MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2010

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) at Utah State University (USU) receives 2¼% of all deposits made to the Mineral Lease Account, "to be used for activities carried out by the UWRL having as a purpose the development and exploitation of water resources in the State of Utah."

This report is submitted to the Legislature by the UWRL 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 2009

2. Budgeted expenditures for FY 2010

3. Planned expenditures for FY 2011

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.

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 but are also recognized throughout the nation and the world. State appropriation funds (SAF) and mineral lease funds (MLF) are targeted on problems facing the State of Utah. In FY 2010, MLF of almost 3.5 million accounted for 39% of total UWRL expenditures with the balance coming from federal, private, and other state sources. Total UWRL expenditures for FY 2010 were almost $9 million.

The UWRL's projects are organized into six major research programs under the direction of engineers and scientists affiliated with the Environmental Division and the Water Division of the Civil and Environmental Engineering Department, and also the Departments of Electrical and Computer Engineering, Mechanical and Aerospace Engineering, and the Department of Biological Engineering at Utah State University. Brief summaries of these major research programs under these 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. Sixty-five graduate students were supported in FY 2010. Undergraduate student involvement in UWRL projects for the purpose of student education and training is also integrated into the basic and applied research programs. The UWRL employed approximately 64 undergraduate students in FY 2010.

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. In

addition to the physical facilities, the State of Utah provides state-appropriated funds (SAF) and mineral lease funds (MLF) for research support at the UWRL.

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. Total research funding through the UWRL was almost $9 million in FY 2010, making it one of the largest institutes in the nation. It is also one of the most productive in terms of research publications and graduate student education.

There are 36 faculty and 30 support staff at the UWRL. During FY 2010, 32 master's students and 33 doctoral students received support from UWRL projects. An additional 64 undergraduate students assisted with UWRL research. UWRL faculty collaborate with colleagues from other USU departments, faculty from other institutions, professionals from the private sector, and government agencies in Utah, and elsewhere. Several of our faculty, 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.

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 $92k 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 drought planning optimization model to identify the cost-effective mix of management actions when planning for and responding to droughts and (2) Establishing a process to improve the accuracy of flow measurement structures in northern Utah. 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, tools development, 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 2010, and FY 2011 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 0.7% of total MLF budgeted and planned expenditures in FY 2010 and FY 2011.

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 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. Participation in national and international professional water and environmental organizations help to bring recognition and external project funding to the state, as well as learning from other research and best practices worldwide.

In order to develop the research program and focus projects, UWRL engineers and scientists have worked with the following network of organizations over the past fiscal years.

Department of Natural Resources

- Division of Water Resources
- State Engineer – Division of Water Rights

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)

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)

Professional Organizations and Associations

American Water Resources Association
American Society of Civil Engineers
American Water Works Association

The Utah Center for Water Resources Research (UCWRR) participated as an active member of the National Institutes for Water Resources (NIWR). As indicated above, 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 opportunities for the UWRL to respond to these needs. UWRL faculty were also active in state sections of professional organizations, and served on state, local, and national committees. All these activities provided opportunities to identify current and future research needs that will affect our state and the nation. This also strengthens the UWRL research identification process to maintain relevancy of our research programs to Utah.

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 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

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 by 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/.

Outreach and service provided by faculty of the UWRL also supports youth programs, such as the Girl Scouts of Utah through math, science, and engineering experiences for ages 5-15.

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 Minister of Higher Education from Mali and the Ambassador from Morocco, as well as delegations from Palestine, Israel, Egypt, Syria, China, Iraq, Lebanon, and most recently a contingent from Senegal, Guinea, Mali and Mauritania.

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. Projects conducted by the UWRL in the past year have produced benefits for every county of the state. 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 production of drinking water and the treatment, reclamation, 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 air quality problems in the state.

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, and characterization and control of dissolved and particulate natural organic matter (NOM). Current research in the groundwater area includes theoretical developments in the stochastic and numerical analysis of pollution transport in groundwater modeling, 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.

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.

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 state agencies on water-related issues (such as the State Attorney General's Office in Litigation involving liability assessment in hazardous waste problems).

Water Resources Planning and Management

This program area addresses institutional and legal aspects of water 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	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
Business Office	$135,475.89	$139,540.17	$143,726.37
Laboratory Infrastructure Support, Travel and Special Request	$27,268.02	$27,000.00	$27,810.00
Project Management of USGS 104	$47,694.74	$49,125.58	$50,599.35
Publications Office	$32,788.60	$33,772.26	$34,785.43
UWRL Administration	$62,421.05	$64,293.68	$66,222.49
Total	**$305,648.30**	**$313,731.69**	**$323,143.64**

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 and, in collaboration with water managers and policy makers in state and local agencies to identify opportunities 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 2010 administrative costs represented approximately 1% 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 2010 on these support activities accounted for 0.7% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2010 for advice and collaborative help on various water problems in the state. In FY 2010, 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 on 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.

To support hydraulics research activities associated with releases from dams in Utah (and related hydraulic phenomena, such as venting), the UWRL has completed a new state-of-the-art hydraulics modeling and testing laboratory.

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	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
Algae Biotechnology for Nutrient Removal in Wastewater Treatment Lagoons: Aerial Monitoring for Algae Harvesting	$43,985.54	$75,000.00	$50,000.00
Biological Phosphorus Removal from Lagoon Wastewater: Pilot Scale Algae Biofilm Rotating Bioreactor	$42,108.12	$48,000.00	$25,000.00
Biological Phosphorus Removal from Wastewater: Algal Biofilm Rotating Bioreactors (ABRB)	$29,067.68	$65,000.00	$75,000.00
Evaluation of Deep Installations of Septic System Drain Fields in Utah: Performance and Treatment Effectiveness	$28,390.46	$29,242.17	$32,500.00
Evaluation of Water Supply and Wastewater Treatment/Reuse Options, Cedar City, Utah	$2,491.42	$3,000.00	$3,200.00
Producing Bioplastic Materials Using Microbe-Based Processes	$9,839.08	$3,000.00	$0.00
Septage Treatment, Handling, and Disposal Practices in Utah	$13,898.75	$14,315.71	$14,745.18
Weber-Morgan Health Department Wastewater Advisory Committee	$1,000.00	$0.00	$0.00
Designated Projects		$172,496.00	$0.00
Undesignated research projects in program area		$26,000.00	$27,500.00
Total	**$170,781.05**	**$436,053.88**	**$227,945.18**

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:

  Wastewater systems across the state of Utah that utilize lagoons, including the City of Logan Wastewater Treatment Lagoons, will not meet future standards for water quality under current design and operation conditions. Improvements in the design and operation of existing lagoon systems for wastewater treatment may be possible based on an understanding of the growth 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). Identification of the sites within a lagoon system where maximum production of algae occurs would allow maximum removal of nutrients from the lagoon by removing the algae (crop).

- Benefits to State:

  The development of technology and processes 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 enable other communities in Utah to utilize the technology for the treatment of reservoirs and wastewaters at costs that are significantly lower than alternative technologies.

- Geographic Areas:

  Study Area: 460-acre City of Logan Wastewater Reclamation Facility that treats the wastewater of six cities: 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 and reservoirs and lakes contaminated with algae in northern and southern Utah.

- Accomplishments:

  Findings: Algae distribution and concentration across the Logan Lagoons are not uniform (Figure 2). 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 3). Results indicate non-uniform distribution of algae within the ponds comprising the Lagoon system (Figure 2). 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 are the areas within the lagoon with the highest concentrations of algae for harvesting.

  Results: These results demonstrate a need to identify and select specific areas of the lagoon system where algae are dominant for efficient algae removal. Removal of the algae in these areas 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 is useful for identifying the best areas for algae harvesting.

Work Plan FY 10/FY11

Project Completed FY 09/ 10.

Informational Resources

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

Presentation: Predicting Algal Concentrations Using Aerial Imaging and Statistical Analysis. Jay D. Jones, Richard Cutler, Ronald C. Sims. *Institute of Biological Engineering 2010 Annual Conference*, Cambridge, MA (March).

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

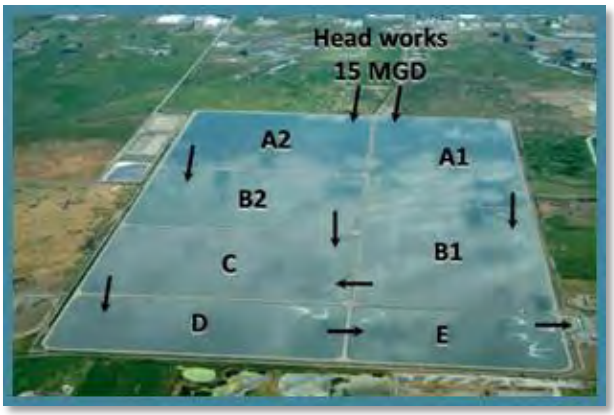


Figure 1. Logan Lagoon treatment system of seven algae ponds and flow of 15 million gallons per day (MGD). Parallel ponds include A1/ B1 and A2/ B2 while ponds C, D, and E are sequential, and total treatment time is 60-90 days.

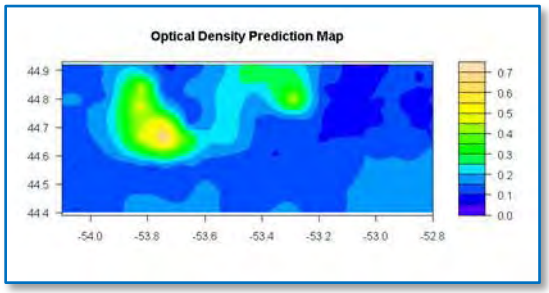


Figure 2. Algae distribution and levels in the Logan Lagoon System. (yellow, orange, green = best sites).

Figure 3. AggieAir remote sensing platform for algae monitoring in the Logan Lagoons operated by Austin Jensen of the Utah Water Research Laboratory.

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

Principal Investigators:
Ronald C. Sims
Charles Miller
Logan Christenson (student)
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 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 algae biofilm rotating bioreactors (ABRB) are being evaluated for the purpose of upgrading Lagoon performance.

- **Benefits to State:**

  Development of economical biotechnology based on biological treatment to upgrade municipal wastewater treatment will provide new jobs in Utah. The new 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, Nibley, and Hyrum.

  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 algae biofilm bioreactor was successfully constructed and operated (Figure 1). The bioreactor provided engineered mixing of wastewater and algae that resulted in the stimulation of algal growth with a simultaneous enhanced uptake of phosphorus (Figure 2).

  Results: Results showing phosphorus uptake into the algae biofilm compared with phosphorus uptake by suspended algae are shown in Figure 2. Phosphorus uptake into the biofilm 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.

Work Plan FY 10/FY11

Future efforts will be to test the pilot-scale reactors under seasonal changes in temperature.

Informational Resources

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

Presentation: Ecological Engineering of Algal Biofilms for Wastewater Remediation and Biofuel Feedstock. Logan Christensen, Ashton Young (Utah State University), Issa Hamud (City of Logan, UT). Institute of Biological Engineering, 2010 Annual Conference, Massachusetts (March).

