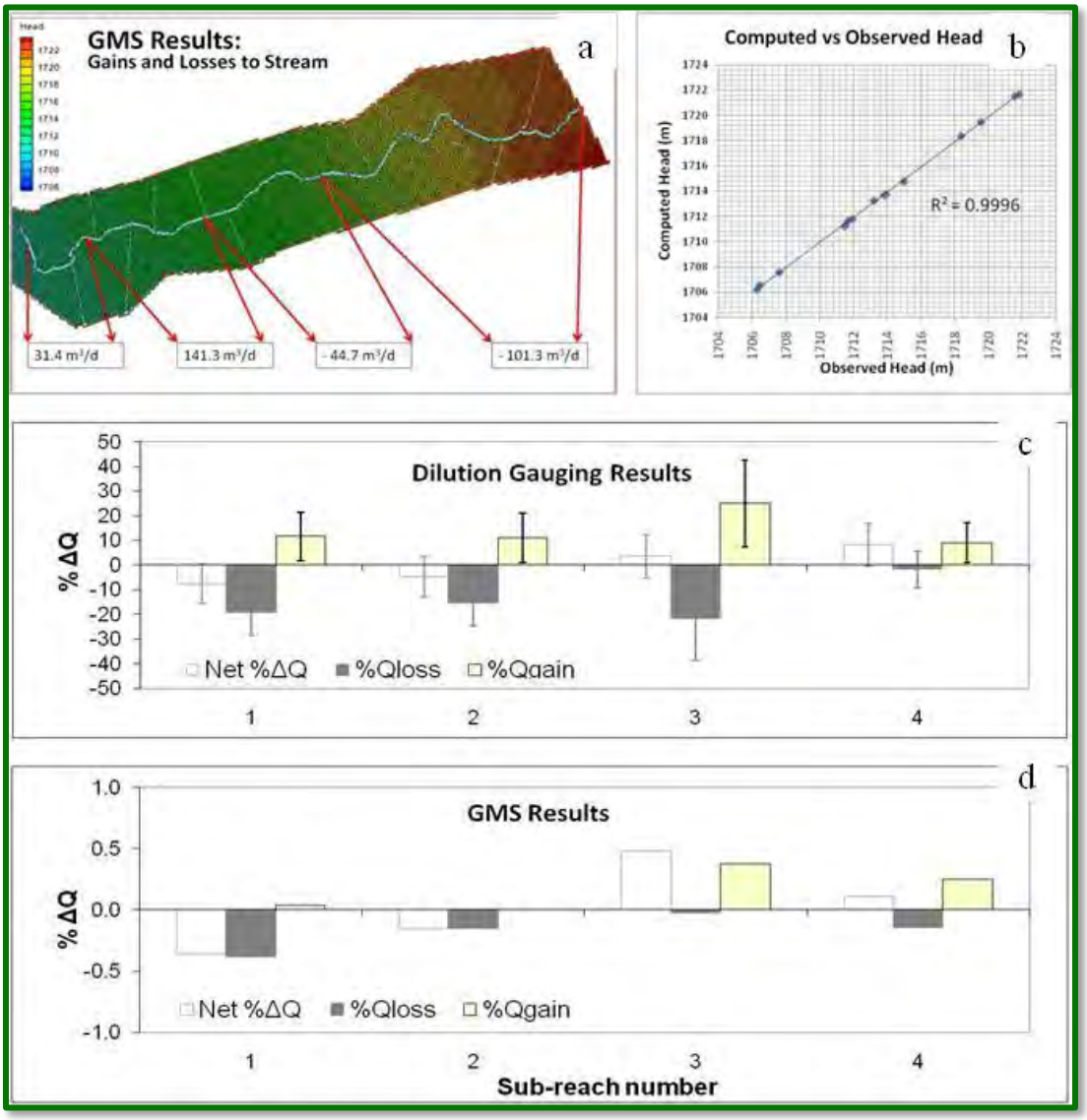


Figure 1. a) groundwater model results of gains and losses; b) groundwater model calibration results; c) % gains and losses by dilution gauging method; d) % gains and losses by groundwater model.

Work Plan FY 11/FY12

- Reduce the modeling and data collection uncertainty through the investigation of the level of uncertainty in each.
- Incorporate the impact of flow exchanges on water quality of the stream.
- Publish the results.

Informational Resources

Contact: Said Ghabayen, (435) 797-7176, Email: s.ghabayen@aggiemail.usu.edu.

Development of Flood Emergency Response Capability Using UAVs

Principal Investigators:
William J. Rahmeyer

Partners/Collaborators:

- ***Local:*** *City of Logan, City of Ogden, Cache County Search and Rescue, City of St. George*
- ***State:*** *Utah Division of Water Resources, Utah Division of Water Rights*
- ***Business/Industry:*** *Rosenberg Associates Civil Engineers*

Project Description

- Need and Purpose:

  Emergency response agencies and personnel who respond to flood events must often contend with significant uncertainties regarding the nature and scope of threats to public safety. Planning and coordinating a real-time response must often be done with limited knowledge of the extent and location of flooding and the location of people who might be at risk. Physical access to flooded areas will frequently be impeded, making it difficult or impossible to acquire data on the state of the flooded system and on the public safety threats that have been created.

  Data acquired by aircraft, satellites, and other remote sensing sources have become very important for many emergency response applications. However, these remote sensing platforms can also be expensive, have low spatial and temporal resolution, and require a long turnover time. A team at the Utah Water Research Laboratory (UWRL) at Utah State University has developed a new remote sensing platform called "AggieAir™" to deal with these shortcomings in order to provide access to remote sensing data for more applications. The AggieAir™ platform consists of unmanned aerial vehicles (UAVs) that are fully autonomous, low-cost, easy to use, and independent of a runway. They can acquire imagery very quickly and with a high spatial resolution. For more information on AggieAir™, refer to http://aggieair.usu.edu/.

  All floods represent a hazard to infrastructure, utilities, and emergency response personnel and may involve potential loss of life and property. This project explored the potential of AggieAir™ to gather real-time data in support of emergency management decisions in emergency flooding conditions by conducting a mock emergency flood demonstration in a 100-year floodplain in Cache Valley, Utah.

- Benefits to the State:

  - The use of UAVs could improve public safety responses to such events as floods, landslides, dam and canal failures, earthquakes, fires, search and rescue, and attacks on property and communities.

  - UAV surveys are economical and produce high-resolution geo-referenced maps, allowing city, county, or state agencies to perform their own surveys as needed.

- Geographic Areas:

  Study Area: The Bear River near Cache, UT.

  Areas Benefited: Any potential flood area in the State of Utah.

- Accomplishments:

Findings: The mock flood demonstration flight was conducted on a stretch of the Bear River in Cache Valley, UT that included a bridge crossing. Following the flight demonstration, state and local emergency response personnel held a meeting to view the flight photographs and discuss the benefits and uses of the UAV for flood response. A later meeting with city officials and a local civil engineering firm in St. George, UT discussed potential uses of the UAV for flood events such as the 2010 Santa Clara flood, including detecting, assessing, and monitoring the following:

- Debris at bridges and culverts.
- Stability of road crossings, bridges, channel banks, canals and levees.
- Sediment aggredation and build-up.
- Detention basins, holding ponds, etc.
- Vehicles, flood victims, and emergency response personnel and assets.
- Pre-programmed dwellings, road crossings, banks, canals, infrastructure, and any homes, buildings, structures and property at risk for flood events.
- Dangers to ground personnel such as oil leaks, broken gas lines, downed power lines, and loose propane tanks.

One of the most significant needs identified in the St. George meeting was the use of UAVs for post-flood damage assessment in order to meet the 30-day deadline to determine government aid for flood damage.

Results: The mock flood demonstration clearly showed the ability of the UAV to produce high resolution photos of bridge crossings, sediment deposits, debris, and river banks. The meetings determined that the UAV could be utilized for post-flood damage assessment and surveys would be a significant benefit for flood emergency response.

Work Plan FY11/FY12

Project is complete.

Informational Resources

Contact: Dr. William J. Rahmeyer, Phone (435) 797 2938, E-mail: william.rahmeyer@usu.edu.

February 8, 2011 AggieAir™ photo of the Utah Highway 23 Bridge

Area Photographed During the February 8, 2011 UAV Flight (images shown along the channel banks and at bridge crossings overlaid on a Google Earth base map)

Effects of Rotenone Treatment for Removal of Non-native Fish on the Macroinvertebrate Assemblage of Boulder Creek, Utah

Principal Investigators:
Chris Thomas

Partners/Collaborators:
- ***State:*** *Utah Division of Natural Resources*
- ***Business/Private:*** *Garkane Power*

Project Description

- Need and Purpose:

  In 2009, the East Fork of Boulder Creek was treated with Rotenone to remove the Brook Trout population that was present. The purpose of the project was to compare the aquatic macroinvertebrate assemblages before and after treatment to determine the impacts on the food sources needed by the native Colorado Cutthroat trout populations in Utah.

  The research focused on aquatic macroinvertebrate density and distribution in the East Fork of Boulder Creek in southern Utah. Macroinvertebrates are the main food source of cutthroat and other salmonid fishes. By examining the current density and distribution of macroinvertebrates, possible changes in the macroinvertebrate assemblage can be predicted in the presence of the Rotenone treatment as a means to protect wild fish populations from invasive species of planted fish. This information will allow prediction of possible effects on Colorado cutthroat trout populations due to changes in macroinvertebrate assemblage.

- Benefits to the State:

  This research benefits the state of Utah by providing information the impacts of Rotenone treatment on macroinvertebrates that are the critical food base for endangered Colorado cutthroat trout.

- Geographic Areas: Garfield County, Utah.

  Study Area: East Boulder Creek Watershed.

  Areas Benefited: State-wide where cutthroat trout populations exist and Rotenone treatment is used to control invasive fish species.

- Accomplishments:

  Findings: The effort to identify all macroinvertebrates in the samples is ongoing.

  Results: Results will not be available until all of the samples have been identified.

Work Plan FY11/FY12

- Sort and identify macroinvertebrates from samples taken prior to and after Rotenone treatment.
- Determine whether Rotenone affected macroinvertebrate populations in Boulder Creek.
- Include information with the final report to Garkane Power and the Utah Division of Natural Resources.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Boulder Creek, Utah

Eliminating the Division Between Ecosystem Engineers and Biologists

Principal Investigators:
Casey S. Williams

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  One of the largest problems in America today is water supply and the lack thereof, specifically in the western United States. Policymakers are often required to make water related decisions based on abiotic information (hydraulics, stream morphology, flow regime, groundwater, etc.) provided by engineers and biotic information (biology, food webs, habitat use, etc.) provided by biologists/ecologists. Unfortunately, the opinions of engineers and biologists do not always agree and are many times actually at odds with one another. This disagreement often leads to conflicting information that causes confusion. Very few individuals or groups are trained to confront both the abiotic and biotic components of water issues.

  The purpose of this project is to support collaborative efforts among engineers and biologists in solving water related issues in the state of Utah. Specifically, one engineer and one biologist (both postdoctoral fellows) worked together to combine the analytical methods of the two specialized fields to improve overall analytical techniques. Additional state related projects were also sought in order to take advantage of this collaboration.

- Benefits to the State:

  This project directly benefits the state of Utah by improving analytical methods for complex water related issues in the state. Several state related projects have been improved by this collaboration, including restoration of Boulder Creek Colorado River cutthroat trout populations and the Bear River Hydroelectric Project. Additionally, a project to implement minimum flows in the San Rafael River was developed and is underway in cooperation with the Utah Division of Wildlife Resources, Bureau of Land Management, and Emery County Water Conservation District.