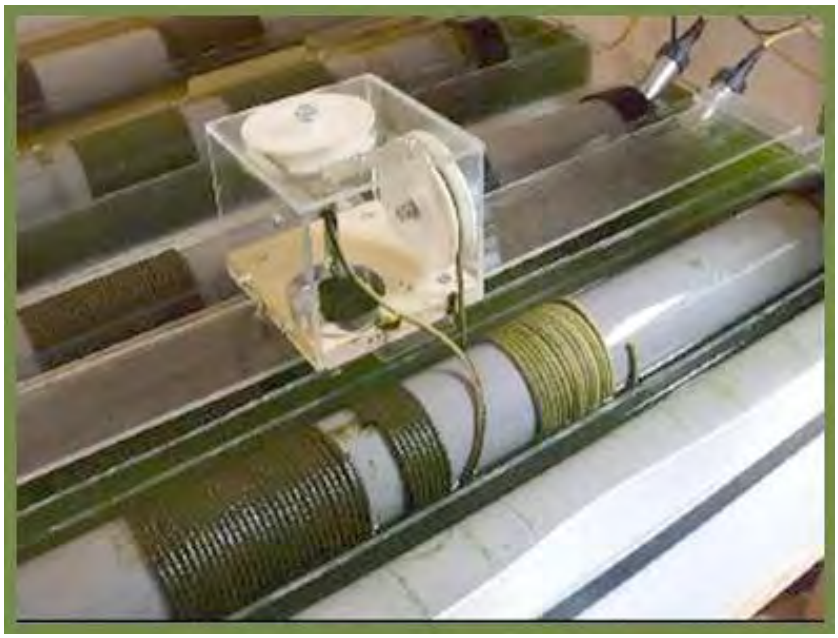


Figure 1. Pilot-scale algae biofilm rotating bioreactor designed and operated to improve algal growth and harvesting, and phosphorus uptake for the Logan Lagoon wastewater treatment system.

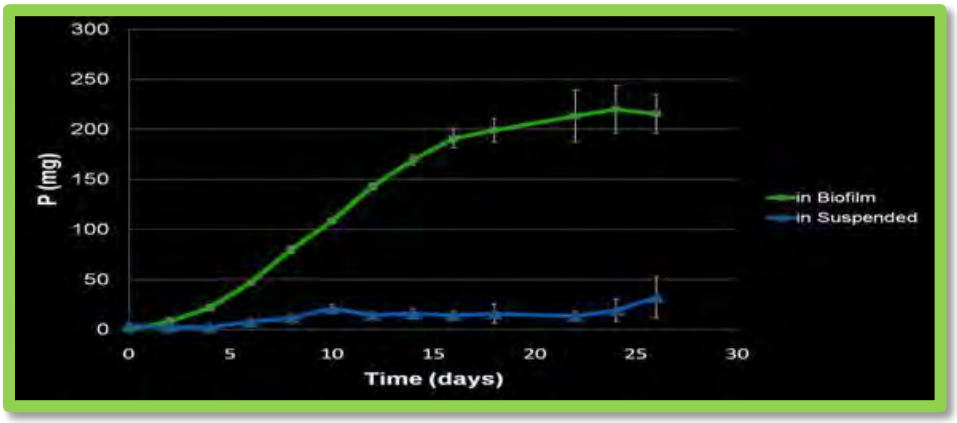


Figure 2. Results for phosphorus removal from Logan Lagoon wastewater into algae in an algae biofilm rotating bioreactor compared with phosphorus uptake by suspended algae.

Biological Phosphorus Removal from Wastewater: Algal Biofilm Rotating Bioreactors (ABRB)

Principal Investigators:
Ronald C. Sims
Charles Miller
Logan Christenson (student)
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 process based on algal growth for the removal of phosphorus from the Logan Lagoon Wastewater Treatment System could save in excess of $100 Million compared with the installation of a chemical precipitation system. Laboratory-scale tests based upon the growing of naturally-occurring lagoon algae in biofilm reactors to increase indigenous algae growth over that observed in the current Lagoon System is being evaluated for effectiveness of phosphorus uptake by the algae.

- **Benefits to State:**

  A reduction in the cost of wastewater treatment to remove phosphorus will allow the State of 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 and will allow the financial support to be redirected to other important projects. Benefits to individual communities will include reduced costs for meeting water quality standards for phosphorus.

- **Geographic Areas:**

  Study Area: Northern Utah region that includes the 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 that includes Northern, Central, and Southern Utah.

- **Accomplishments:**

  Findings: Laboratory-scale algal biofilm rotating bioreactors were constructed using several different materials for testing the growth of algae that are naturally present in the Logan Wastewater Reclamation facility (Figure 1). Bioreactors provided engineered mixing of wastewater and algae that resulted in the stimulation of algal growth with a simultaneous uptake of phosphorus.

  Results: The results demonstrate that the algae that currently grow in the Logan Lagoons are able to grow as a biofilm (Table 1). The best support material for algae growth was cotton rope. Materials including polypropylene and nylon were not effective for growing algae. Cotton rope material was selected to be the support material for use in pilot-scale algae biofilm bioreactor tests.

Work Plan FY 10/FY11

Future efforts will develop scaled-up Algae Biofilm Rotating Bioreactor systems for removal of nutrients from wastewater, including nitrogen and phosphorus, and for harvesting algae.

Informational Resources

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

Presentation: Ecological Engineering of Algal Biofilms for Wastewater Remediation and Biofuel Feedstock. Logan Christensen, Ashton Young (Utah State University), Issa Hamud (City of Logan, Utah). Institute of Biological Engineering 2010 Annual Conference, Massachusetts (March)

Figure 1. Rotating biofilm reactor materials tested to support algae growth included polyester, cotton, polypropylene, nylon, jute, and acrylic.

Table 1: Avg. Biomass yield of different substrate materials

Substrata	Avg. Biomass Yield (g/m^2)	Std. Deviation
Cotton Rope	91.2	10.4
Jute	51.4	5.1
Acrylic	49.3	0.4
Polyester	19.3	1.8
Polypropylene	0	0
Nylon	0	0

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

Principal Investigators:
Judith L. Sims
Ashleigh Restad (student)
James Beardall (student)
Lonnie Brown (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 groundwater 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, with little attention 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 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 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. Preliminary results indicate that satisfactory treatment of wastewater contaminants is occurring in both shallow and deep systems.

Work Plan FY 10/FY11

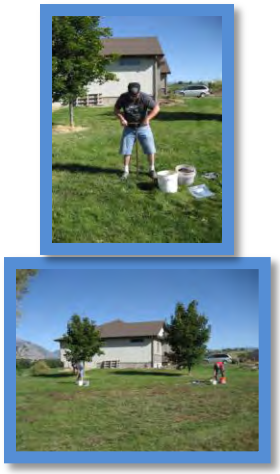
During FY10/ 11 we will continue sampling and analyzing leachate produced within the eight study drain fields and will analyze the results of the contaminant measurements as we continue to determine treatment effectiveness in shallow and deep drain fields. We will also begin analyzing for personal care product chemicals and pharmaceuticals in the leachates.

Informational Resources

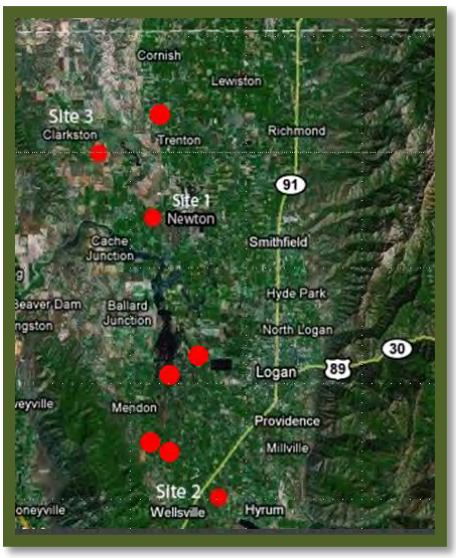
Contact: Judith L. Sims, (435) 797-3230, E-mail: judith.sims@usu.edu.

Publication: Restad, A., Beardall, J. and Sims, J. 2010. Evaluation of Deep Installations of Septic System Drainfields in Utah: Performance and Treatment Effectiveness. *Presentation, 10th Annual On-Site Wastewater Association Annual Conference*, Thanksgiving Point, Lehi, Utah, February 10-11, 2010.

Deep trench installation, Clarkston, November 2008.



Deep trench system installation, Wellsville, November 2008.



Site locations in Cache Valley.

Evaluation of Water Supply and Wastewater Treatment/Reuse Options, Cedar City, Utah

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***Local:*** *Cedar City, UT*

Project Description

- **Need and Purpose:**

  This analysis was carried out at the request of Mayor Gerald Sherrat of Cedar City, Utah, (population 27,000) to evaluate proposed options for the exchange of water rights, treatment of municipal wastewater, and supply of treated wastewater effluent for irrigation use within the Cedar Valley. This study highlighted 1) current water supply and water use rates by the community of Cedar City, 2) sustainable yield estimates for Cedar City's water supply; 3) future supply development needs and reuse options, 4) current wastewater treatment performance and nutrient management requirements, 5) wastewater treatment options and estimated system costs, and 6) recommendations for meeting future water supply and treatment demands to ensure a sustainable future for the growing Cedar City community.

- **Benefits to State:**

  Evaluating the potential for effluent reuse and water rights exchange for Cedar City provides direct benefits to this community in terms of water quality and water resource planning for their future. This work has potential benefits to other communities within the state that may be faced with:

  1. Planning for growing community populations under conditions of dwindling water rights and water availability.
  2. Planning for sustainable growth and community development under pressure of carbon emission reductions, pollution prevention, and sustainable agricultural practices.
  3. For Cedar City, this proposed water exchange not only represents potential increases in water availability, but also marketable carbon credits and monetary benefits to local farmers by eliminating petroleum-based fertilizers currently used in local agriculture with nutrient laden recycled wastewater. Fertilizer value and carbon credit enhancements could be realized throughout the state where safe and viable water reuse systems can be implemented.

- **Geographic Areas:**

  Study Area: Cedar City and Cedar Basin, Iron County.

  Areas Benefited: Irrigated agriculture and municipal wastewater treatment via Publically Owned Treatment Works occurs statewide, so all counties in the state would potentially benefit.

- **Accomplishments**:

  Findings: Significant outdoor use of culinary water (52% of total municipal use) contributes to the high per capita water use rate in Cedar City (252 gal/ cap/ d), making it imperative that water conservation or water reuse options be seriously considered by the community in the near future. The high outdoor water use also appears to contribute to the higher than normal concentrations of

pollutants entering the community's wastewater collection system. Concerns regarding the protection of the Class 1A Pristine Aquifer in the Cedar Valley from excessive nutrient loading suggest the use of alternative nutrient management options for Cedar City's wastewater.

Results: The current secondary wastewater treatment plant using nitrifying trickling filters provides up to 50% nitrogen removal, but this is not sufficient to ensure prevention of groundwater nitrate contamination below the effluent land disposal area. Suggested improvements in the effluent disposal irrigation system include, moving from flood irrigation to sprinkler irrigation and controlling soil slope and grading. In addition, with effluent nitrate concentrations as high as 16 mg/ L, some level of nutrient removal is necessary to ensure protection of the Cedar Valley aquifer from eventual nitrate contamination.

Four nutrient removal treatment train options compatible with the existing nitrifying trickling filter plant were evaluated in terms of nitrogen removal performance and capital and annual operating costs. Based on nutrient removal efficiency and incremental cost above the existing treatment plant configuration, the Attached Growth Post-Denitrification and the Suspended Growth Pre-Denitrification processes should be considered for further analysis and detailed evaluation. Of particular interest are those options providing partial nitrogen removal that would allow for benefits to be accrued to parties participating in water rights exchanges with Cedar City; up to $40,500/ yr in the form of crop nutrient value and potential salable carbon credits of $454,208 would exist in the reclaimed water.

Technology transfer activities of the study results were completed during FY09, including dissemination of results to the annual meeting of the Water Environment Association of Utah and the 6th International Conference on Sustainable Water Environment, Newark Delaware.

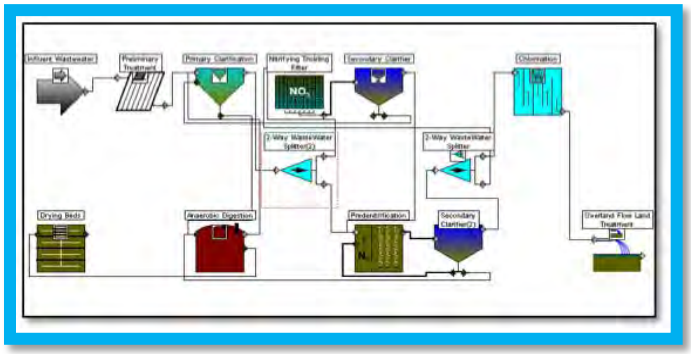
Work Plan FY 10/FY11

No additional work planned at this time.

Informational Resources

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

Website: https:/ / public.me.com/ rdupo/ UWRL.



Attached Growth Post-Denitrification Process Flowsheet for Nutrient Management and Water Reuse

Producing Bioplastic Materials Using Microbe-Based Processes

Principal Investigators:
Ronald C. Sims
Charles Miler
Libbie Linton (student)
Trent Mortensen (student)

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

Project Description

- **Need and Purpose:**

  Microbe-based processes for the production of bioplastic materials as a substitute for petroleum-based plastics are needed for environmental quality and sustainability and for national security. Rapid and accurate quantification procedures will create opportunities to use domestic feedstocks, including wastewater and waste chemicals, for the production of domestic sustainable plastics that can be used in the environmental, commercial, and medical industries. Methods for quantification of bioplastic materials of microbial origin are needed.

- **Benefits to State:**

  Bioplastics from microbes technology will generate new 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 accumulating in the 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 six communities in Northern Utah.

  Areas Benefited: All areas of the state of Utah, including rural sites and cities.

- **Accomplishments:**

  Findings: A procedure was developed that includes single-step extraction followed by the quantitative analysis of bioplastic material using NMR (nuclear magnetic resonance). The procedure is an application for mixed microbial cultures from agricultural waste treated in anaerobic digesters and also for municipal wastewater treatment plants in Utah.

  Results: The analytical procedure developed is useful for rapid and non-destructive quantification of microbe-based bioplastics materials of different composition and origin. The procedure can be used on pure cultures, as well as complex waste samples with high concentrations of organic compounds, and requires less time and materials than traditional procedures that include gas chromatography.

Work Plan FY 10/FY11

The project was completed in FY 09/ 10.

Informational Resources

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

This project was presented at the Massachusetts Institute of Technology as part of the 2009 International Genetically Engineered Machine (iGEM) competition and was awarded a Gold Medal. Details of the project and the presentation can be viewed at the website address:
http:/ / 2009.igem.org/ Team:Utah_State/ Project..

Microbial Production and Quantification of Polyhydroxyalkanoates (Bioplastics). 2010. Elisabeth Linton, M.S. Thesis, Biological Engineering Department, Utah State University, Logan, UT.

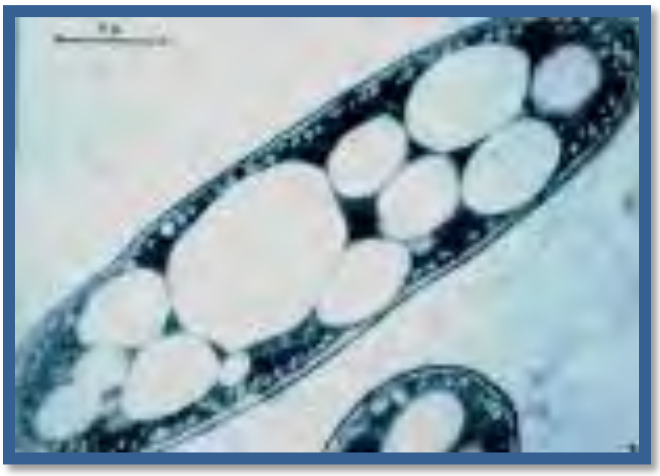


Figure 1. Bioplastic particles produced by bacteria at Utah State University.

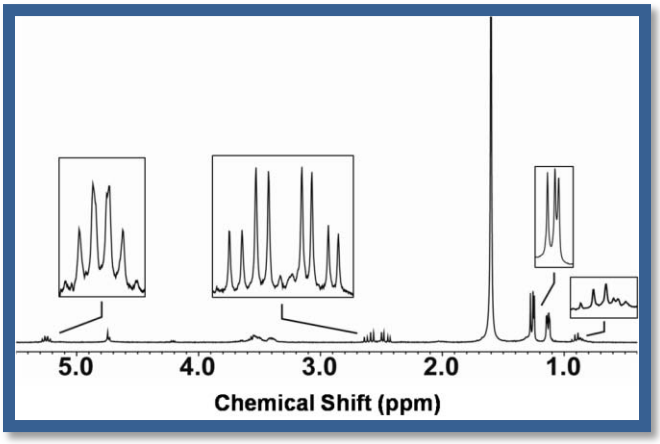


Figure 2. NMR spectrum of bioplastic material from anaerobic digester sample. The peaks can be integrated to quantitatively determine bioplastic content.

Septage Treatment, Handling, and Disposal Practices in Utah

Principal Investigators:
Judith L. Sims
Caitlin Elder (Research Assistant)
Kendall Brown (Research Assistant)

Partners/Collaborators:
- ***State:*** *Paul Krauth, Mark Schmitz, and David Snyder, Division of Water Quality, Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

  Septic systems, frequently used in rural and suburban residential developments in Utah, can provide adequate water quality and environmental protection when properly designed, sited, constructed, maintained, and operated. However, septic systems do require maintenance, including periodic removal of scum, solids, and wastewater (referred to as septage) that accumulate in the primary treatment device, i.e., the septic tank.

  Septage has a high potential for adverse impacts on ground and surface waters if not handled, treated, and disposed of properly. When land applied, septage can create a potential threat to humans and become a source of non-point source contamination if the wastes are not disposed of according to the federal regulations for septage disposal (40 CFR Part 503). Septage can also adversely impact wastewater treatment facilities if not carefully added to the wastewater stream. There is a paucity of information on septage disposal in the State of Utah and a serious potential for adverse impacts of improper septage disposal on human health and the quality of surface and ground waters. Hence, the overall goal of this project is to develop an understanding of the current status of septage management so that appropriate actions can be taken to ensure protection of public health and the environment.

- **Benefits to State:**

  Information and training was developed for Utah's septic tank pumpers and for local health department staff responsible for septage management programs. Areas of focus included state and federal regulations that govern septage disposal, as well as best management practices concerning septage disposal and treatment in Utah. The potential for contamination from improper septage disposal is high, but a proactive approach to septage management will ensure that treatment and disposal is accomplished in a manner that will be protective of public health and the environment.

- **Geographic Areas:**

  Study Area: All twenty-nine counties and the 12 local health departments.

  Areas Benefited: The entire State of Utah.

- **Accomplishments:**

  Findings: Utah septic tank pumpers were surveyed to assess their degree of knowledge concerning Utah regulatory requirements, as well as best industry practices for septage removal and disposal (Figure 1). Pumpers were identified through health department records and through telephone and internet "yellow pages." In June 2009, 279 surveys were sent to potential pumpers. Follow-up telephone surveys were conducted for pumpers who did not respond to the mailing. By October 2009, thirty-one pumpers had responded to the surveys.

We also surveyed environmental health staff in the twelve Utah local health departments (LHDs) concerning the present status of septage disposal practices in each local health department, as well as the educational needs of local health departments with regards to septage management. Nine of the twelve local health departments responded to the survey.

Results: Based on the survey responses, an educational program was developed for pumpers that focused on providing information regarding approved disposal sites, regulations, business information/ bonding, truck operation and maintenance, and safety considerations. In addition, educational brochures concerning septic system management were developed for pumpers to distribute to their clients.

The educational activities developed for the LHDs, based on survey responses, included providing resources that the LHDs can make available to pumpers, educating LHD staff on truck inspection procedures, and helping LHDs improve reporting procedures for septage disposal locations.

Work Plan FY 10/FY11

The project was completed June 30, 2010.

Informational Resources

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

Sims, J.L. (2009). Survey forms for pumpers and for local health departments. Utah Water Research Laboratory, Utah State University, Logan, Utah.

Sims, J.L., C. Elder, and K. Brown. 2010. Survey of Utah Liquid Scavengers and Health Departments. Presentation, 10th Annual Conference, Utah On-Site Wastewater Association, Thanksgiving Point, Lehi, UT, February 10-11, 2010.

Management of Liquid Scavenger (Septic Tank Pumper) Operations in Utah

The Utah On-Site Wastewater Treatment Training Program at Utah State University in cooperation with the Division of Water Quality of the Utah Department of Environmental Quality is conducting a survey of septic tank pumping practices in the State of Utah. Results of the survey will be used to help us improve the management of wastewater pumped from septic tanks. These materials removed from the tank are referred to as septage.

R317-550, Rules for Waste Disposal By Liquid Scavenger Operations, provides the following definitions:

Liquid Scavenger Operation - means any business activity or solicitation by which wastes are collected, transported, stored, or disposed of by a collection vehicle. This shall include, but not be limited to, the cleaning out of septic tanks, sewage holding tanks, chemical toilets, and vault privies.

Scavenger Operator - means any person who conducts the business of a liquid scavenger operation.

Figure 1. Pumper Questionnaire Guidance.

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 is composed of representatives from local government, land developers, consulting engineers, Central Weber Sewer Improvement District, the Utah Geological Survey and academia (Utah State University). The committee meets on an as-needed basis—approximately three times each year. 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 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: 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 general, 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 Weber River Canyon.

Work Plan FY 10/FY11

It is anticipated that Dr. Sorensen will continue to serve as member of the committee in FY 10/ FY11.

Informational Resources

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

Environmental Quality Management and Remediation

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

Project Name	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
Analysis of Microbial Diversity and Dechlorinating Potential at Solvent Contaminated Sites Throughout Utah	$29,763.05	$30,655.95	$42,500.00
ATK Static Test Environmental Assessment	$36,771.01	$37,874.14	$39,010.36
Conditions Affecting the Clean-Up of TCE- Contaminated Aquifers in Northern Utah	$112,917.56	$45,000.00	$5,150.00
Environmental Feasibility of Proposed Green Waste Collection Program in Salt Lake County	$2,491.42	$0.00	$0.00
Evaluation of Duckweed as a Technology for Management of Nutrients and Emerging Contaminants in Municipal Wastewater Systems	$65,182.61	$72,640.00	$74,819.20
Impact of Metals and Metal Ions on Soils and Plants	$18,106.03	$42,600.00	$0.00
Investigations into Cache Valley's Wintertime PM2.5 Issues and Examination of Potential Remediation Scenarios	$48,624.90	$79,000.00	$0.00
Monitoring Organic Contaminants in Air Using Plants as Passive Samplers	$5,688.81	$60,000.00	$47,000.00
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$2,491.42	$2,566.16	$3,312.11
Remediation of Chlorinated Sovent Contamination of Groundwater	$42,896.17	$72,500.00	$4,900.00
Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)	$2,491.42	$85,000.00	$87,550.00
Study of Cache Valley's Ambient Vertical Ozone Profiles	$32,638.03	$49,500.00	$0.00
Uptake of Organic Contaminants from Groundwater and Transfer into Edible Plants: Species Differences	$25,495.36	$26,260.22	$0.00
Volatile Organic Compounds in Indoor Air: Source Identification, Emission Flux Determinations and Model Development	$14,916.04	$26,000.00	$0.00
Designated Projects		$966,005.00	$0.00
Undesignated Projects		$212,000.00	$237,000.00
Total	**$440,473.83**	**$1,807,601.47**	**$541,241.67**

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 when exposure pathways are completed, such as fruit trees and fruit growing above groundwater plumes. Results at phytoremediation sites suggest that significant differences in TCE transformation and metabolic products are occurring in trees and may be due to differences in microbial communities within the trees themselves (the endophyte community).