- Geographic Areas: Boulder Creek in Garkane County, Bear River in Cache County, and San Rafael River in Emery County, Utah.

  Study Area: Garkane, Cache, and Emery counties.

  Areas Benefited: Garkane, Cache, and Emery counties and state-wide.

- Accomplishments:

  Findings: Through collaborative efforts, a cutthroat trout bioenergetics model has been successfully applied to several ongoing projects. This model requires an understanding of both river hydraulics and biology of salmonid fishes.

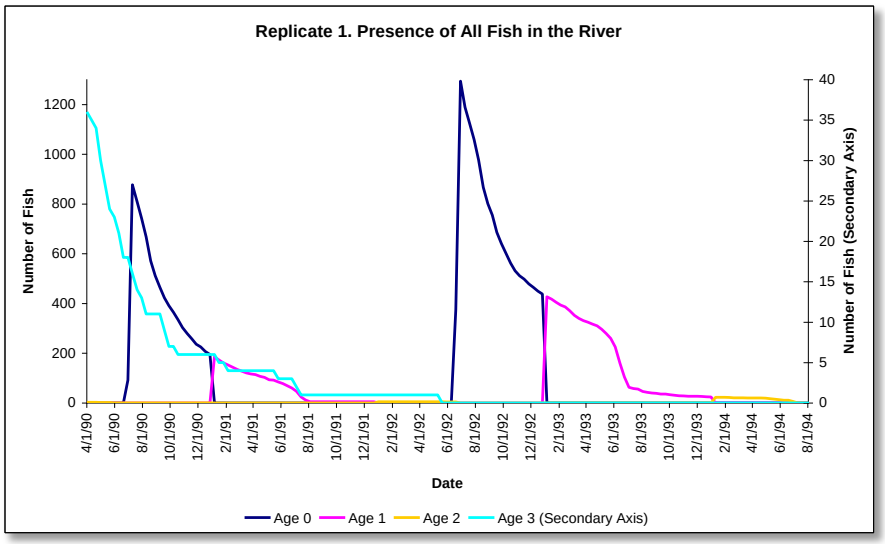
Results: The results of this project have shown that collaboration between engineers and biologists increases the understanding of various models and improves ability to communicate the findings of research to both technical and non-technical audiences.

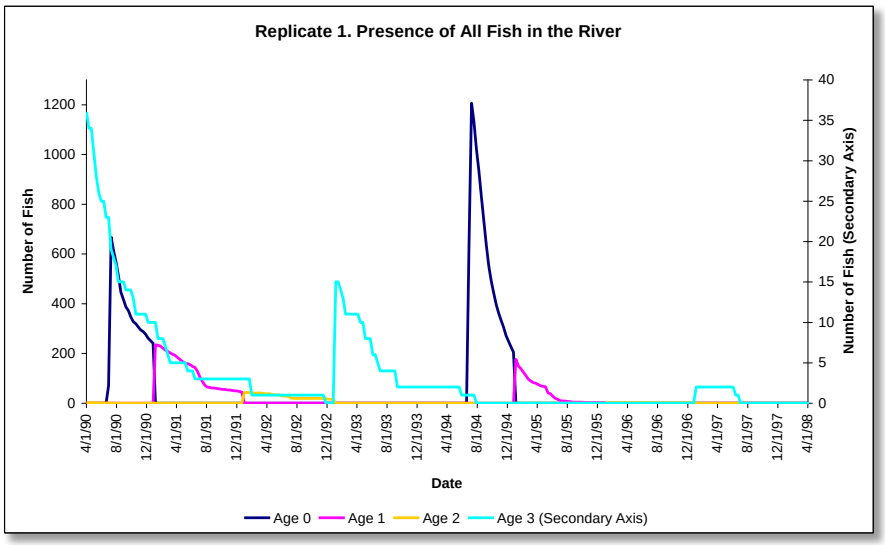
Work Plan FY11/FY12

This project is complete, and no further work is planned.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.





Model results for Bonneville cutthroat trout under various scenarios in the Bear River, Utah and Idaho

Estimating Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated Systems at Different Spatial Scales

Principal Investigators:
Christopher M.U. Neale
Hatim Geli (student)

Partners/Collaborators:

- ***Local:*** *Bear River Canal Company*
- ***State:*** *Utah Agricultural Experiment Station*
- ***Federal:*** *US Bureau of Reclamation, USDA Agricultural Research Service*
- ***Business/Industry:*** *Palo Verde Irrigation District*

Project Description

- Need and Purpose:

  Reliable estimates of crop evapotranspiration (ET) are needed for improved water management of large irrigation projects, irrigation scheduling, integrated water demand estimates at different canal command levels, and water rights adjudication and control. Improved and timely estimates of irrigation water demand can increase understanding of the water pathways within the irrigation system and identify water management and application efficiency improvements. For large canal-supplied irrigation systems in Utah, satellite imagery from sensors such as the Thematic Mapper on the Landsat satellite has the appropriate scale and is cost effective. The satellite imagery can be supplemented with airborne imagery for critical periods of crop growth if imagery is unavailable due to the presence of clouds. A modeling environment that can use multi-temporal and multi-sensor remotely sensed imagery for estimating spatial ET is needed.

- Benefits to the State:

  Improved water management can lead to water savings and potentially to improved water quality, as decreases in diversions for irrigation can be stored for future use during drought years and guarantee minimum flows for the health of rivers systems and for other uses. The methodology being developed can be used in other irrigated areas of the state.

- Geographic Areas: Northern and Central Utah and Southern California.

  Study Area: Bear River Canal Company in Box Elder County and irrigated areas of Sevier County. Palo Verde Irrigation District in Southern California.

  Areas Benefited: All counties in Utah with irrigated agricultural areas and systems.

- Accomplishments:

  The remote sensing methodology has been applied to the water balance of two large irrigation systems: the Bear River Canal Company (BRCC) in northern Utah and the Palo Verde Irrigation District (PVID) in southern CA. Results will allow policy makers to analyze potential changes in water management strategies to improve water use efficiency.

  Findings: Spatial evapotranspiration estimated from a series of satellite imagery acquired over a growing season can be used to establish seasonal crop water use in large irrigated systems and establish the water balance and efficiency of the system at different levels.

Results: A new method of processing and correcting measured scintillometer data for estimating sensible heat fluxes and derive ET was applied to data collected in a Tamarisk dominated riparian forest at the Cibola Refuge, CA and in Richmond, UT. Remotely sensed evapotranspiration using satellite imagery was incorporated into a model to evaluate and optimize irrigation application in the fields of the Bear River Canal Company.

Work Plan FY11/FY12

Future efforts will continue to concentrate on disseminating information to water managers and publishing the results in journal articles.

Informational Resources

Contact: Christopher Neale, (435) 797-3689, E-mail: christopher.neale@usu.edu.

References:

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Taghvaeian, S. (2011). *Water and Energy Balance of a Riparian and Agricultural Ecosystem Along the Lower Colorado River*. Ph.D. Dissertation. Department of Civil and Environmental Engineering, College of Engineering, Utah State University, Logan, UT.

Finding Appropriate Complexity for Distributed Hydrologic Models

Principal Investigators:
Luis A. Bastidas
Saket Pande, Technical University of Delft, Netherlands

Partners/Collaborators:

- ***Federal:*** *National Weather Service, Colorado Basin River Forecast Center*

Project Description

- Need and Purpose:

  This project explored the use of Statistical Learning Theory as a way to determine the optimal modeling framework in terms of the appropriate levels of detail, while at the same time producing good and robust simulations of runoff and soil moisture from fields. To achieve this we developed a way to measure the complexity of the models and, at the same time, incorporate different scale observations such as point in situ measurements, small aircraft remote sensing observations, and satellite observations.

  The project aimed to reconcile two constraints in hydrologic modeling: 1) the increase in the resolution of the terrain representations and 2) limitations in the number of parameters that can be properly identified, at fine resolutions, due to lack of information and huge computational requirements.

  The study was carried out using a simple hydrologic model for the development of the measure. An application of the simplified models to water resources in arid regions was also tested. Another application involved the use of the distributed Research Development Hydrologic Model (RDHM) model from the National Weather Service with the help of the Colorado Basin River Forecast Center, located in Salt Lake City. These agencies have provided high resolution spatial data and have helped to implement the model in our Linux based computers.

- Benefits to the State:

  The study focused on semiarid regions and on mountainous areas with snow cover, which includes a significant part of the western United States and, in particular, the State of Utah. In the future the developed procedures can be applied to areas within the State. This will allow for better hydrological simulations, which in turn will mean better estimation of the water resources available.

- Geographic Areas:

  Study Area: Due to some limitations with the extent of radar coverage over the Utah area, and as a first approximation, we tested the procedures with data from the Durango River Basin, which is mostly located in Colorado but has similar hydrologic conditions to those observed in Utah.

  Areas Benefited: All areas in Utah and throughout the Intermountain West.

- Accomplishments:

  Findings/Results: We have developed a theoretical approach to quantitatively measure the complexity of simple models and have implemented a procedure to numerically evaluate the measure for more complicated physical representations (more complex models). This latter

procedure is currently being tested. The results about the complexity measure have been finalized and accepted for publication.

We have also implemented several pattern based similarity measures to evaluate the performance of distributed models. These measures are beyond the commonly used mean error functions. They are inherently multi-dimensional and multi-objective and are based on the mathematics of set theory and the so called Earth's Movers Distance. We have concurrently evaluated the discharge at various points, together with the snow water equivalent and snow cover values derived from satellite and gage observations. All the computer simulations have been finished. Currently, we are post-processing the results.

A paper and a book chapter on the application of parsimonious models to water resources have been published. A paper on the theoretical development of the complexity measure with simple hydrologic and water resource models is in press.

Work Plan FY11/FY12

The main goals of the project are considered to be achieved, and thus the project is finished. We are currently looking for opportunities for further funding for additional testing and applications of the procedures developed.

Informational Resources

Contact: Dr. Luis A. Bastidas, (435) 797-8228, E-mail: luis.bastidas@usu.edu

References:

Bastidas, L.A., S. Pande, G. Schoups, and N. van de Giesen (2010). Hydrological model output space and prediction uncertainty. *AGU Fall Meeting*, San Francisco, CA. December.

Kim, J. and L.A. Bastidas (2011). A Comparative Distributed Evaluation of the NWS-RDHM using Shape Matching and Traditional Measures with In Situ and Remotely Sensed Information. *AGU Fall Meeting*, San Francisco, CA. December 5-9.

Kim, J., L.A. Bastidas, and E.P. Clark (2010). Uncertainty evaluation and appropriate distribution of the RDHM in the Rockies. *AGU Fall Meeting*, San Francisco, CA. December 12-17.

Pande, S., H.H.G. Savenije, L.A. Bastidas, and A.K. Gosain (2010). A parsimonious modeling approach for water management in dryland areas. In S. Khan, H. Savenije, S. Demuth, and P. Hubert (Eds.). *Hydrocomplexity: New tools for solving wicked water problems*. IAHS, Publication 388.

Pande, S., L.A. Bastidas, H.H.G. Savenije and A.K. Gosain (2011). A parsimonious hydrological model for a data scarce dryland region. *Water Resources Management*, Doi: 10.1007/s11269-011-9816-z.

Pande, S., L.A. Bastidas, S. Bhulai, and M. McKee (2011). Parameter dependent convergence bounds for hydrologic models. *Journal of Hydroinformatics*, in press.

Flood Potential Due to 100-Year Storm Events for Small Utah Cities

Principal Investigators:
Michael C. Johnson
Marshall W. Saunders

Partners/Collaborators:
- ***State**: Todd Adams, Water Resources*
- ***Business/Private:** Matt Stayner, Bowen Collins*
- ***Federal:** Edward Clark, CBRFC*
- ***USU Staff:** Mark Winkelaar*

Project Description

- Need and Purpose:

  With the population growth in Utah, many cities are expanding their borders into the mountain range benches. Consequently, these homes are in the path of potential floods. In the event of a severe thunderstorm, a river or small stream can expand far beyond its banks. Even areas that don't normally have streams can accumulate enough rain water to create a flash flood. Since peak flood runoff information in these mountain ranges does not currently exist, cities are left without this critical potential flood information when considering city planning or flood prevention.

- Benefits to the State:

  By determining peak flood runoff in these mountain ranges, a city can better plan around potential flood areas and implement flood prevention methods. Many cities in the State of Utah are unable to afford an engineering firm to perform a detailed study of the mountain areas. The results of this study will provide Utah cities with detailed information about the amount of flood water coming out of the basins and will guide future growth and implementation of flood control structures for homes that are already in place. The project results could potentially save the state considerable money by avoiding the need for disaster clean up if and when floods occur.

- Geographic Areas:

  Study Area: The study area includes all basins in the state of Utah that are near or in a city and are considered to have the possibility of significant flood water damage. The following list indicates the number of currently identified study sites in each county: Box Elder, 5; Cache County, 12; Carbon County, 9; Davis County, 19; Juab County, 2; Millard County, 1; Morgan County, 11; Salt Lake County, 18; Sanpete County, 6; Summit County, 6; Tooele County, 1; Utah County, 31; Weber County, 10; Wasatch County, 2; and Washington County 5.

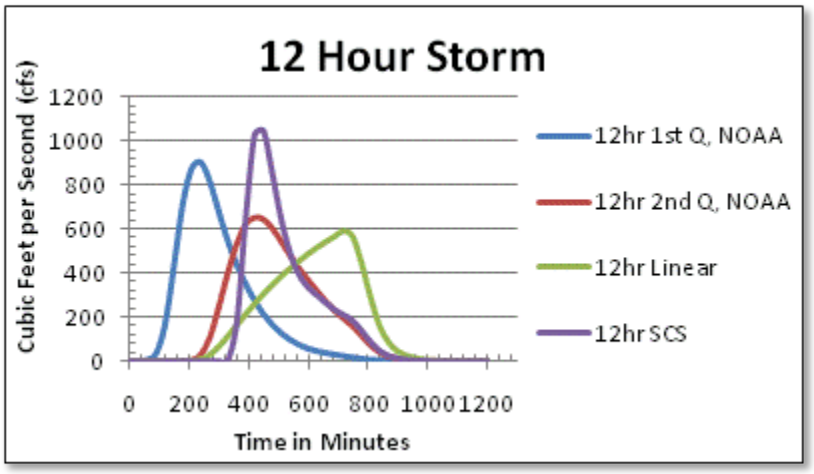
  Areas Benefited: This project will benefit all cities in the state that are experiencing growth and need data to plan for potential flood issues.

- Accomplishments:

  Findings: Currently, of the 138 identified study areas, 110 studies have been completed or are in the finishing stages.

  The hydrograph figure below is an example of peak runoff flood water from the study on one of the 138 identified study sites. This hydrograph is in Hyde Park Canyon for a 12-hour storm. Similar hydrographs are being completed for the other 137 study sites for 1-, 2-, 3-, 6-, 12-, and 24-hour storms. Each line represents a different way to distribute rainfall during the length of the

storm with a different peak value for the same volume of runoff. For example, the 12-hour linear distribution that was used as a lower bound has a peak of about 600 cubic feet per second at about 720 minutes after the storm has started.



Hydrograph of peak runoff flood water

Results: The results indicate a high probability of flooding in sub basins that do not contain a natural stream. Consequently, this condition presents a potential hazard for the citizens and property in the path of the flood waters. This study also showed that the State of Utah has very limited rainfall curve information and that some curves differ widely.

Recommendations: Rainfall curve distributions should be made specific to Utah's storms and mountain regions. In many parts of Utah, rainfall gauge data is either lacking or insufficient in period of time or coverage. Since current soil and vegetation data combine valley and mountain areas, soil and vegetation data need to be specific to mountain regions only, which would improve the input data.

Work Plan FY11/FY12

- Complete the study area identification and perform a 100-year storm event analysis for each additional study area.
- Assemble the data into the report that is organized by county and city, distribute the report to the Utah Division of Water Resources and to cities across the state to help them guide Utah's future development, and promote an awareness of the possible flooding hazards along the various basins in Utah.

Informational Resources

Contact:

Dr. Michael C. Johnson, (435) 797-3176, E-mail: michael.johnson@usu.edu.
Mr. Marshall W. Saunders, (435) 797-3152, E-mail: marshallsaunders@aggiemail.usu.edu.

Habitat Monitoring of the Bear River

Principal Investigators:
Chris Thomas

Partners/Collaborators:
- ***State**: Reed Harris – Utah Division of Natural Resources*
- ***Business/Private:** Warren Colyer – Trout Unlimited*

Project Description

- Need and Purpose:

  Proposed construction of the Bear River Narrows Hydroelectric Project in southeastern Idaho has the potential to impact Bear River aquatic macroinvertebrate assemblages both above and below the Utah/Idaho border, thereby impacting cutthroat trout populations in Utah. The proposed dam would inundate approximately 5 miles of the Bear River Narrows, much of which includes possible spawning and nursery grounds that support the cutthroat populations in the Bear River. However, impacts to aquatic macroinvertebrate assemblages and resulting changes in cutthroat trout in Utah related to dam construction are difficult to predict due to a lack of pre-dam assemblage information.

  This project will focus on aquatic macroinvertebrate density and distribution in the Bear River of southern Idaho and Northern Utah. Macroinvertebrates are the main food source of cutthroat and other salmonid fishes. By examining the current density and distribution of macroinvertebrates, we will be able to predict possible changes in the macroinvertebrate assemblage in the presence of the proposed dam. This information will also allow us to predict possible effects on Bonneville cutthroat trout populations due to changes in macroinvertebrate assemblage.

- Benefits to the State:

  This research will benefit the state of Utah by providing information to be used as a basis for predicting macroinvertebrate assemblage changes due to reservoir construction and the resulting changes in cutthroat trout assemblage. Specifically, information provided will help the state to meet the objectives of the Range-Wide Conservation Agreement and Strategy for Bonneville Cutthroat Trout, Utah's Endangered Species Mitigation Program, and the conservation efforts of Trout Unlimited.

- Geographic Areas: Bear and Cub Rivers, Cache County, Utah.

  Study Area: Cache County.

  Areas Benefited: Cache County and state-wide where Bonneville cutthroat trout populations exist.

- Accomplishments:

  Findings: Based on pre-project and post-project habitat analysis, little impact is expected on habitat and macroinvertebrates below the inundation area (reaches 3-1) and into Utah. This conclusion is based on near identical flow release patterns, little expected change in the river

substrate characteristics, and similar thermal regimes. Overall water quality is expected to be similar to existing characteristics.

Results: If a permit is granted and the Twin Lakes Dam is built, it will have little effect on the Bear River macroinvertebrate assemblages in Utah, and would therefore have minimal impact on any cutthroat trout population in Utah.

Work Plan FY11/FY12

This project is complete. No further work is planned.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Collection of Drift Samples

Collection of kick samples for Benthic Macroinvertebrates

Improving Hydrologic Model Predictions for the Effects of Land Use and Climate Change

Principal Investigators:
David G. Tarboton
Ibrahim Mohammed (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Land cover and climate change, along with their associated impacts on water resources, are among the pressing areas of research within the western United States. This work is focused on improving the capability for modeling the hydrologic response and sensitivity of watersheds to land use or land cover change, along with climate change. This work addresses the runoff produced from watersheds as well as the downstream impacts of this runoff on water resources and receiving water bodies such as the Great Salt Lake (GSL).

- Benefits to State:

  Water is a critical resource in Utah, and this project will provide a better understanding and improved ability to predict water availability in the future as a result of land use and climate changes. Planning for development and growth in the state requires information on water availability as well as information on the impacts of the growth on water resources. The Great Salt Lake is a critical resource in Utah whose level is affected by runoff from surrounding watersheds. This project also addresses improving understanding of the dynamics of the Great Salt Lake.

- Geographic Areas:

  Study Area: The study area is the semi-arid Western U.S., particularly Utah, with a focus on watersheds draining into the Great Salt Lake.

  Areas Benefited: Water Resources in watersheds throughout Utah may be subject to impacts from changes in land use and climate, so all counties in the state would potentially benefit from a better understanding of these impacts.

- Accomplishments:

  Findings: This work has focused on: 1) Distributed modeling using detailed spatial information and improving inputs to such hydrologic models, and 2) Understanding the dynamics of the Great Salt Lake. We address each of these in the results below.

  Results: A Regional Hydro-Ecological Simulation System (RHESSys) model was used to study the sensitivity of water balance components to land cover and climate changes in the Weber Basin, as an exemplar for this region. This work examined the differences in runoff generated from coniferous and deciduous forested areas and provides a way to quantify, using a physically based approach, the sensitivity to changes in the type of land cover (specifically forest type) on water resources. The work also focuses on the downstream impacts on the level of the Great Salt

Lake, as well as preferred lake level states and their underlying causes. Preferred lake levels are related to the lake's bathymetric form as expressed in the relationship between level, volume, and area interacting with water inputs to the lake. Ongoing work is using a water balance approach to generate representative realizations of future GSL level from input climate and streamflow sequences. A k-nearest neighbor approach, a statistical technique to resample representative values from past data, is being used to generate sequences of precipitation, streamflow, and climate inputs. These provide forecasts for the ranges of future GSL levels up to several years ahead. By changing the temperature and streamflow inputs in these sequences we quantify the sensitivity of these range forecasts to possible change.

Work Plan FY11/FY12

The use of the physically-based RHESSys modeling approach will help us better understand and quantify the sensitivity of watersheds to changes in individual input factors. This is needed to complement prior work that has taken an empirical approach based on extensive data examination where overall effects can be quantified, but where it is difficult to separate out the sensitivity to different causal factors. Similarly, the water balance approach to fluctuations in the level of the GSL provides a model that can be used to examine the sensitivity to individual inputs.

Informational Resources

Contact: Dr. David G. Tarboton, (435) 797-3172, Email: david.tarboton@usu.edu.

References:

Mohammed, I.N. and D.G. Tarboton (2011). On the Interaction between Bathymetry and Climate in the System Dynamics and Preferred Levels of the Great Salt Lake. *Water Resour. Res.*, 47:W02525, http://dx.doi.org/10.1029/2010WR009561.