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

- **Benefits to State:**

  Determination of 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:

  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.

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

- **Accomplishments**:

  Findings: Overall, the results of the hybrid poplar study showed that the treatment the trees were exposed to 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 based on both microbial quantity and diversity data. Perhaps 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, indicating 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 this study 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 its immediate environment (soil, water, and air).

Results: Endophytic and plant-associated microorganisms including archaea, bacteria, and fungi are implicated in degrading 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 may be underestimating the mass of contaminant that is actively being degraded. These interactions should always be considered when selecting a remediation strategy, especially if that strategy involves phytoremediation.

Work Plan FY 10/FY11

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: rdupo@cc.usu.edu

Website: https:/ / public.me.com/ rdupo/ UWRL.

ATK Static Test Environmental Assessment

Principal Investigators:
William J. Doucette and Laurie McNeill
Scout Mendenhall (M.S. student)
Danny Ryan (undergraduate)

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

Project Description

- **Need and Purpose:**

  The static testing of solid rocket motors at the ATK Promontory site can displace large amounts of soil that then becomes 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 if there are any potential impacts on human and ecological health associated with the post-test deposition of this material.

- **Benefits to State:**

  This research will help ATK (a leading employer in the State of UT) to better understand the environmental effects of their static 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 the towns of Tremonton, Corrine, and Penrose.

- **Accomplishments**:

  Findings/Results: Preliminary results from the February 25, 2010 static test show enhanced corrosion rates for the metal coupons exposed to the deposition. The enhanced corrosion rates are likely due to the acidic nature of the liquid deposition that was not neutralized by contact with the soil. After four months of exposure to the environment, corrosion rates decreased, although most exposed samples still have higher corrosion rates than non-exposed samples. Initial results also suggest that the particulate matter levels (PM 2.5, PM 10 and TPM) measured in the air at the sampling sites within the plume were not significantly different than the control site.

Work Plan FY 10/FY11

1. Samples exposed to the February 2010 static test will continue to be monitored.
2. Characterization of deposition material and native soils will continue.
3. A variety of samples (aluminum, steel, plastic) will be placed at the ATK facility and will be exposed to different chemical treatments in order to investigate which component(s) of the deposition material are most corrosive.
4. Another set of samples will be placed during the September 2010 static test and evaluated as during the February 2010 test.
5. A long term experiment using various samples will be set up around the ATK facility to investigate long-term corrosion rates.

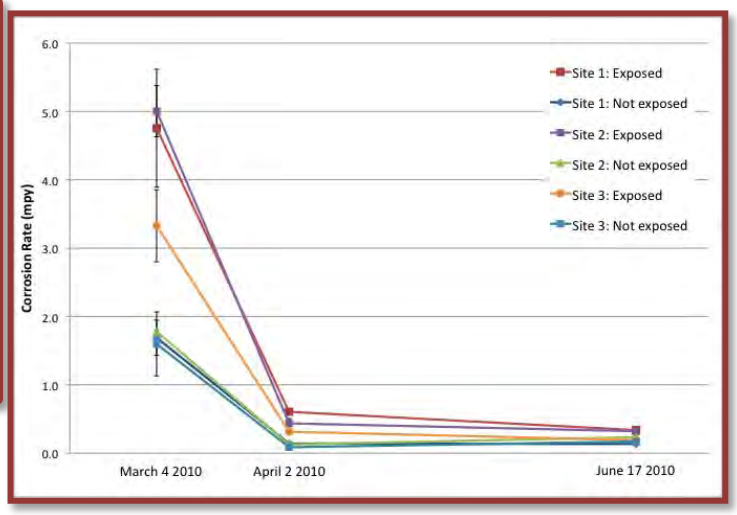
Environmental Quality Management and Remediation

Informational Resources

Contact: Dr. William Doucette, (435) 797-3178, E-mail: William.Doucette@usu.edu
Dr. Laurie McNeill, (435) 797-1522, E-mail: Laurie.McNeill@usu.edu

Static rocket test, February 25, 2010

Mild steel samples at ATK site #1, March 1, 2010 (one week after static test). Samples on the left were exposed to material deposited during the static test, while samples on the right were not exposed.



Corrosion rates from collected samples. Error bars represent standard deviation of triplicate samples.

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

Principal Investigators:
Darwin L. Sorenson
Subathra Muruganandam (Post Doctoral Associate)

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

Project Description

- **Need and Purpose:**

  Chlorinated solvents, especially 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 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 help provide control for 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 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 for improvement of the Utah environment and protection to 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 trichloroethene (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: The availability of iron to serve as a respiratory electron acceptor may greatly influence the onset of dehalorespiration in which chlorinated solvents serve as the electron acceptor. Microcosm experiments showed:

- Addition of the fermentable substrate, glucose, greatly stimulated iron reduction in geochemically different OU5 and OU9 aquifer solids.
- Addition of an electron shuttle, anthraquinone disulfonate (AQDS), generally increased iron reduction.
- The well known dissimilatory iron reducing bacteria genera Geobacter and Anaeromyxobacter did not increase in numbers when glucose was added, indicating that other kinds of bacteria were important in iron metabolism.
- Molecular methods showed that the bacterial communities were different between the two aquifer materials and that they responded differently to the addition of glucose or acetate as carbon and energy sources.
- Microbial mechanisms for transferring electrons to mineral iron differed between the aquifer material communities, and they changed when AQDS was added.
- The addition of acetate as a carbon and energy source did not stimulate iron reduction in either aquifer material.

Work Plan FY 10/FY11

A detailed analysis of large flow-through aquifer material columns made using TCE contaminated aquifer material collected in Clinton, Utah began in May 2010 and will continue into October 2010. These columns have been operated for several years under the direction of Dr. R. Ryan Dupont and have, relatively recently, developed the ability to completely dechlorinate TCE. Field pilot scale testing has been proposed for the OU5 source area on Hill AFB. Work on this project will be a collaboration among similar projects under the direction of Professors Joan E. McLean and R. Ryan Dupont.

Informational Resources

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

Publication:

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.

Environmental Feasibility of Proposed Green Waste Collection Program in Salt Lake County

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:

- ***Local:*** *Linda Hamilton, Public Works Director, Salt Lake County; Rick Graham, Public Works Director, Salt Lake City; John Ioannou, Manager, Salt Lake Valley Solid Waste Management Facility*

Project Description

- **Need and Purpose:**

  This project is evaluating the environmental impact of implementing a curbside green waste collection program in Salt Lake County, particularly with respect to changes in Green House Gas (GHG) emissions and improvements in the overall carbon footprint of Salt Lake County.

  Various scenarios are presented within this study that assume different levels of public participation in a green waste recycling program, and comparisons are made to the current Base-Case situation in terms of changes in projected GHG emissions and energy requirements for green waste management. A scenario is also included in which green waste recycling is eliminated at the Salt Lake Valley Solid Waste Management Facility, including decisions regarding implementation of green waste collection and recycling County-wide to reduce the overall carbon emissions of the valley.

- **Benefits to State:**

  Evaluating the environmental impact of solid waste management options can lead to reduced carbon emissions and energy use throughout Salt Lake County and throughout the state because communities all over the State of Utah collect, process, and dispose of solid waste. This solid waste management evaluation methodology can be used to reduce carbon emissions and improve energy utilization in all Utah communities and counties by:

  - Identifying the carbon and energy footprints of current solid waste management practices.
  - 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 the sustainability of solid waste management practices within the state.

  For Salt Lake County, the proposed County-wide green waste recycling program represents a significant investment in collection and green waste processing costs. In addition, methane gas recovery for energy production takes place at the Salt Lake Valley Solid Waste Management Facility. Diverting green waste from the landfill for composting potentially diverts methane production potential from the gas recovery/ energy generating facility. The overall environmental benefits of the green waste diversion were quantified through this analysis.

- **Geographic Areas:**

  Study Area: Salt Lake 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: The findings of this analysis were unexpected. Results indicated that the elimination of the green waste recycling program in Salt Lake County would result in the most significant reductions in GHG emissions and energy utilization of all of the options considered because of the landfill gas collection and energy generation that take place at the Salt Lake Valley Solid Waste Management Facility, the carbon sequestration provided through landfilling, and the energy requirements for composting. As more green waste is diverted for composting due to increased public participation, the GHG emissions and energy consumption required to manage this diverted material significantly increase.

  Results: Acknowledging the many benefits of a green waste diversion and composting program, including revenue generation, landfill space preservation, valuable commodity (compost) production for soil conditioning and soil improvement, and public involvement in waste reduction and recycling, it appears most prudent for Salt Lake County to propose a voluntary green waste recycling program aimed at providing more efficient, commercial-scale collection of the currently recycled green waste stream, but not actively seek to increase the green waste recovery rate from the municipal waste stream. Substituting commercial collection for the private vehicle collection/ transport activities currently taking place could realize a modest reduction in GHG emissions (544 MTCO2/ yr) and a significant reduction in energy use (7,830 million BTUs) while still providing the benefits of a community composting operation to the citizens of Salt Lake County.

  Technology transfer activities of the findings of this study were completed during FY09 including dissemination of results to the Salt Lake Valley Solid Waste Management Council, the Salt Lake County Mayor, the Recycling Coordinators from city and county governments in the Salt Lake Valley, and the local chapter of the Solid Waste Association of North America (SWANA).

Work Plan FY 10/FY11

- Disseminate the findings of this project through FY10 to interested parties including the Salt Lake County Sanitation Division and other solid waste management entities in the State.

- Continue energy and environmental footprint analyses for Salt Lake County Sanitation related to improving the efficiency of their curbside recycling program

Informational Resources

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

Website: https:/ / public.me.com/ rdupo/ UWRL.

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
Maureen Kesaano (student)

Partners/Collaborators:

- ***Local:*** *Don Hartle, City Manager, Wellsville City; Issa Hamud, Director, Environmental Department, Logan City*

Project Description

- **Need and Purpose:**

  Nutrients, particularly phosphorous, and contaminants, especially personal care products and pharmaceuticals (PCPP), in municipal wastewater systems have become a growing concern to environmental regulatory agencies due to their effects on the aquatic systems that receive these waste effluents. Conventional wastewater treatment systems are not effective in their removal. Current chemical or advanced biological treatment alternatives are prohibitively expensive, particularly for small, rural communities.

  This study is being conducted to evaluate the effectiveness of duckweed (Lemna minor and Wolffia globosa) for the uptake and transformation of phosphorous, nitrogen and PCPP contaminants from municipal wastewater, especially in communities like Wellsville City and Logan City that have lagoon wastewater treatment systems.

- **Benefits to State:**

  Protection and enhancement of surface water quality, in terms of nutrient enrichment impacts, is of concern in many watersheds in the state. This project aims to develop an effective low-cost method for water quality improvements with a net positive energy and environmental footprint.

- **Geographic Areas:**

  Study Area: Cache County.

  Areas Benefited: All locations in the state with actual or potential nutrient 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 this 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 lb of dried duckweed material could be harvested from the 56 ac of Wellsville lagoons on an annual basis. Duckweed used as animal feed is more than twice the value of alfalfa based on the organic matter, protein, and crude fiber of the duckweed biomass, and this quantity of dried material could serve as an annual substitute for soybean meal feed supplement for approximately 120 animals. Based on observed methane generation in laboratory digesters, this mass of dried material could generate 1,000,000 ft^3 of methane per year. Finally, ethanol fermentation studies have indicated that approximately 90,000 lb of starch could be harvested in this dried duckweed material, producing approximately 1,500 gal of ethanol at observed duckweed biomass fermentation rates.

These results indicate that modest value would be associated with the processing and conversion of harvested duckweed biomass to animal feed, methane, or ethanol 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 (≈ $150/ lb N or P removed) that would otherwise be required to manage nutrients in these wastewater effluents.

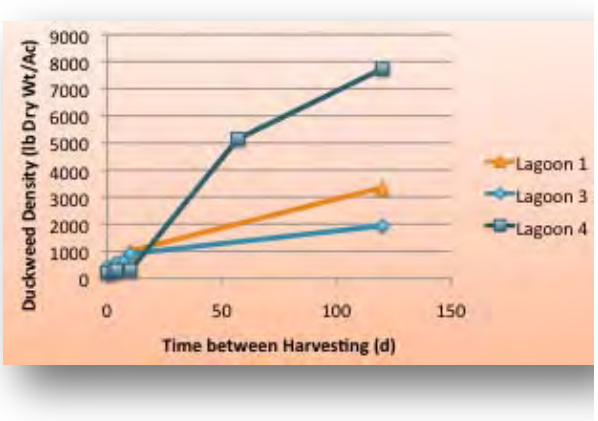
Work Plan FY 10/FY11

Laboratory studies to optimize the anaerobic degradability, ethanol production, and animal feed digestibility of the harvested duckweed will be carried out. The produced plant biomass will also be utilized in laboratory flask studies to evaluate the potential for these species to bioconcentrate metals and bioconcentrate and metabolize hazardous PCPP contaminants that occur in municipal wastewater. The impact of this bioconcentration on subsequent sludge processing steps (animal feed, anaerobic digestion, ethanol fermentation) will also be evaluated.

Informational Resources

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

Website: Website: https:/ / public.me.com/ rdupo/ UWRL.



Duckweed Growth in the Wellsville Lagoons

Duckweed Cover on the Wellsville Lagoons

Impact of Metals and Metal Ions on Soils and Plants

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

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Metal oxide nanoparticles 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 affects 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 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 in the State of Utah.

- **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, by protecting environmental quality and human health as related to metal exposure.

- **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 (Figure 1). Cell growth is affected on exposure to 10 mg/ L copper ions; there was no affect on exposure to the same concentration of copper oxide nanoparticles. Both silver ions and silver nanoparticles were toxic to the bacteria. We are addressing the question of whether the biological response is due to the ions associated with the nanoparticles or whether the nanoparticles are directly bioavailable and toxic. We are developing analytical procedures to distinguish ions versus nanoparticles in bacteria and plant tissue.

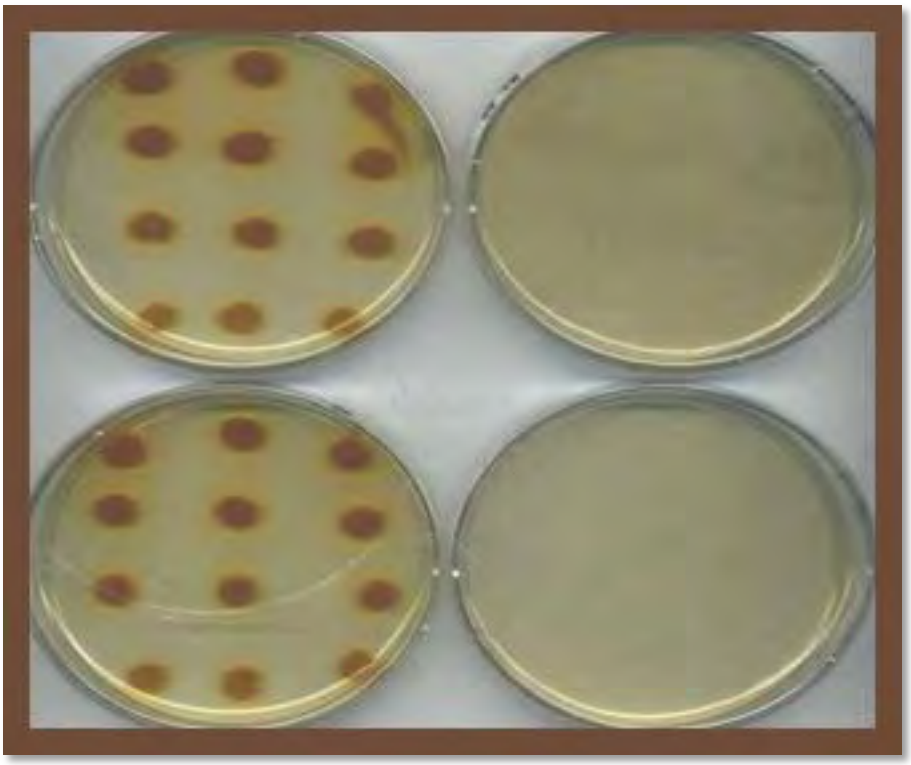
Work Plan FY 10/FY11

The main objective to be addressed in the coming year is how environmental variables affect plant-bacteria-metal interactions.

Informational Resources

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

Control – no silver addition 10 mg/ L silver as silver nanoparticle



10 mg/ L silver bulk silver 10 mg/ L silver as silver ions

Environmental Quality Management and Remediation

Investigations into Cache Valley's Wintertime $PM_{2.5}$ Issues and Examination of Potential Remediation Scenarios

Principal Investigators:
Dr. Randal S. Martin
Ms. Emyrei Reese (student)
Ms. Wendy Meiners (student)

Partners/Collaborators:
- ***Local:*** *G. Koford, Bear River Health Department*
- ***State:*** *Utah Division of Air Quality & Air Monitoring Center*

Project Description

- **Need and Purpose:**

  Awareness of potential problems with Cache Valley's wintertime $PM_{2.5}$ (ambient particulate matter less than or equal to two and one-half micrometers in diameter) began early in this decade, with values reaching as high as 137.5 µg/ m^3, more than twice the then standard of 65 µg/ m^3. The national standard was lowered to 35 µg/ m^3 in 2006. The Cache Valley air shed, a cross border region including portions of both Utah and Idaho, was officially declared a federal non-attainment area in December of 2009. This declaration initiated a 3-year time frame for the state agencies and local stake holders to develop a State Implementation Plan (SIP) to outline a remediation plan, with implementation to begin by December of 2013. Significant work has been, and continues to be, performed to understand the complexities of the $PM_{2.5}$ formation and fate of Cache Valley's somewhat unique air pollutant problems. A detailed understanding of the $PM_{2.5}$ mechanisms is necessary in order to be able to model and ultimately implement successful minimization and remediation scenarios.

- **Benefits to State:**

  The Cache Valley air quality studies initiated under the MLF program, and cooperatively supported previously by other local and state agencies, has led to the establishment of a viable and sustainable air quality research program at Utah State University, as well as direct cooperation on numerous other projects with other departments and colleges at USU and cooperation with colleagues at other universities, state and federal agencies, and research foundations. These studies have led to work well beyond the Cache Valley, within and without the state, including a recently funded proposal examining wintertime ozone formation in Utah's Uintah Basin. Additionally, information developed under this and other programs has been compiled into various PowerPoint presentations and given to numerous local and regional groups and associations in order to educate agencies and other stake holders on the state of knowledge and progress on the Cache Valley $PM_{2.5}$ issues.

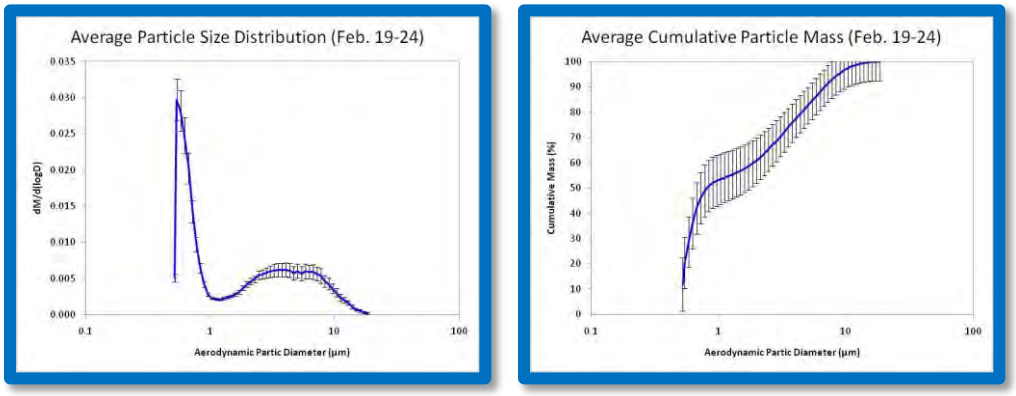
- **Geographic Areas:**

  Study Area: Cache Valley, UT (including the entire, cross border airshed).

  Areas Benefited: Primarily the Cache Valley, but findings and future work could logically be extended to the Wasatch Front, which was also declared a $PM_{2.5}$ non-attainment area in December 2009.

- **Accomplishments**:

  Findings: Refinement of the chemical composition and the limiting factors in the secondary formation of Cache Valley's $PM_{2.5}$ continues, as well as research into the dominant mechanisms of the formation. As an example of the continued research, an instrument purchased on a separate project, an Aerodyne Aerodynamic Particle Sampler (APS), was installed at the Logan city sampling site and operated during the winter season. The figures below show some average results and , as can be seen, the size distribution is bimodal. The strong peak in the submicron region, accounting for around 50% of the particle mass, is likely attributable to ammonium nitrate, the dominant secondary product identified in other studies. The larger diameter mode is broader and may be associated with organic carbon or crustal materials.



  Results: The key result of this past year's work was the hosting of a workshop held at the Utah Water Research Laboratory in late October of 2011 concerning the first phase of the SIP. Invited attendees included several representatives From EPA Regions 8 and 10, the Utah Division of Air Quality, the Idaho Department of Environmental Quality (IDEQ), and Utah State University/ Utah Water Research Laboratory.

Work Plan FY 10/FY11

Work will continue on characterizing Cache Valley's particle size distribution and composition, with the aim of further refining the limiting parameters in order to identify the most effective remediation scenarios. The PI will also continue to work on outreach programs to enhance public education concerning $PM_{2.5}$ and will continue to work closely with UDAQ, IDEQ, and local stakeholders to successfully develop the SIP following the required timeline.

Informational Resources

Contact: Dr. Randal S. Martin, (435) 797-1585, E-mail: randy.martin@usu.edu.

Monitoring Organic Contaminants in Air Using Plants as Passive Samplers

Principal Investigators:
William J. Doucette
Julie Chard

Partners/Collaborators:
- ***Local:*** *Kyle Gorder and 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 to lesser extent, when they are stored. 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 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 of VOCs. However, the efficiency of capture has not been well characterized , and plants themselves give off VOCs. In addition, damp soils can provide an environment for the growth of microorganisms that can impact allergic individuals. By actively drawing air through the root-zone while providing sufficient water and nutrients, we propose to create a simple system that can effectively remove VOCs in indoor air through sorption and/ or aerobic biodegradation while eliminating or significantly reducing the potential for allergen production.