Interstate Movement of Bonneville Cutthroat Trout

Principal Investigators:
Casey S. Williams
Thomas B. Hardy

Partners/Collaborators:
- ***State**: Reed Harris – Utah Division of Natural Resources*
- ***Business/Private:** Warren Colyer – Trout Unlimited*
  Kirk Dahle – Trout Unlimited

Project Description

- Need and Purpose:

  Proposed construction of the Bear River Narrows Hydroelectric Project in southeastern Idaho has the potential to impact Bear River migration routes and Bonneville cutthroat trout distribution across the Utah/Idaho border, thereby impacting cutthroat trout populations in Utah. The proposed dam would inundate approximately 5 miles of the Bear River Narrows, much of which includes possible spawning and nursery grounds that support cutthroat populations in the Bear River. However, impacts to cutthroat trout in Utah related to dam construction are difficult to predict due to a lack of information pertaining to habitat availability and cutthroat trout distribution and migration patterns in the Bear River in both Utah and Idaho.

  This work focused on habitat delineation, cutthroat trout migration patterns and potential effects of impacts on the existing cutthroat population in the Bear River above and below the Utah/Idaho state line. Detailed habitat delineation, including mesohabitat measurements and hydraulic modeling, was conducted throughout the study area. In addition, a survey of current fish assemblage structure and Bonneville cutthroat trout distribution and migration patterns were conducted using accepted methods of fish collection and biotelemetry

- Benefits to the State:

  This work will benefit the State of Utah by providing information to be used as a basis for conservation efforts of Bonneville cutthroat trout throughout its range. Specifically, information provided will help the state to meet the objectives of the Range Wide Conservation Agreement and Strategy for Bonneville cutthroat trout, Utah's Endangered Species Mitigation Program, and conservation efforts of Trout Unlimited. This study will provide explicit information concerning migration and conservation of genetic diversity of interconnected local cutthroat trout populations within the metapopulation of the Bear River Geographic Management Unit.

- Geographic Areas: Bear and Cub Rivers, Cache County, Utah.

  Study Area: Cache County, Utah.

  Areas Benefited: Cache County and state-wide where Bonneville cutthroat trout populations exist.

- Accomplishments:

  Findings: Seasonal fish, habitat, and temperature surveys have been conducted at five broad reaches of the Bear River in Idaho and Utah. During two years, thirty-three Bonneville cutthroat trout were implanted with telemetry tags and tracked throughout the year. Fish survey data and

habitat analysis (including temperature) indicate that the Bear River habitat within Utah is not capable of supporting Bonneville cutthroat for extended periods of time; however, the Bear River may act as a migration corridor among populations in the drainage.

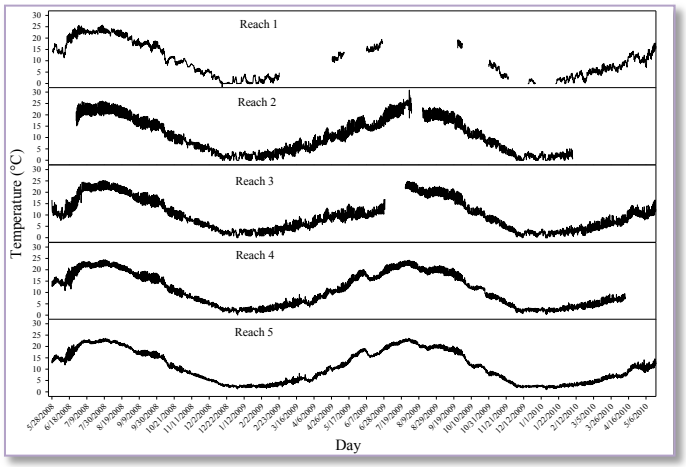
Results: Fish surveys indicate a small population of Bonneville cutthroat trout exists in the Bear River upstream of the Utah/Idaho border, and another population is known to exist in the Cub River, which is a tributary to the Bear River. The telemetry study verified interstate migration of Bonneville cutthroat trout along the Bear River and suggests an intact genetic connection with cutthroat trout in the Cub River. Thus, the Bear River may be a vital factor in maintaining the current Bear River metapopulation of Bonneville cutthroat trout. Potential impacts of the proposed Bear River Narrows Hydroelectric Project to the Bear River in Utah are negligible and will most likely not affect available habitat resources.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Electrofishing the Bear River

Bear River Bonneville cutthroat trout



Temperature data for the Bear River, Idaho and Utah

Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates

Principal Investigators:
Christopher M.U. Neale
Jonna Van Opstal (student)

Partners/Collaborators:
- ***Local:*** *Bear River Canal Company*
- ***State:*** *Utah Agricultural Experiment Station*
- ***Federal:*** *USDA NRCS*

Project Description

- Need and Purpose:

  There is a growing demand for fresh water for municipal use along the Wasatch front and in Cache Valley. The increase in urban areas has led to water quality and quantity pressures on the exiting water resources. The Bear River basin is one of the few systems in the US West that still has unallocated water. It is only a matter of time before additional dams will have to be built within the system to tap these water resources, while adjusting to a changing runoff hydrograph due to expected climate change. Solutions for improved management of the water resources in the Bear River basin will require involvement of multiple stakeholders and possible policy adjustments to the existing water laws. Improving the water management in large surface irrigated areas will be one of the important elements of the solution due to the high consumptive use of these systems and large diversions from the river. This study is to provide the necessary information so that system operation management decisions can be made in the future to adapt to changing conditions. The results will be relevant and applicable to other similar systems in the state of Utah.

- Benefits to the State:

  Improved water management can lead to water savings and potentially to improved water quality as decreases in diversions for irrigation can be stored for future use during drought years and guarantee minimum flows for the health of rivers systems and for other uses. The methodology being developed can be used in other irrigated areas of the state.

- Geographic Areas: Includes northern and central Utah.

  Study Area: Bear River Canal Company in Box Elder County and irrigated areas of Weber and Sevier County.

  Areas Benefited: Irrigated agricultural areas and systems in all counties in Utah.

- Accomplishments:

  The project initiated in June 2011, and several field visits to the research site and meetings with the BRCC manager Dan Davidson have occurred.

  Findings: Preliminary analysis of water quality samples collected at different points of the irrigation canal and drainage system indicate changes in water quality within the system.

  Results: The project has just initiated; no significant results are available at this point.

Work Plan FY11-12

A detailed research plan will be written for the BRCC, including a water quality sampling scheme, water measurements and evapotranspiration estimation for the summer of 2012, when intense field research will be conducted to establish the water and solute balance within the system.

Informational Resources

Contact: Dr. Christopher M.U. Neale, (435) 797-3689, E-mail: christopher.neale@usu.edu.

Low Cost Vertical Take Off and Landing Remote Sensing Systems for Water Engineering

Principal Investigators:
YangQuan Chen
Brandon Stark (student)

Partners/Collaborators:
- ***Local:*** *Jim Walder, SRWUA*
- ***Federal:*** *Roger Hansen, USBR*
- ***Local:*** *Austin Jensen, USU, UWRL*

Project Description

- Need and Purpose:

  To better manage water and other natural resources such as wetlands and floodplains, the Utah Water Research Laboratory (UWRL) and the Center for Self-Organizing and Intelligent Systems (CSOIS) have been actively developing UAV-based PRS (Personal Remote Sensing) systems using fixed-wing UAV platforms known as AggieAir. In many applications, it is highly desirable for UAVs to take off and land vertically in a constrained area or to make close "point measurement" such as for wetland invasive species characterizations. The goal of this project is a mature Vertical Take-Off and Landing (VTOL) platform to compliment AggieAir for personal remote sensing application in water related scenarios.

- Benefits to the State:

  AggieAir fixed-wing UAVs have proven to be very useful for managing natural resources in the State of Utah and other places across the country. For example, the ability to acquire decision-relevant data on soil moisture and evapotranspiration in a timely fashion and at a low cost gives canal companies and irrigation districts in the state the ability to (1) provide farmers with highly detailed information about soil moisture conditions in individual fields enabling them to better manage scarce irrigation resources, and (2) manage complex irrigation delivery systems more efficiently, thereby saving water that could be used to increase agricultural output or allocated to other users whose demands are continually growing. The water savings could be as much as 5 or 10 percent of current deliveries.

  AggieVTOL UAVs complement the AggieAir UAVs and will benefit the State of Utah in many similar ways, enabling many new emerging applications.

- Geographic Areas:

  Study Area: In collaboration with UWRL field engineers, Cache Junction and Bear River will be used as a test and demonstration site, including Bear River Migratory Bird Refugee (BRMBR).

  Areas Benefited: Wetland management in the BRMBR. All counties in the state could benefit.

- Accomplishments:

  Findings: An inexpensive unmanned aerial vehicle (UAV) known as AggieVTOL that can take-off and land vertically has been developed and is being made robust and capable of carrying and controlling various types of remote sensing equipment and gathering remotely sensed data, which can then be processed for distribution to water managers and farmers. AggieVTOL is a modular multi-rotor rotorcraft UAV prototype platform. Performance results demonstrate the effectiveness of the platform.

Results: 1) The low-cost AggieVTOL prototyping approach is using open source Paparazzi architecture, 2) After rigorous peer review, a book chapter (35 pages) has been accepted to be published with IGI Global; 3) Fully autonomous way point navigation has been demonstrated; 4) Grants have been successfully obtained from NSF (2011-2012) and NASA (2011-2014) despite fierce competition.

Work Plan FY11/FY12

- AggieVTOL under OSAM (open source autonomous miniature) will target robustness issues.
- Optimize quadrotor VTOL UAV to have 20 minutes autonomous flight time with full payload (one camera).
- Target two cameras (RGB and NIR) for octorotor VTOL UAV.
- Continue design iterations and a manufacturability study toward a salable product design.

Informational Resources

Contact: Dr. YangQuan Chen, (435) 797-0148, E-mail: yangquan.chen@.usu.edu.

Website: http://mechatronics.ece.usu.edu/yqchen/ and http://aggieair.usu.edu/.
Team Wiki: http://www.engr.usu.edu/wiki/index.php/.
OSAM_UAVYoutube Channel: http://www.youtube.com/user/.
USUOSAMICUAS2011 Tutorial: http://uasconferences.com/ICUAS%2711_Tutorial.pdf.
News paper story: "USU Still Flying High" http://www.usu.edu/ust/index.cfm?article=50035 and http://www.auvsi.org/news/#SUAS2011.
AggieVTOL bookchapter: http://www.igi-global.com/bookstore/titledetails.aspx?TitleId=58292.

Figure 1. Two iterations of AggieVTOL

Figure 2. AggieVTOL in flight

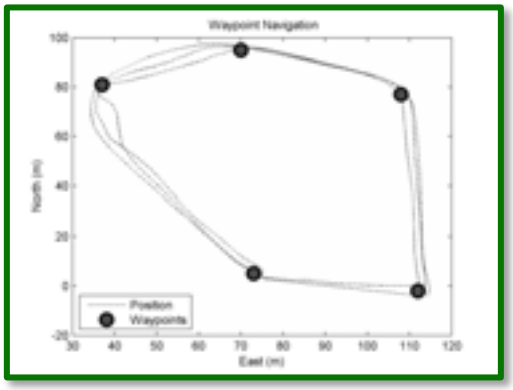


Figure 3. Recorded tracks of an AggieVTOL flight

Figure 4. View from AggieVTOL camera

Multispectral Image Processing for Water Management and Other Agricultural Applications

Principal Investigators:
Huifang Dou
Swathi Gorthi (student)

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Water management is an important problem not only in the state of Utah, but also in many parts of the United States, and beyond. With the population increasing in most parts of the world, the water shortage problem is getting worse. Identifying soil moisture situations over large areas can help reduce water consumption in irrigation systems while increasing crop and forage productivity. Multispectral images, remotely sensed from satellites or aircrafts, provide an effective way to analyze water content over large crop fields and rangelands. However, the low spatial resolutions of the images and practical temporal limits, as well as weather related obstructions (like clouds), make accurate prediction of daily agricultural water consumption using remote sensing a difficult problem. Therefore, effective algorithms must be explored in order to accurately determine water content from remote sensing data. With the use of smart sensors and algorithms, we will be able to accurately determine soil moisture content, vegetation type, land usage and cropping, and other needed information.