- **Benefits to 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: A flow-through plant growth chamber has been constructed of glass and stainless steel. Potential background emissions of VOCs from potted plants are being quantified by sampling

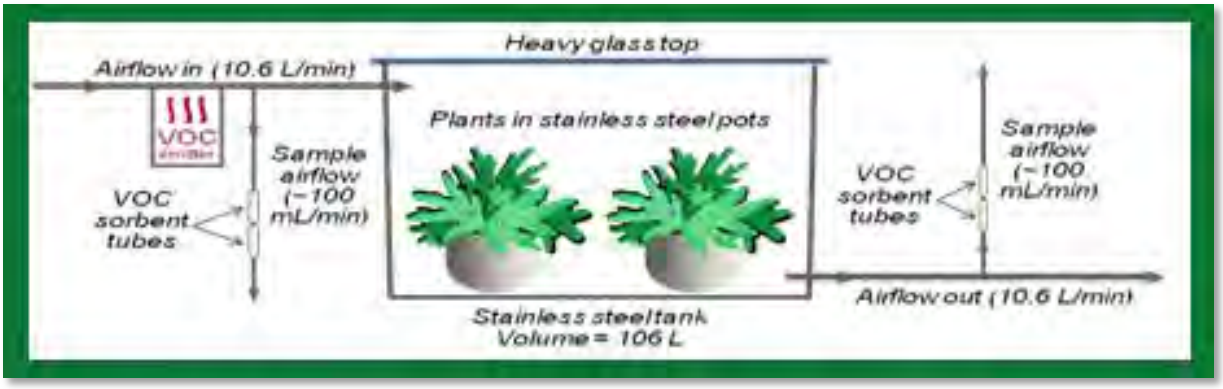
the air exiting the chamber with sorbent tubes and analyzing the tubes by thermal desorption gas chromatography/ mass spectrometry (GC/ MS).

Work Plan FY 10/FY11

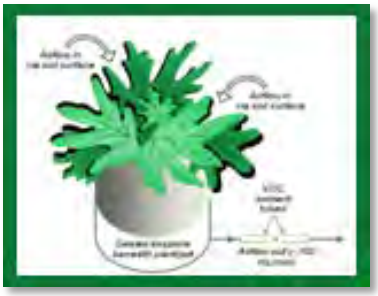
Representative VOCs typically found in indoor environments will be introduced into the chamber at known, environmentally relevant concentrations. Environmental conditions within the chamber will be controlled to maintain adequate plant health while mimicking those commonly found in residential dwellings. Variables to be evaluated include plant species, pots with and without vacuum applied (i.e. air drawn through the root system), plant growth medium (soil, soil with activated carbon, soilless plant growth media), chemical concentration and type, and individual chemicals versus chemical mixtures. A chemical mass balance will be performed by comparing the measured concentration of chemical introduced into the chamber to that exiting the chamber. A subset of 14C-labeled chemicals will also be evaluated to determine the potential loss mechanisms (sorption and biodegradation). The ability of plants to act as passive samplers will be evaluated and compared to conventional passive and active sampling methods.

Informational Resources

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



Flow through chamber.



Schematic of plant based monitoring and treatment system.

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

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

Partners/Collaborators:
- ***Local:*** *Issa Hamud, Logan City Environmental Department*
- ***Federal:*** *Kyle Gorder, Mark Roginski, 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 of interest 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 on-going 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 made possible by this research funding has provided 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 and their graduate students and technicians to carry out quantitative analyses of DNA from field generated soil, groundwater, plant, and reservoir samples; soil and water samples from pilot-scale laboratory columns; pure and mixed culture samples; and laboratory microcosm reactors to enhance our understanding of microbial community structure and interactions in natural and engineered contaminated environments. These RT-PCR tools are being used in conjunction with other microbial community analysis techniques, primarily ARISA analysis, to aid in exploring the make-up of impacted microbial communities of interest.

- **Benefits to 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 Utah reservoir microbial community composition to investigate microbial sources of taste and odor and eutrophication problems in them.
  3. Evaluate differences in microbial communities within impacted trees at Hill AFB that is an innovative application of molecular biology tools to phytoremediation sites 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.

- **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 1) tracking the progress of remediation and the growth and maintenance of remediation cultures applied at a chlorinated solvent site at Hill AFB; 2) evaluating the molecular composition and diversity of groundwater plumes adjacent to Hill AFB; 3) identifying the sources of algal blooms and surface water impacts in Pineview Reservoir; 4) evaluating the presence and abundance of arsenic reducing species in soil and groundwater adjacent to the Logan City Landfill; 5) assessing the composition and diversity of bacterial, archeal, and fungal communities associated with poplar plants in a phytoremediation study at Hill AFB; and 6) 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: rdupo@cc.usu.edu.

Website: https:/ / public.me.com/ rdupo/ UWRL.

Remediation of Chlorinated Solvent Contamination of Groundwater

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorenson
Kathita Chittaladakorn (BS student)
Lindsay Stevens (BS student)

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

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 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 have been leached with TCE containing groundwater and one of three carbon sources for over six-years. Analysis of the leachate over time has shown that TCE was completely dechlorinated with the addition of whey as the carbon source. Only partial degradation was observed with other carbon sources. We are presently investigating the biogeochemical conditions that are necessary for partial and full dechlorination within the columns

by coring the columns (Figure 1) and analyzing the sediments for microbial and geochemical parameters (Figure 2). Dechlorination only took place in the top 1 foot of the six foot columns. Necessary conditions for full dechlorination include highly reduced conditions, depletion of bioavailable iron, the presence of dechlorinating bacteria, and a supporting microbial community.

Work Plan FY 10/FY11

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

Figures 1 and 2. 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.

Informational Resources

Contact: Joan McLean, E-mail: joan.mclean@usu.edu.

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

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

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 has been unsuccessful due to low population levels of native dechlorinating microorganisms and the apparent competition for the added carbon by non-dechlorinating, iron-reducing bacteria found there in high concentrations. Laboratory scale studies have indicated the need for bioaugmentation, along with a source of carbon, for successful reductive dechlorination of TCE in OU5 aquifer material.

  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 and 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 State:**

  This project benefits Utah in a number of ways: 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) Cost-effective recovery of impacted water resources at two specific Hill sites and many more sites across the state with similar contamination scenarios.

- **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 in the small microcosm studies, partial dechlorination of TCE is observed 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 2400 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, and 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 in the background soil, 2) the carbon source is the determining factor in the microbial community that develops over time, 3) community extracted from the mobile groundwater is more indicative of TCE transformation potential than community composition determined from the soil phase, and 4) all carbon sources support reductive dechlorination in the presence of high sulfate conditions.

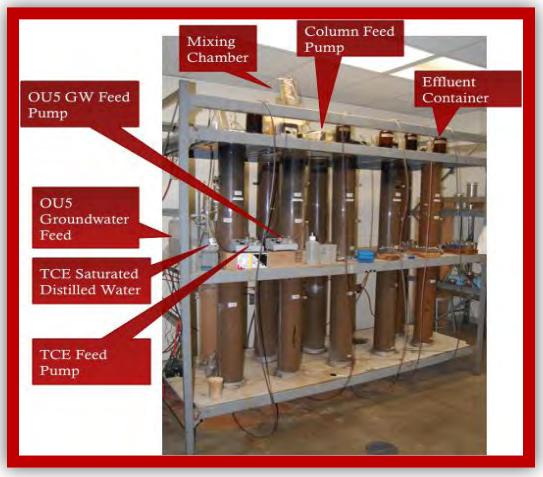
Work Plan FY 10/FY11

Influent and effluent monitoring of the columns will continue through FY'10, and incremental samples of soil within the columns will be collected at the beginning of FY11 for molecular biology, soil and water quality analyses to assess the persistence, growth, and continued distribution of the dechlorinating inocula, and significance of sulfur metabolism throughout the pilot scale columns.

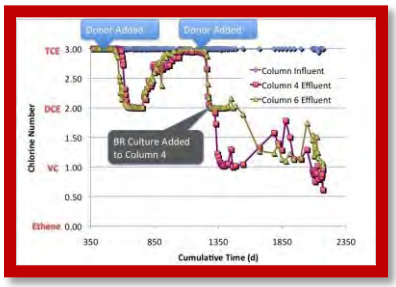
Informational Resources

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

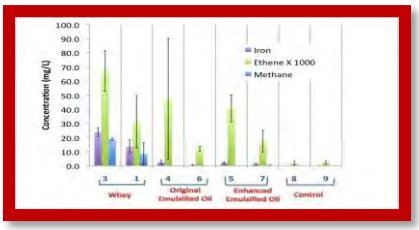
Website: https:/ / public.me.com/ rdupo/ UWRL.



Flow through columns.



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



Example of water quality results from columns.

Study of Cache Valley's Ambient Vertical Ozone Profiles

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

Partners/Collaborators:

- ***Local:*** *G. Koford, Bear River Health Dept.*
- ***State:*** *Utah Division of Air Quality (UDAQ) & Air Monitoring Center (UAMC)*

Project Description

- **Need and Purpose:**

  In December of 2009, the Cache Valley, as well as most of Utah's Wasatch Front, was officially declared non-attainment for the air pollutant $PM_{2.5}$ (particulate matter less than two and one-half microns in diameter) by the U.S. Environmental Protection Agency. This declaration initiated a 3-year time frame for the state agencies and local stake holders to develop a State Implementation Plan (SIP) to outline a remediation plan. Past research in this region has 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) plays a significant role in this series of atmospheric chemical reactions. Specifically, it 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 performed 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 flights (afternoon and morning). Confirmation of these findings could have significant implications on the effectiveness of any potential local remediation scenarios. 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.

- **Benefits to State:**

  The Cache Valley air quality studies initiated under the MLF program, and cooperatively supported previously by other local and state agencies, has led to the establishment of a viable and sustainable air quality research program at Utah State University, as well as direct cooperation on numerous other projects with other departments and colleges at USU and cooperation with colleagues at other universities, state and federal agencies, and research foundations.

- **Geographic Areas:**

  Study Area: Cache Valley, UT (including the entire cross-border airshed).

  Areas Benefited: Primarily the Cache Valley, but findings and future work could logically be extended to the Wasatch Front, and to the Uintah Basin, which has recently identified a wintertime O_3 problem.

- **Accomplishments**:

  Findings: The modification and application of light-weight air pollutant systems (in this case, O_3) seem promising. Initially, passive (Ogawa) badge systems were evaluated, but these were found to be inconsistent and required too long of sampling times (>8 hours) at the ambient concentrations. In late 2009, a light-weight (2.1 kgs) Model 202 O_3 monitor was purchased from 2B Technologies, and characterization studies of the instrument were performed. Since its original purchase, the instrument was also officially certified as an EPA equivalent method (EQOA-0410-190).

  Results: In 2010/ 2009, the purchased monitor has been (and continues to be) stripped down and the components consolidated to make the monitor even smaller and lighter-weight in order to be carried aloft by a tethered balloon system or one of UWRL's Unmanned Aerial Vehicles (UAV). Additionally, multiple tests have been performed on the operation of the modified Model 202 using smaller and lighter battery systems, and under temperature systems expected in the Cache Valley's wintertime atmosphere.

Work Plan FY 10/FY11

Work on developing protocols for economically and accurately measuring vertical ozone profiles will continue into FY11. The system is currently being reworked one final time by a USU electronics technician to optimize the final package. An application for approval from the Federal Aviation Administration (FAA) to fly the package via the tethered balloon from December 2010 – March 2011 has been submitted, with a plan to measure multiple O_3 profiles under both inversion and non-inversion episodes. Assuming approval from collaborators (UWRL's AggieAir), the system will also be tested in flight on a UAV. There may also be an opportunity to collaboratively apply the tethered balloon or UAV package on a recently proposed research project in the Uintah Basin (submitted to the Uintah Impact Mitigation Special Service District).