- Benefits to the State:

  Utah agriculture generates more than $1 billion in income for our farmers and ranchers while helping to fuel the state's rural economy. This research program will assist water resource managers to efficiently promote the orderly and timely planning, conservation, utilization, and protection of Utah's water resources. This research program will also benefit Utah's farmers and ranchers by providing them with information and guidance about crop and forage growth status and soil moisture conditions.

- Geographic Areas:

  Study Area: Sevier and Millard Counties

  Areas Benefited: All counties in the state would benefit from this research.

- Accomplishments:

  Findings: Based on the analysis of last year's results, we studied and implemented several different supervised learning techniques for producing accurate estimates of soil moisture content using meteorological and remotely sensed data. The models developed can be extended to applications in the remote sensing systems developed in CSOIS, USU. The different models employed extend over a wide range of machine learning techniques, starting from basic linear regression models based on Bayesian framework, decision tree learning, and recursive partitioning, to the modern non-linear statistical data modeling tools like artificial neural networks. Moreover, ensemble methods such as bagging and boosting can be implemented on all models to achieve considerable improvements in accuracy.

Results: In this study, data collected in SMEX02 were used to test the models. The model inputs are vegetation indices obtained from remotely sensed images, soil temperature, air temperature, and precipitation. The output is surface soil moisture content (0-6cm). The results of Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) for different models are summarized in Table 1. As we can see, the boosting RVM provides the best results compared to other models. The corresponding training (Figure 1) and testing (Figure 2) results are shown below. The blue lines indicate the predicted soil moisture and the red lines indicate the measured soil moisture. The green lines are absolute errors for training and testing accordingly.

Table 1: Summary of Results

#	Models	MAE	RMSE
1	Support Vector Machines (SVM)	0.0499	0.0546
2	Relevance Vector Machines (RVM)	0.0279	0.0323
3	Multivariate Adaptive Regression	0.0279	0.0484
4	Model Trees Using M5 Algorithm	0.0411	0.0536
5	Adaptive Basis Function Construction	0.0389	0.0453
6	Multilayer Perceptron Networks	0.0677	0.0856
7	Ensemble Adaptive Basis Function Construction	0.0376	0.0431
8	Bagging RVM	0.0935	0.1034
9	Variance Optimized Bagging RVM	0.1115	0.1217
10	Boosting RVM	0.0205	0.0264

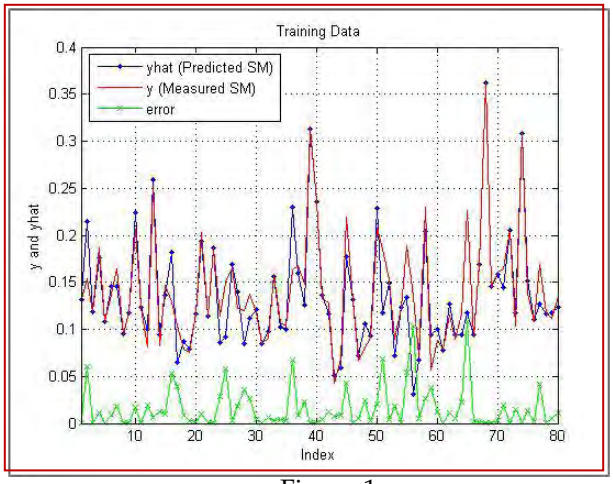


Figure 1

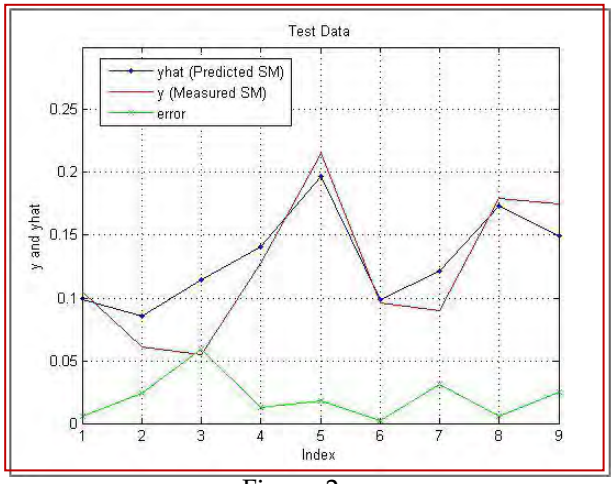


Figure 2

Work Plan FY11/FY12

The research effort for the next year includes the following: Based on remotely sensed multispectral images real-time acquired from Unmanned Autonomous Vehicles (UAV) and developed models for estimating soil moisture, a software package will be developed and integrated with the UAV system to provide a user-friendly platform that farmers, ranchers, and water managers can use to monitor, evaluate, and predict soil moisture content at designated key areas in Utah. These activities will be coordinated in collaboration with on-going research at the Utah Water Research Laboratory.

Informational Resources:

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Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment

Principal Investigators:
Dr. YangQuan Chen
Calvin Coopmans (student)

Partners/Collaborators:
- ***Local:*** *Jim Walder, SRWUA*
- ***Federal:*** *Roger Hansen, USBR*

Project Description

- Need and Purpose:

  Efficiency in agricultural water usage can be improved by offering low-cost, high-resolution (both spatial and temporal), multispectral remote sensing capabilities for irrigation scheduling and real-time water management. Autonomous unmanned aerial vehicle (UAV) technology and compact multispectral-imaging are both becoming lower cost and more affordable. Irrigated agriculture uses a large fraction of the fresh water resources around the world. In Utah, diversions for irrigated agriculture represent approximately 85 percent of the state's water use. Typically, water use in agriculture is very inefficient, and small improvements in efficiency would save significant quantities of water that could potentially be used to irrigate more land or be diverted to other, higher valued uses, such as municipal supply.

- Benefits to the State:

  The ability to acquire decision-relevant data on soil moisture and evapotranspiration in a timely fashion and at a low cost will enable canal companies and irrigation districts in the state to (1) provide farmers with highly detailed information about soil moisture conditions in individual fields, enabling them to better manage scarce irrigation resources, and (2) manage complex irrigation delivery systems more efficiently, thereby saving water that could be used to increase agricultural output or allocate to other users whose demands are continually growing. In the Sevier River Basin, these advances will result in more water available for application in agriculture and less loss from system inefficiencies. The water savings could be as much as 5 or 10 percent of current deliveries.

- Geographic Areas:

  Study Area: Sevier River Basin, including Sevier and Millard Counties.

  Areas Benefited: Irrigated agriculture is statewide, so all counties in the state could benefit.

- Accomplishments:

  Findings: An inexpensive unmanned aerial vehicle (UAV) has been developed and made robust with the capability to carry and control various types of remote sensing equipment, and gather remotely sensed data, which can be processed for distribution to water managers and farmers.

  Results: Enhanced airworthiness of a team of several working, fully open-source UAVs has been tested for various mission scenarios such as irrigation water management and ecological assessment and patent disclosures have been filed. A full-day tutorial workshop on UAV-based "Personal Remote Sensing" at ICUAS2011 was offered (Denver, May 24, 2011), and teaching

modules are standardized for training natural resource managers in the State of Utah. Grants were received from NSF (2011-2012) and NASA (2011-2014).

Work Plan FY11/FY12

- Continue to explore and mature the 100 miles platform development (airframe development and flight testing).
- Develop TIR payload module for Paparazzi architecture.
- Integrate RGB/NIR/TIR payload capability.
- Develop innovative payload management architecture and commercialize (AggieCap).
- Enhance airworthiness using AggieNav and dual IMU.
- Help as the technical support and R&D center for the UAV service center under UWRL. Perform field test flights:
  - Gather, calibrate, and process remotely sensed data.
  - Plan and develop an interface to supply data to water system managers and possibly to farmers.

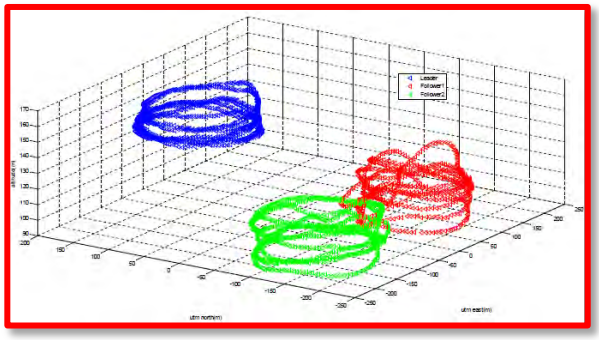
Informational Resources

Contact: Dr. YangQuan Chen, (435) 797-0148, E-mail: yangquan.chen@usu.edu.

Website: http://mechatronics.ece.usu.edu/yqchen/ and http://aggieair.usu.edu/.
Team Wiki: http://www.engr.usu.edu/wiki/index.php/OSAM_UAV.
Youtube Channel: http://www.youtube.com/user/USUOSAM.
ICUAS2011 Tutorial: http://uasconferences.com/ICUAS%2711_Tutorial.pdf.
Newspaper story: "USU Still Flying High" http://www.usu.edu/ust/index.cfm?article=50035 and http://www.auvsi.org/news/#SUAS2011.

The extended range AggieAir new frame design (August 2011) – maiden flight.

AggieAir-ER (Extended Range)



Multi-UAV flight results

Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology

Principal Investigators:
Darwin L. Sorensen
Lindsey D. Carrigan (student)
Prajith Dev (student)
Thomas Reuben (student)
Brady Worwood (student)

Partners/Collaborators:

- ***Local:*** *Scott Paxman and Brad Nelson, Weber Basin Water Conservancy District*
- ***State:*** *Kari Lundeen, Utah Division of Water Quality*

Project Description

- Need and Purpose:

  Nuisance blooms of algae and cyanobacteria occur annually in Pineview Reservoir, Weber County, Utah. Previous water quality studies of the reservoir have identified both phosphorus and nitrogen as the nutrients limiting algae and cyanobacterial growth and have called for management action in the watershed to limit the loads of these nutrients to the reservoir. The socioeconomic costs of these actions are likely to be substantial. The present study, conducted in collaboration with the Weber Basin Water Conservancy District, seeks to provide empirical information for managers so that Pineview Reservoir water quality can be preserved or improved in the most cost-effective way.

- Benefits to the State:

  Utah's growing population and water demand will likely lead to the use of Pineview Reservoir as a key water body for the storage and distribution of municipal water to the greater Ogden and, possibly, the greater Salt Lake City areas in the future. Learning the factors that control phytoplankton productivity in the reservoir will allow effective control methods to be selected. The approach and results of the study are likely to be applicable to other water bodies in Utah and the surrounding region.

- Geographic Areas:

  Study Area: Ogden Valley including Huntsville town, Eden, and Liberty in Weber County.

- Areas Benefited: Ogden Valley, the greater Ogden area, and potentially, similar watersheds and reservoirs in Utah and the intermountain west.

- Accomplishments:

  Results: Pineview Reservoir productivity and water quality is typical of oligotrophic-mesotrophic conditions much of the year. Diatom communities dominate the reservoir throughout the year, including during bloom periods. The reservoir is thermally stratified during summer months and phosphorus accumulates in the bottom (hypolimnion) layer of the reservoir as summer progresses. A significant fraction of this phosphorus is removed from the reservoir as water is withdrawn for irrigation and other uses. Annual surface water nutrient loading has been lower than estimated in earlier studies (e.g., the Total Maximum Daily Load study), but loads associated with snow-melt runoff contribute the largest fraction of the total. Short but intense snow-melt events in the late winter and early spring on the valley floor may contribute

substantial, "first flush," phosphorus loads. Ground water also contributes less nitrogen and phosphorus than estimated in earlier studies, but certain shoreline sectors near Huntsville contribute a large fraction of the total load associated with ground water.

Work Plan FY11/FY12

In-reservoir process monitoring will continue at approximately monthly intervals during the ice-free period. Efforts to describe and evaluate watershed processes that contribute phosphorus and nitrogen to the reservoir will be maintained. High frequency monitoring instrumentation on the South Fork and North Fork of the Ogden River will continue to operate. Ground water quality monitoring near the reservoir will be emphasized to determine the characteristics and possible sources of nutrients entering the reservoir from ground water.

Informational Resources

Contact: Dr. Darwin L. Sorensen, (435) 797-3207, E-mail: darwin.sorensen@usu.edu.

Figure 1. Flow measurement

Figure 2. Light measurement through the ice on Pineview Reservoir

Quantifying the Flow Field in Baffled Fish Culverts

Principal Investigators:
Blake P. Tullis
Mohanad Khodier (student)

Partners/Collaborators:
- ***State:*** *Scott T. Anderson, Director, Division of Solid and Hazardous Waste*
- ***Local:*** *Denis Stuhff, UDOT-Hydraulic*

Project Description

- **Need and Purpose:**

  Many culverts are approaching or are past their original design lives. These aging culverts will need to be repaired, rehabilitated, or replaced. Because entire replacement is so expensive and intrusive, alternate measures to extend the culvert project life are growing increasingly popular. One such method is slip lining, where a 'sleeve' is installed within an existing culvert barrel and stabilized. Plastic pipe sleeves are very popular for slip lining, but the reduced friction within the barrel can create a barrier to fish due to increased water velocities. Hence, mitigation of the increased velocities should go hand-in-hand with slip-lined projects where fish passage (present or future) is to be considered. Experience has been very limited in providing for fish passage through slip-lined culverts.

  As the single largest owner of culverts in the State of Utah, the Utah Department of Transportation (UDOT) has a keen interest in fish passage through rehabilitated culverts. As such, UDOT is currently funding the fish behavioral component of this study at the Utah Water Research Laboratory. Baffles installed in culvert liners has been a recommended possible solution for culvert relining when fish passage is a concern, but very limited data are available in the literature regarding baffle performance, in relation to fish passage, in circular culverts. Consequently, the flow dynamics (turbulence) and the corresponding swimming behavior of fish to that flow environment will be evaluated.

- Benefits to the State:

  UDOT does not currently have a design standard for baffled slip-lined culverts. The results of this study will be used to aid UDOT in developing a baffled culvert protocol for rehabilitated culverts where fish passage is a concern. The results of the study should have nationwide application and perhaps even international application.

- Geographic Areas:

  Study Area: All work will be completed in the Hydraulics Lab at the Utah Water Research Laboratory (UWRL) at Utah State University.

  Areas Benefited: Culvert rehabilitation projects statewide where fish passage issues may be of concern.

- Accomplishments:

  Findings/Results: This project began half way through FY10-11. The efforts in FY10-11 were primarily preparatory for the project (e.g., literature review, conducting flume flow experiments to develop a familiarity with the Particle Image Velocimetry (PIV) system and water seeding requirements, designing and building a curved acrylic window to mount on the side and bottom of the baffled culvert to facilitate flow visualization by the PIV camera and laser sheet.

Work Plan FY11/FY12

In FY11-12, laboratory experiments will be conducted in which the flow field around the baffles in a baffled culvert will be investigated and quantified using both a PIV (2D) and an acoustic doppler velocimeter (ADV) (3D) velocity measurement system. Efforts will be made to appropriately characterize the flow turbulence and relate that to actual fish passage test results from a related UDOT funded study.

Informational Resources

Contact: Dr. Blake P. Tullis, Phone (435) 797 3194, E-mail: blake.tullis@usu.edu.

Website: http://www.neng.usu.edu/uwrl/www/faculty/btullis.html.

Real-Time Management of Irrigation Systems in the Sevier River Basin

Principal Investigators:
Mac McKee
Wynn Walker

Partners/Collaborators:
- ***Local:*** *Jim Walker, Sevier River Water Users Association (SRWUA)*

Project Description

- Need and Purpose:

  As water demands increase in the western states, concerns for endangered species and water quality will have a greater impact on the allocation of water resources. Emphasis will have to be placed on more efficient water management if existing water rights are to continue to be met. Improvements in efficiency of water management require a low-cost mechanism for obtaining and distributing information about the state of the water supply system. This project is developing and adding significant data analysis functionality to the existing Sevier River Water Users Association (SRWUA) web site to support real-time and long-term water management information needs.

- Benefits to the State:

  Application of this and related technologies in the Sevier River Basin in the past several years have shown an improvement in the decision-relevant information available to system managers in their efforts to increase the efficiency of basin-wide water management. Similar results could be achieved in virtually every river basin in Utah, especially those with substantial irrigated agriculture. The forecasting techniques developed by this project could potentially provide valuable information for better long-term decisions by farmers and ranchers for investments in crops and livestock, especially in years where drought might be likely. Similarly, the short-term forecasting methods developed by this project can provide system managers with information necessary to more precisely control the operation of large irrigation systems, such as those found in the Sevier Basin, thereby saving water and increasing the overall productivity of the system.

- Geographic Areas:

  Study Area: Sevier River Basin, including Sevier and Millard Counties.

  Areas Benefited: Irrigated agriculture is statewide, so all counties in the state would potentially benefit.

- Accomplishments:

  Findings: Real-time reservoir and canal operations can be improved in the Sevier River Basin by several percent with the use of data-driven models such as those developed by this project.

  Results: Products generated by the project this year include:

  - A real-time reservoir operations model for forecasting releases required to meet downstream water demands for Sevier Bridge and DMAD reservoirs. This model has been programmed to run on SRWUA computers and is being implemented to support the operations decisions of Sevier Bridge and DMAD reservoirs.

- A model to produce daily forecasts of flows into DMAD reservoir. This helps solve a critical management problem for releases from Sevier Bridge Reservoir for which the river commissioner is responsible. This model is being programmed for distribution on the SRWUA computers.
- Flights of the UWRL autonomous aerial vehicles (UAVs) were conducted by the AggieAir™ Flying Circus housed at the UWRL (see http://aggieair.usu.edu) and experiments are on-going to use this imagery to provide estimates of soil moisture everywhere in the Canal B command area.

Work Plan FY11/FY12

- Continue to work with the US Bureau of Reclamation and the SRWUA to implement all operations models on the SRWUA web site.
- Continue development of short-term irrigation demand forecasts for the Canal B area in order to improve canal performance with respect to efficiency of water deliveries. This work will place greater emphasis on the use of remotely sensed data acquired with UAVs and the use of data available from LanSat.
- Develop agent-based models of irrigator behavior for the Canal B area to test the importance of economic data in anticipating short-term irrigation demands.

Informational Resources

Contact: Dr. Mac McKee, Phone (435) 797 3188, E-mail: mac.mckee@usu.edu.

Aerial Imagery of the Canal B Area Obtained from UAV Flights, Used to Estimate Soil Moisture

Restoration of Interstate Migration Routes for Bonneville Cutthroat Trout

Principal Investigators:
Casey S. Williams

Partners/Collaborators:
- ***State**: Roger Wilson– Utah Division of Wildlife Resources*
- ***Business/Private:** Kirk Dahle, Trout Unlimited*
  Paul Mason, Trout Unlimited

Project Description

- Need and Purpose:

  Range-wide declines in Bonneville cutthroat trout populations are often associated with habitat loss and/or fragmentation of migratory pathways. Much of the current range of Bonneville cutthroat trout includes fragmented habitat that has resulted in limited movement, formation of sink populations, and extirpation of cutthroat trout from historic ranges. One of the primary goals of successful conservation efforts is re-establishment of population connectivity. However, success or failure of such reconnection efforts often goes unmeasured.

  This research will help describe the migratory patterns and increased range of Bonneville cutthroat trout in a recently reconnected stream system. Specifically, downstream migration distances, migration timing, spawning area, and seasonal habitat use of the Cub River Bonneville cutthroat trout population will be determined.

- Benefits to the State:

  This research will benefit the state by providing information to be used as a guide for conservation efforts and reconnection of Bonneville cutthroat trout habitat throughout its current range. Specifically, information provided will help the state of Utah to meet the objectives of the Range-Wide Conservation Agreement and Strategy for Bonneville cutthroat trout, Utah's Endangered Species Mitigation Program, and conservation efforts of Trout Unlimited. This study will provide explicit information concerning migrations and conservation of interconnected cutthroat trout populations within a large region: that of the Bear River Geographic Management Unit.

- Geographic Areas: Bear and Cub Rivers, Cache County, Utah.

  Study Area: Cache County.

  Areas Benefited: Cache County and state-wide where Bonneville and Colorado River cutthroat trout restoration is being conducted.

- Accomplishments:

  Findings: Initial tagging efforts have been conducted and biotelemetry tags have been surgically implanted into 17 Bonneville cutthroat trout. Fall tagging efforts put tags in

17 more fish below the diversion dam. Tracking was accomplished in springtime by plane. No cutthroats were found in the Utah section of the Cub River.

Results: Winter 2010 and spring 2011tracking efforts have helped identify spawning areas of migratory Bonneville cutthroat trout in the Cub River above the diversion barrier. Downstream migration during the wintertime has been tracked by plane, and no tagged Cutthroat trout have migrated into Utah. There is significant habitat in the Cub river drainage within Utah, and it can be difficult to get radio tagging results with such cover. One of the tagged fish did move up above the diversion dam again this spring to spawn but high water has hampered the fish ladder operation. Other tagged fish could have moved over and above the ladder because high flows topped the ladder, causing it to be uncontrolled. At this point in time, we feel additional efforts will not result in BCT tagged in the Cub River being found in Utah.

Work Plan FY11/FY12

This project is now complete.

Informational Resources

Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Bonneville cutthroat trout immediately after tagging

The same Bonneville cutthroat trout upon recapture

Statewide Water Resources Modeling for Utah

Principal Investigators:
Gary P. Merkley
Leah Meeks (student)

Partners/Collaborators:

- ***State:*** *Utah Division of Water Rights, Utah Division of Water Resources*

Project Description

- Need and Purpose:

  Management of water resources is becoming more important as water demands continue to increase, and as water supply tends to decrease, especially considering global-warming model predictions. As a semi-arid state, Utah has a growing need for improved water management. Various state and federal agencies and others have modeled certain hydrologic and legal aspects for specific geographic regions in Utah. For example, the Utah Division of Water Rights is currently using MODSIM for the Green River and using ArcView GIS to generate maps of some of the state's water resources. While region-specific models can supply information about water resources in a particular area, a model for statewide water management is needed for long-term planning and management. Such a comprehensive model for Utah does not currently exist.

- Benefits to the State:

  The proposed work will use data from different locations throughout the state of Utah. Once created, the model could be applied by local and state agencies to help manage Utah's water resources by providing a practical tool for planning purposes. This would help Utah's water resources agencies make better and more informed planning decisions and recommendations.