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 (MS Student)

Partners/Collaborators:
- ***Local**: Kyle Gorder and 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 shallow 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 mainly 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 reports 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 chemical 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 differences than actual species differences. Thus, we propose to extend the use of our pressure chamber technique to examine the uptake of organic contaminates in the Curcurbitaceae family and determine if the reported species variability is real or an artifact of the experimental methods used.

- **Benefits to 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: Initial plant uptake experiments have been conducted using several environmental organic contaminants (caffeine, pyrene, diethyl phthalate, triclocarban, sulfamethoxazole, fluoxetine, carbamazepine, tris (2-chloroethyl) phosphate, and progesterone) and two plant species (soybean and zucchini). Plant uptake data generated to date, 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

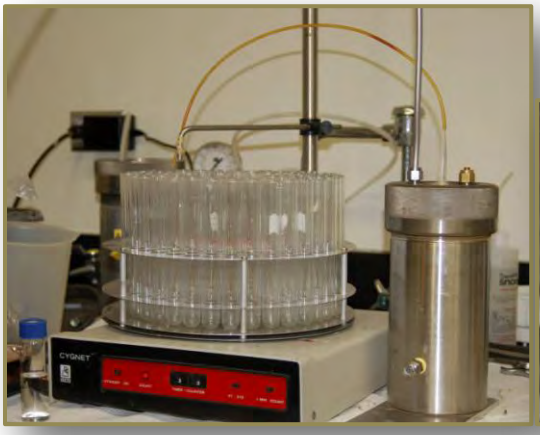
Compound	Soybean TSCF	Zucchini TSCF	Analysis Method
Caffeine	0.68±0.10	0.70±0.14	Liquid scintillation
Pyrene	0.16±0.6	To be determined	Liquid scintillation
sulfamethoxazole	>0.01	To be determined	LC/ MS
fluoxetine	0.7	To be determined	LC/ MS
tris (2-chloroethyl) phosphate	0.9	To be determined	To be determined
progesterone	>0.01	To be determined	To be determined

Work Plan FY 10/FY11

Additional plant uptake experiments will be performed to complete Table 1 and for hybrid poplar trees.

Informational Resources

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



Pressure chamber system

Xylem exiting plant

Extraction of plant tissue

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

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

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

Project Description

- **Need and Purpose:**

  Historic waste management and disposal practices at Hill Air Force Base in Utah have resulted in the contamination of shallow groundwater with a variety of volatile chlorinated organic compounds. Contaminated groundwater has migrated outside of the facility beneath residential communities. As part of the clean-up program, indoor air is monitored to determine if contaminants are volatilizing from the groundwater and into residences. The migration of volatile chemicals from the subsurface into overlying buildings is referred to as vapor intrusion. An air-monitoring program implemented to detect vapor intrusion has identified chlorinated solvents such as trichloroethylene (TCE), 1,2-dichloroethane (1,2-DCA), tetrachloroethylene (PCE), and carbon tetrachloride (CCl4) in homes outside areas of groundwater contamination, suggesting indoor sources in these cases. The objectives of this study are to 1) measure chlorinated solvent emission rates from consumer products in a laboratory emission chamber, 2) estimate potential exposure concentrations in an indoor environment based on laboratory emission rate measurements, and 3) compare and contrast these results with concentrations observed in residential indoor air samples.

- **Benefits to 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. We hope to demonstrate that the laboratory measured emission rates of chlorinated solvents from consumer products can be used to predict indoor air concentrations and help 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**:

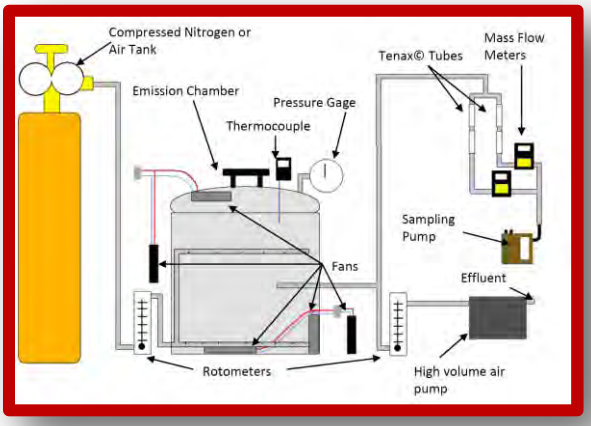
  Findings: Initial measurements of chlorinated solvent emission from several consumer products including a gun cleaner, a toilet bowl cleaner and a hobby adhesive have been made. Initial screening-level calculations suggest that the measured emission rates from these items can lead to indoor concentrations high enough to be of regulatory concern. The estimated concentrations will be compared to actual concentrations measured in residences located around Hill AFB.

Work Plan FY 10/FY11

Continue laboratory emission measurements, field measurements and model development.

Informational Resources

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



Schematic of the flow through emission chamber system.

Emission chamber containing consumer product.

Emission chamber sampling of consumer de-greaser.

Surface and Groundwater Quality and Quantity

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

Project Name	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
A Methodology for Improved Groundwater Recharge Estimation in Semi-Arid Regions	$35,799.94	$36,873.94	$0.00
A Three-Dimensional Hydrodynamic and Thermal Model of Cutler Reservoir	$34,977.49	$0.00	$0.00
Data Collection and Modeling Support for the Little Bear and Bear Rivers	$37,991.83	$39,131.58	$2,300.00
Development of Technology for Streambed Thermal Property Instrument (SPI)	$26,269.92	$17,000.00	$0.00
Effects of Ground-water-Surface Water Interactions on Instream Temperatures in High Gradient Mountain Streams	$20,270.86	$14,000.00	$0.00
Evaluation of Best Management Practices for Sustainable Groundwater Protection at Biosolids Land Application Sites	$64,129.25	$68,700.00	$0.00
The Fate of Pharmaceuticals and Personal Care Products Associated with Northern Utah Wastewater Treatment Effluents	$22,332.06	$28,500.00	$0.00
Incorporation of Heat into Solute Models	$17,736.67	$18,500.00	$0.00
"Lab-on-a-Chip" – Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$102,309.07	$64,540.61	$0.00
Modeling Stream Flow Surface Water/Groundwater Interactions to Improve Water Management	$441.54	$0.00	$0.00
Monitoring Program to Assess Tributary Nutrient Loading into Cutler Reservoir for TMDL Support	$9,295.89	$9,574.77	$0.00
Optimizing Wet Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies	$32,616.72	$33,595.22	$0.00
Precipitation/Weather Monitoring in the Little Bear River	$9,295.89	$3,191.59	$0.00
Quantification and Management of Salt Production in the Desert Lake Watershed	$99,192.02	$72,500.00	$0.00
Release of Arsenic from Aquifer Solids Under Anaerobic Conditions	$152,254.59	$75,600.00	$0.00
Technical Support for Bear River System Data Acquisition	$45,587.94	$69,500.00	$0.00
Temperature and Solute Model for the Virgin River	$30,912.87	$0.00	$0.00
Uptake and Release of PPCPs (Pharmaceuticals and Personal Care Products) and Other Organic Contaminants from Sediments, Soils, and Biosolids	$7,349.42	$10,600.00	$0.00
Weber Basin Decision Support System (DSS) Modernization	$49,616.25	$51,104.74	$2,400.00
Designated Projects		$127,961.00	$0.00
Undesignated Projects		$12,000.00	$86,000.00
Total	**$798,380.22**	**$752,873.45**	**$90,700.00**

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

Principal Investigators:
Jagath J. Kaluarachchi

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 aims to develop the Complementary Relationship methodology to estimate ET independent of land cover and land use that uses such simple meteorological data as temperature, wind speed, relative humidity, and dew point. The key advantages of the Complementary Method are simplicity of data, ability to gather metrological data relatively easily, ability to predict ET during both growing and non-growing seasons and under all types of land cover, ability to combine with climate prediction models given the use of meteorological data only, and the ability to predict regional ET as opposed to point estimates.

- **Benefits to 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:**

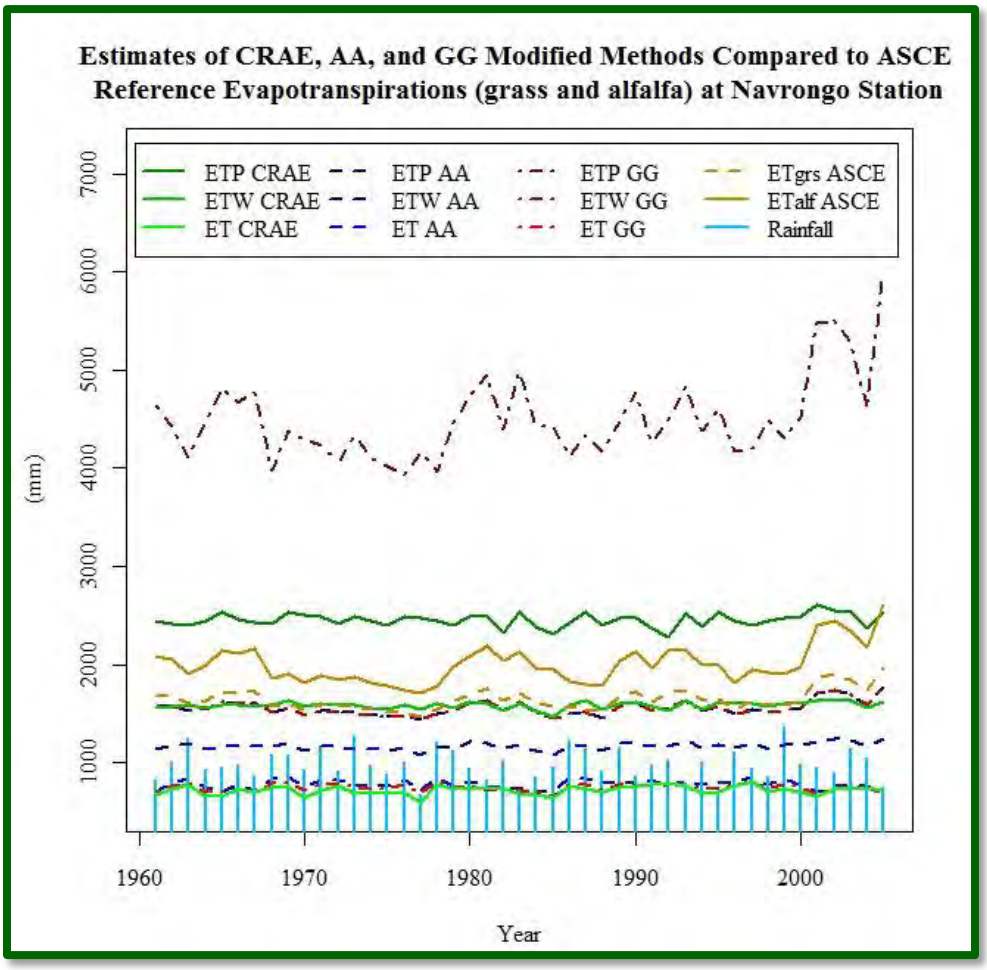
  Study Area: Applicable areas across Utah where meteorological data are gathered. At the present time, we are using data available from elsewhere, but the application will be conducted for Utah's Cache Valley in the next year.

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

- **Accomplishments:**

  Findings: The Complementary Method is almost completed and the applications are presently being conducted.

  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 FY 10/FY11

We will continue to use the Complementary Method to complete the ET estimation, and the work related to recharge estimation will start thereafter.