- Geographic Areas:

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- Accomplishments:

  Findings: We worked with the Utah Division of Water Rights and the Division of Water Resources during approximately the first three months of 2011. A tentative agreement was made with the Division of Water Rights about collaboration on a model that would benefit the State of Utah.

  Results: The project has now been realigned with the projects being conducted by Dr. Rosenberg.

Work Plan FY11/FY12

The funding for the research has remained intact, but with a different scope of work.

Informational Resources

Contact: Dr. Gary P. Merkley, (435) 797-1139, E-mail: gary.merkley@usu.edu.

Website: http://www.neng.usu.edu/bie/faculty/merkley/.

Stream Restoration in Boulder Creek, Utah: Effects of Increased Stream Discharge and Non-Native Fish Removal

Principal Investigators:
Casey S. Williams
Thomas B. Hardy

Partners/Collaborators:
- ***State**: Mike Ottenbacher – Utah Division of Wildlife Resources*
- ***Federal**: Mike Golden – U.S. Forest Service*
- ***Business/Private:** Mike Avant – Garkane Energy*

Project Description

- Need and Purpose:

  This project evaluated realistic quantifiable objectives for instream flow restoration associated with hydropower operations. Colorado cutthroat trout were monitored within the main stem Boulder Creek, as well as the East and West forks of Boulder Creek, in order to assess the effects of both non-native trout removal and restoration of bypass flows below the East Fork Diversion structure on Colorado cutthroat trout.

  Quantitative assessments of mitigation actions associated with non-native fish removal and bypass flow releases provide information that will help resource managers and hydropower operators set realistic quantifiable objectives during FERC relicensing proceedings. Given the economic trade-off between power production and bypass flows for fish populations, quantifiable objectives are needed for FERC relicensing proceedings.

- Benefits to the State:

  This research will directly benefit the State by informing resource managers of the quantitative relationships between incremental flow releases in bypass reaches below hydropower facilities and expected population responses in salmonid populations. This will provide a more realistic assessment of expected environmental benefits in the cost-benefit analysis used by FERC when setting hydropower operating licenses.

- Geographic Areas: Boulder Creek Drainage, Garkane County, UT.

  Study Area: Garkane County, UT.

  Areas Benefited: Garkane County, UT and state-wide where FERC hydropower licensing exists

- Accomplishments:

  Findings: The main stem of Boulder Creek and the affected areas of the East and West Forks of Boulder Creek have been surveyed for Colorado Cutthroat Trout population distribution, and population density and structure have been determined. Reintroduced populations of cutthroat trout in the lower West Fork constitute a reproducing population similar to remnant populations in the upper areas of the drainage. Based on these findings, further eradication of non-native fishes, increased flows, and reintroduction of cutthroat trout should result in establishment of viable populations of Colorado River cutthroat trout throughout the remainder of this system.

Results: Annual population density, age structure, and distribution of the aquatic resources at all sampling locations has been completed and submitted to the appropriate state and federal resource agencies.

Work Plan FY11/FY12

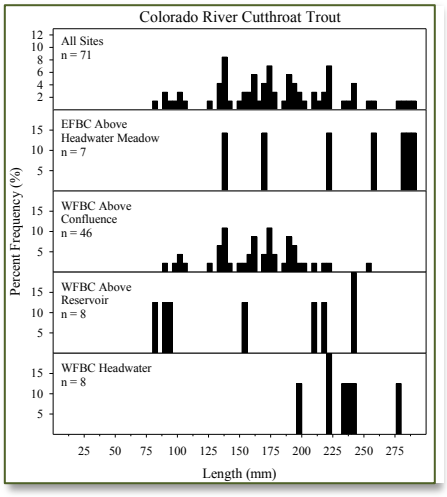
Additional monitoring of flow and fisheries resources will be undertaken throughout summer 2011.

Informational Resources

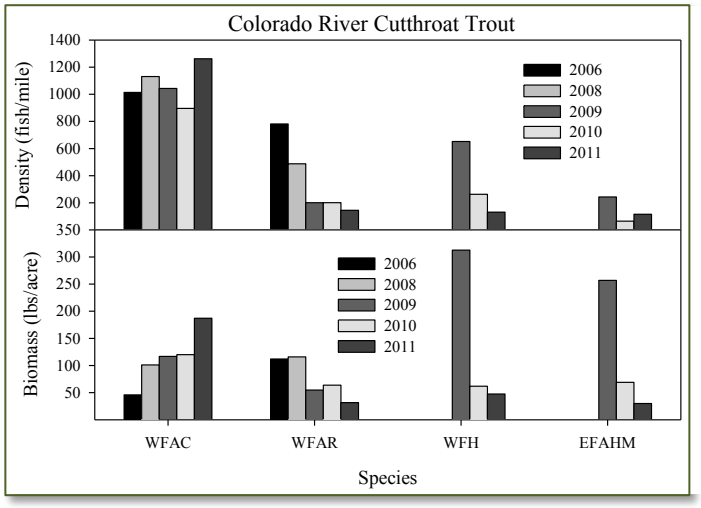
Contact: Mr. Chris Thomas, (435) 797-1184, E-mail: chris.thomas@usu.edu.

Publications:

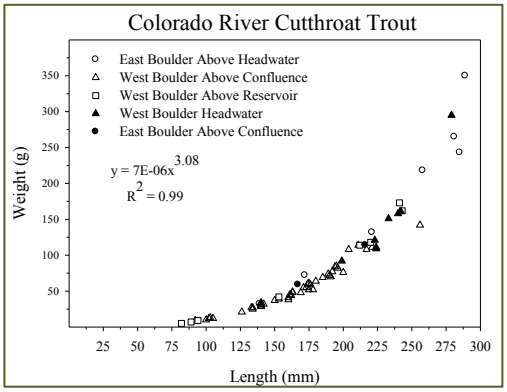
Hardy, T.B., C.S. Williams, C.W. Thomas (2011). *Trout population monitoring in Boulder Creek*: Utah Water Research Laboratory, Utah State University, Logan, UT.



Colorado River cutthroat trout length distribution



Colorado River cutthroat trout density and biomass



Rainbow Trout

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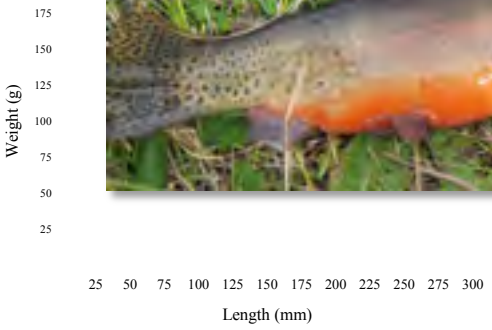
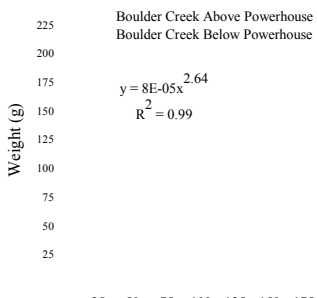
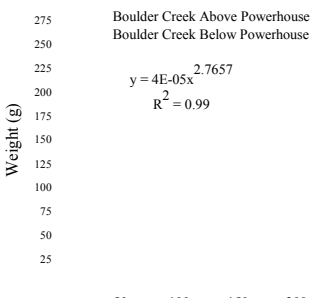


Brown Trout





Treated Wastewater Use in Agricultural Irrigation

Principal Investigators:
Gary P. Merkley
Leila Ahmadi (student)

Partners/Collaborators:
- ***Local:*** *Cache Valley municipalities*
- ***Business/Industry:*** *Cache Valley farmers*

Project Description

- Need and Purpose:

  As in many places in the USA and around the world, Utah is experiencing a continuing trend to incrementally transfer water from agricultural applications to municipal and industrial (M&I) uses. As this occurs, two principal problems are emerging:

  1. The water supply for agricultural irrigation is diminishing, threatening sustainable agricultural productivity.
  2. Ways must be found to manage the increasing quantities of treated wastewater from M&I sources.

  The solution to the first principal problem can, to a significant extent, entail the solution to the second problem. That is, a transfer of water from agricultural to M&I users involves a significant wastewater return flow component which must be disposed of and which could compensate for the "loss" of water to agricultural users. The feasibility of such a complementary solution must be analyzed to determine the implications of using treated wastewater for agricultural irrigation.

- Benefits to the State:

  Understanding of the technical issues regarding the use of treated M&I wastewater for agricultural irrigation in Utah can potentially lead to a lessening of the impacts of water transfers on sustainable agricultural production, and provide an economically- and environmentally-beneficial destination for wastewater from treatment plants. This can also lead to a win-win situation for two groups that have increasingly competed for available water resources.

- Geographic Areas:

  Study Area: Cache Valley, Utah.

  Areas Benefited: Irrigated agriculture is found statewide, so all counties in the state would potentially benefit.

- Accomplishments:

  Findings: All of the data have been collected and the model is running. Most of the report has already been drafted.

  Results: Preliminary modeling results show that alternative treated wastewater management scenarios for agricultural irrigation can be evaluated and compared in terms of water supply, water quality, and economics.

Work Plan FY11/FY12

Some additional simulation runs are being performed. The project will be completed in October 2011.

Informational Resources

Contact: Dr. Gary P. Merkley (435) 797 1139, E-mail: gary.merkley@usu.edu.

Website: http://www.neng.usu.edu/bie/faculty/merkley/.

References:

Ahmadi, L. and G.P. Merkley (2009). Planning and Management Modeling for Treated Wastewater Usage. *Irrig. and Drain. Sys., Springer*, 23(2-3):97-107.

UAV Remote Sensing Service Center

Principal Investigators:
Thomas B. Hardy
Mac McKee

Partners/Collaborators:
None

Project Description

- Need and Purpose:

  Many current sources of remote sensing data (e.g. manned aircraft and satellite platforms) are either too expensive, have low spatial resolution, or don't update frequently enough to be practical for many applications. A low-cost, small unmanned aerial vehicle (UAV) called AggieAir™ can fill this need by providing inexpensive, multispectral aerial imagery quickly and frequently. In addition, AggieAir™'s independence from a runway for takeoff and landing enables it to be launched from almost anywhere. Examples of applications which could benefit from AggieAir™ include agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, fish and wildlife tracking, and many others.

  AggieAir™ has been developed over the last few years and has now reached a stable and robust status. Therefore, it is beneficial to start using AggieAir™ on a regular basis to provide aerial images for applications that could benefit from remote sensing data. In addition, the money made from these applications could be used to help fund continued AggieAir™ development and research. To facilitate this, a service center has been established to handle the operational and maintenance needs so the research can keep running undeterred. The service center is also a good source of feedback to help steer AggieAir™ research and development in the right direction.

- Benefits to the State:

  The data provided from the service center has the potential to help Utah save water and manage environmental resources more efficiently. The service center can help save water by offering farmers a low-cost solution to mapping the soil moisture of their crops in order to irrigate more efficiently. Furthermore, this data can also help canal operators manage water diversions more effectively. The service center can also map roads and highways to monitor the quality of the asphalt and to update the road inventory (e.g. number of lanes, signs, culvert crossings, etc.). Roads can also be surveyed before, during, and after construction by the service center UAVs. Currently this is only done before construction.

  The service center will also indirectly provide new jobs and economic growth to the state of Utah. The long term goal is to use the service center as the first step toward starting a business that will be based around the AggieAir™ UAV platform. The service center will allow us to test the waters as well as gain experience to learn what would be required to make this happen.

- Geographic Areas:

  Study Area: State-wide.

  Areas Benefited: State-wide.

- Accomplishments:

  Findings/Results: The funds from this project have developed and fully equipped a new service center at the Utah Water Research Laboratory called AggieAir™ Flying Circus (AAFC) (see

http://aggieair.usu.edu). As planned, the AAFC uses AggieAir™ on a regular basis to provide aerial images for applications that benefit from remote sensing data. The images below display some of the maps generated by the AAFC and the analysis of the imagery to address water management problems in a variety of applications.

Manuals have been completed so that the AggieAir™ service center can offer training services to customers who have purchased the UAVs from USU. Sales of aircraft have been made in the past year to two organizations that wish to use AggieAir™ for their own remote sensing purposes. Additional field crews have been trained to fly the UAVs and process the imagery they collect. In the past year, the AggieAir™ Flying Circus has provided support to research contracts in three states, with a very large number of flights conducted on a wide array of resources management problems in Utah. The AAFC is currently engaged by research projects on the spread and control of the invasive and highly destructive species *Phragmites australis* in the Bear River Migratory Bird Refuge, on the management of wetlands by the Utah Department of Transportation, on the removal of nutrients and production of energy at the Logan City Sewage Lagoons, on the operation and maintenance of irrigation canals in the state, on the quantification of salt that flows into the Green River from the Price River Basin, and on a large number of other similar projects.

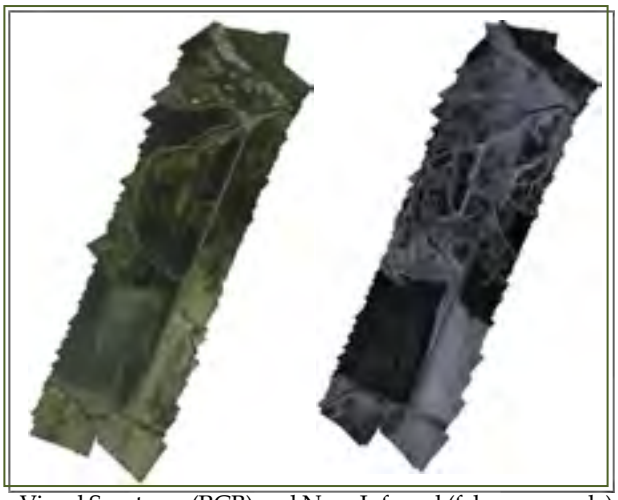
The AAFC obtained two Certificates of Authorization (COA) from the US Federal Aviation Authority (FAA) in this past year that certify the AggieAir™ platform as being airworthy and authorize its use subject to FAA rules. A license was signed between USU and a private company in Utah to manufacture the aircraft, and negotiations are now underway to create a spinoff company that will market AggieAir equipment and services. New payloads are under development that will include a wider array of sensors, and a new airframe is being designed that will provide much better capability in the field.

Work Plan FY 11/FY12

- Expand the AAFC business base through acquisition of more research contracts.
- Develop and license a spinoff company to market AggieAir™ technology, both aircraft and downstream services.
- Complete the development and deployment of new aircraft and payloads.

Informational Resources

Contact: Mr. Austin Jensen, Phone (435) 797 3315, E-mail: austin.jensen@aggiemail.usu.edu.
Website: http://aggieair.usu.edu/.



Visual Spectrum (RGB) and Near-Infrared (false grey-scale) imagery (25 cm resolution) acquired from one UAV Flight over the Bear River Migratory Bird Refuge, UT.

Visual Spectrum (RGB) imagery of the Utah Highway 23 Bridge in Cache Valley, UT acquired during an emergency flood response demonstration flight.

Water Conservation and Managing Water Shortages

Principal Investigators:

David E. Rosenberg
Arthur Caplan,
Joanna Endter-Wada
Bereket Tesfatsion
Adel Abdallah
Diana T. Glenn
Guy Balard
Katie Davis Henderson

Partners/Collaborators:

- ***Local:*** *Issa Hamud, Mark Neilson, City of Logan; Tage Flint, Scott Paxman, Weber Basin WCD; Rene Flemming, City of St. George; Candace Schaible, Central Iron WCD; Kim Singleton, City of Sandy; Stephanie Duer, Salt Lake City; Steve Glain, City of West Jordan; Nancy Hardman, Central Utah WCD; Rod Wood, City North Salt Lake; Bart Forsyth, Courtney Brown, Jordan Valley WCD*
- ***State:*** *Scott Adams, David Cole, UDWR*
- ***Federal:*** *Fred Liljegren, USBR*
- ***Business/Industry:*** *Peter Mayer, Aquacraft, Inc.*

Project Description:

- Need and Purpose:

  Water conservation can cost-effectively extend limited existing surface and groundwater supplies to accommodate rapid future population growth. The State Legislature and Governor have recognized the importance of water conservation and set ambitious targets to reduce average per-capita water use by 25% by 2025. Initial education and awareness efforts such as "Slow the Flow" have stagnated or reduced per-capita water use over the last decade, yet it is still unclear what exactly caused the reduced use and whether reductions can persist to achieve state-mandated goals. Utah water utilities need more and better tools to identify customers with high potential to conserve water, determine how technology and behavioral factors contribute to water savings when a water-wasting appliance is retrofitted, and understand what incentives (economic, informational, technological, community, etc.) encourage and motivate customers to conserve. Additionally, customers need more information to support their outdoor landscape choices as landscape irrigation is the largest component of municipal water use. Utah's arid climate also makes water conservation an important part of drought planning strategies and there is a need to coordinate a diverse range of management actions such as groundwater extraction, trades, exchanges, and surface water storage. Here again, Utah water utilities can benefit from better tools to simulate water availability, plan for droughts, and respond to water shortages.

- Benefits to the State:

  Active water conservation projects are helping Utah water providers achieve the state goal of 25% reduction in per-capita water use while maximizing the effectiveness of utility conservation programs (increasing water volume saved while reducing program costs and staff time). Water conservation research projects are making analysis tools and information available to home owners and utility operators to help them select and implement water and energy-efficient activities. The reservoir carryover storage project will provide Utah water utilities and the UDWR with new tools to better model and proscribe reservoir operations and will allow a range of further studies that can connect reservoir operations to water conservation, infrastructure expansions, demand cutbacks, and runoff predictions. These tools will help to better plan drought responses and to estimate runoff and flows to the Great Salt Lake, as well as flows required for environmental purposes. Using and extending these tools can reduce drought costs, decrease the likelihoods that customers will face costly cutbacks through droughts, and show how to more cost-effectively operate structural and non-structural components of the water system.

- Geographic Areas:

  Study Areas:
  - Intervening to encourage water conservation projects: Cities of Logan and North Salt Lake in Cache and Davis counties; Jordan Valley WCD in Salt Lake County.
  - Integrated energy and water savings project: Metropolitan Water District of Salt Lake and Sandy in Salt Lake County.
  - Drought planning project: Weber Basin in Summit, Weber, Morgan, and Davis counties.

  Areas Benefited: Municipal water providers and landowners statewide in all counties.

- Accomplishments:

  Findings:
  - Households are willing to participate in the proposed 5-year conservation study and have varied choices for informational, technical, financial, and community-based conservation programs.
  - Hot water use (as a fraction of total appliance water use) varies widely among households and is independent from the total volume of use. These ranges contrast with average values used in prior work to estimate energy consumption and payback periods for water conserving appliance retrofits.
  - The existing Weber Basin water system faces few shortages.
  - Up to a point, reservoir carryover storage in the Weber Basin is helpful. It can increase resilience and decrease vulnerability (magnitude of shortages), but it decreases reliability (likelihood of shortages).

  Results:
  - Submitted $2.3 million grant for 5-year water conservation study to National Science Foundation's (NSF) Cyber-Enabled Discovery and Innovation (CDI) Program.
  - Cities of Logan and North Salt Lake agreed to collaborate in the proposed 5-year study.
  - Presented results of estimating, verifying, and building an interdisciplinary water conservation research program at the Efficient 2011 Conference held at the Dead Sea, Jordan, March 29 - April 2, 2011. Presented preliminary water-energy results at Spring Runoff Conference at Utah State University, March, 2011.
  - Built and verified reservoir simulation model for the Weber Basin using the Water Evaluation and Planning (WEAP) software.
  - Presented results of work to manage water shortages in the Weber Basin at the Utah Section of the American Water Resources Association 39th Annual Water Resources Conference in Salt Lake City, Utah on May 10, 2011.

Work Plan FY11/FY12

- Re-submit proposal for 5-year water conservation study to NSF CDI program.
- Build a systems model to include household and utility water-energy linkages for Salt Lake City.
- Finish Weber Basin reservoir operations study by comparing operational impacts of reservoir carryover storage to water conservation and new supply development alternatives.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.
Website: http://www.engr.usu.edu/cee/faculty/derosenberg/projects.htm.
Website: http://www.efficient2011.com/technical/paper/196.pdf.

Water Resources Modeling for Utah's Cache Valley

Principal Investigators:

David E. Rosenberg
Gary P. Merkeley
Leah Meeks (student)

Partners/Collaborators:

- ***Local:*** *Bob Fotheringham, Cache County*
  Bracken Henderson, UACD
- ***State:*** *Gertrudys Adkins, Lee Sim, James Greer, Matt Lindon, and Boyd Clayton, Utah Division of Water Rights*
  David Cole, Utah Division of Water Resources
- ***Business/Industry:*** *Joan Degiorgio, The Nature Conservancy.*

Project Description:

- Need and Purpose:

  Management of water resources is becoming more important as water demands continue to increase and as water supply tends to decrease, especially considering global-warming model predictions. As a semi-arid state, Utah has a growing need for improved water management. Various state and federal agencies and others have modeled certain hydrologic and legal aspects for specific geographic regions in Utah. For example, the Utah Division of Water Rights is currently using MODSIM for the Green River and ArcView GIS to generate maps of some of the state's water resources. The Cache Valley is a unique area because it has many of the water ailments that are becoming more prominent in Utah and the western United States: draught, flooding, water quality, full water allotment, increasing demand, and transition from agricultural to urban land uses. Managers require systems modeling tools and capabilities that can integrate the hydrologic, legal, and management aspects of the water system to inform management.

- Benefits to the State:

  Because of its unique geographic and demographic location, the Cache Valley is on the forefront of many water resources issues that are currently affecting many locations throughout Utah. Once created, a systems model can be used as an example and framework for modeling other areas of Utah by local and state agencies to help manage Utah's water resources by providing a practical tool for planning purposes. This use will help Utah's water resources agencies make better and more informed planning decisions and recommendations.

- Geographic Areas:

  Study Area: Cache Valley, Cache County, Utah.

  Areas Benefited: Municipal water providers and landowners statewide in all counties.

- Accomplishments:

  - Since the project start in January, 2011, we have secured the participation of and had multiple phone calls and in-person meetings with Division of Water Rights and Resources staff to discuss how to incorporate Utah water rights into a water management model for the valley.
  - We have also started a comparative analysis of the hydrologic, human, environmental, and ecological network components of the Cache Valley water system.

Work Plan FY11/FY12

- Complete the comparative network analysis and submit results for dissemination.
- Integrate UDWR water rights database data into the water resources management model.
- Submit a large proposal as part of a USU interdisciplinary research to the National Science Foundation's Water Sustainability and Climate program.

Informational Resources

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Website: http://www.engr.usu.edu/cee/faculty/derosenberg/projects.htm.

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