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 of 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 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, 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 validate the model.

  Results: Shown in Fig. 3 are measured water temperatures at several locations within the reservoir throughout the summer of 2010. The results indicate a very uniform spatial temperature distribution, with temperatures exceeding 27 degrees C during the month of July. Computed temperature distributions over the reservoir at a depth of 1 meter are plotted in Fig. 4. A comparison with experimental data indicates good agreement with temperatures on the order of 14 degrees C.

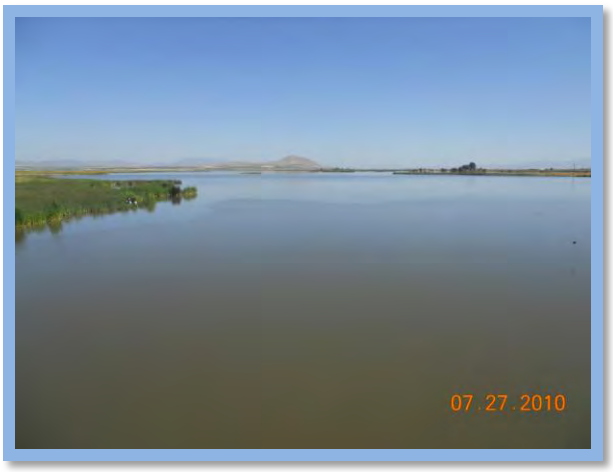


Figure 1. Cutler reservoir looking north from Benson marina.

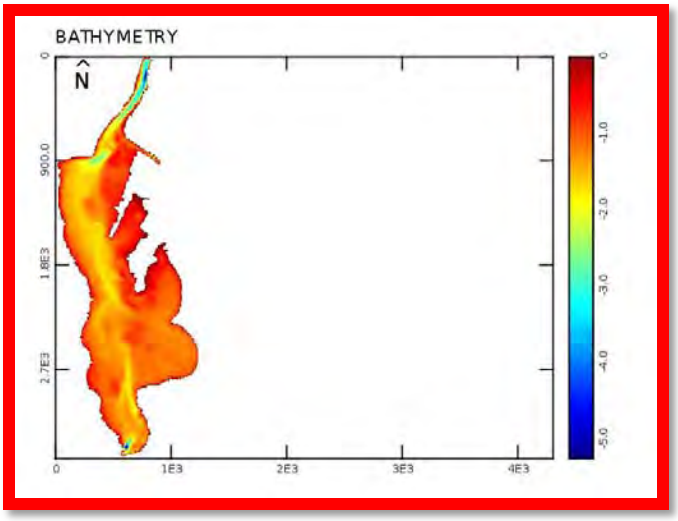


Figure 2. Bathymetry (water depth in meters) north of Benson marina (located at bottom of figure).

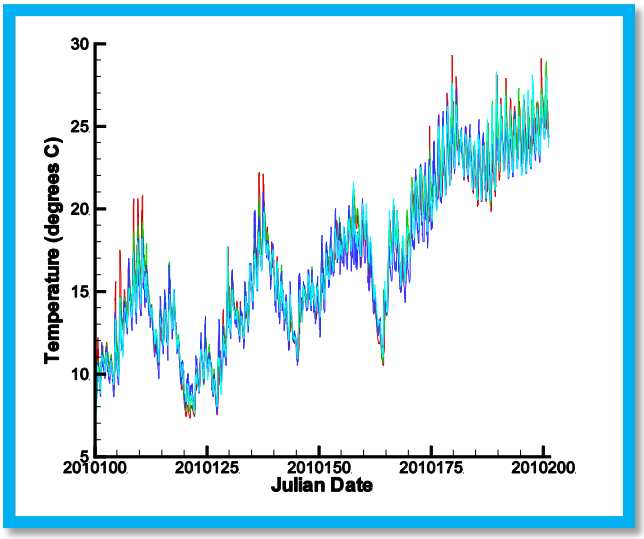


Figure 3. Measured water temperatures.

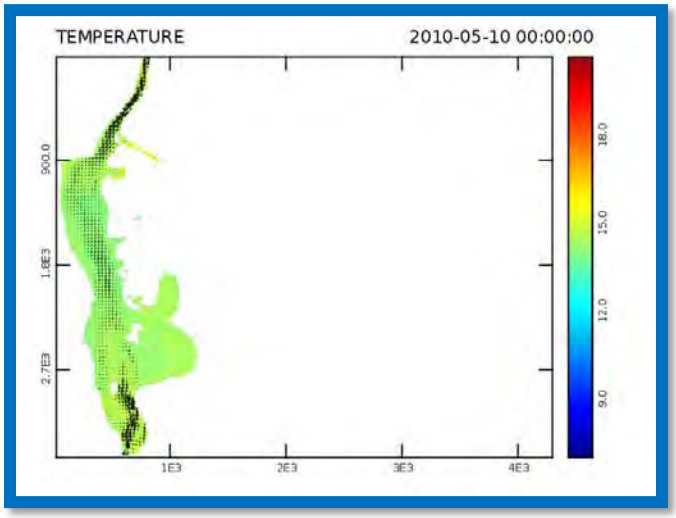


Figure 4. ELCOM predicted temperature distribution and velocity vectors at 1m depth.

Work Plan FY 10/FY11

The ELCOM hydrodynamic calculations will be completed. Experimental temperature distributions through the end of the summer will be obtained and compared with the numerical simulations.

Informational Resources

Contact: Dr. Robert Spall, E-mail: spall@engineering.usu.edu.

Data Collection and Modeling Support for the Little Bear and Bear Rivers

Principal Investigators:
David K. Stevens

Partners/Collaborators:
- ***Local:*** *City of Logan*
- ***State:*** *Utah DWQ*
- ***Federal:*** *U.S. EPA/USDA*
- ***Business/Industry:*** *Twin Lakes Canal Co.*

Project Description

- **Need and Purpose:**

  The Bear River spans three states with numerous border crossings, ending its run at the Great Salt Lake in Northern Utah. Through external and internal funds, researchers at the UWRL have laid much of the groundwork for an integrated data collection and modeling system. A number of pieces are needed to complete the picture:

  1. Expand monitoring to include six major and a number of lesser lakes and reservoirs along the river and tributary corridors, particularly to meet needs of the City of Logan and the Twin Lakes Canal Company.
  2. Continue to monitor water quality at seven sites in the Little Bear River.
  3. Reduce the time needed to complete simulation of complex river networks with human-caused changes in the flow patterns and water quality.

- **Benefits to State:**

  Specific benefits to the State of Utah of the Bear River Decision Support project at the UWRL include:

  1. The ability to study nutrient sources in Cutler and Hyrum Reservoirs at several locations; the ability to measure dissolved oxygen, temperature, and other water quality constituents in those reservoirs; and the ability to deploy and retrieve thermistor chains to monitor the thermocline development and breakdown.
  2. The completion of a third water year of monitoring for nutrients in the Little Bear River.
  3. The development and application of modern parallel computing methods to the Little Bear and Bear River hydrologic, watershed, and river water quality models.
  4. The improved ability to provide resource managers and other stakeholders tools for simulating the Bear River system in a timely way that could be used for decision support.

- **Geographic Areas:**

  Study Area: Logan, Benson, Richmond, Smithfield, Hyde Park, North Logan, Nibley, River Heights, Cache County.

  Areas Benefited: Cache County, other Utah watersheds with similar water quality problems.

- **Accomplishments**:

  Findings: Data collected during the past fiscal year includes flow, water quality and temperature data, and sediment nutrient and oxygen dynamics for the Bear River, the Logan River, Spring Creek, Swift Slough, the Little Bear River, and Cutler and Oneida (Franklin County, ID) Reservoirs at several locations. Both field and laboratory measurements have been obtained and the data have been included in databases supporting the project. Appropriate quality assurance and quality control procedures have been followed.

  Results: Although data analysis is ongoing, preliminary results show that significant quantities of nutrients flow into Cutler Reservoir from the Bear River and other tributaries. Nutrient and oxygen dynamics in the Cutler sediments are typical of warm water, human impacted systems and reflect the proximity of nutrient loadings. The data are being incorporated into surface water quality models for use in load assessment. Preliminary reports were completed and delivered to the City of Logan and the Twin Lakes Canal Co.

Work Plan FY 10/FY11

The deliverables of the project will be considerable amounts of data collected in Cutler Reservoir using the boat, modernized software tools, calibrated and corroborated water quality models for the rivers and reservoirs in the Bear River basins in Utah and Idaho, a completed Bear River Basin decision support system, a final report, and a software users manual. The final version of the project software and report will be presented at the Utah Water Users, Utah AWWA and Utah Water Environment Association annual meetings.

Informational Resources

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

Website: http:/ / www.bearriverinfo.org

Database: Cutler Reservoir Database (waterdata.uwrl.usu.edu), Oneida Reservoir Database (waterdata.uwrl.usu.edu).

Development of Technology for Streambed Thermal Property Instrument (SPI)

Principal Investigators:
Bethany T. Neilson
Heng Ban

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 collection methods to estimate parameters necessary to make more accurate predictions of instream temperatures. 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 State:**

  This project provides 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: the Virgin River Chub (Gila seminuda) and woundfin minnow (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 Areas:**

  Study Area: Curtis Creek, Cache County, near Hyrum, UT; Virgin River, Washington County, near Hurricane and St. George, UT, Jordan River in Salt Lake County.

  Areas Benefited: Curtis Creek, Cache County, near Hyrum, UT; Virgin River, Washington County, near Hurricane and St. George, UT, Jordan River in Salt Lake County.

- **Accomplishments:**

  Findings: A larger, more robust version of the SPI probe was created. A gravity-fed flow cell was built for the laboratory testing of the probe. The flow cell simulates a streambed by pumping water through a bed of small glass particles. The robust probe is inserted into the flow cell and measures the bulk thermal properties for no flow situations. During flow tests, the probe measures the flow

rate as well as the flow direction. MathCAD software was used to generate theoretical curves in order to determine the sensitivity and workable range of the probe and calculation method.

Results: Methods for calculating the flow using large probes were developed using Matlab software with custom curve fitting. Increased heat (up to four amps) was required to allow for a higher temperature rise that yielded more consistent curve fitting. The flow cell allows for testing the physical bounds of the SPI probe including heat limitations, measurable flow rates, and overall signal noise. Additionally, the theoretical MathCAD sheet allows the sensitivities and uncertainties of the calculation method to be tested.

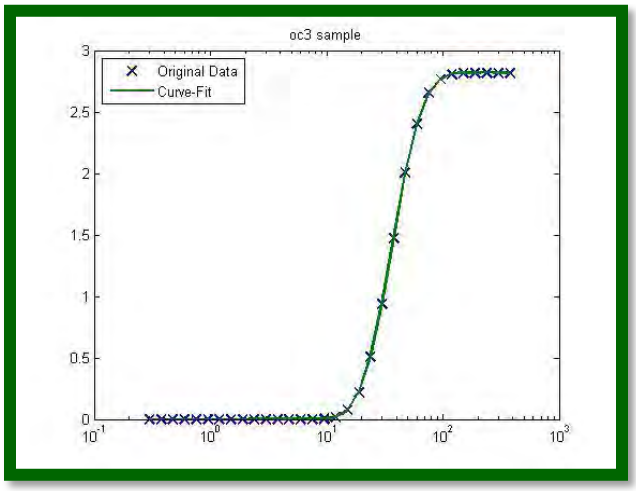


Figure 1. Time response of a downstream off-set probe (current of 3A) with a curve fitting solver used to estimate the flow rate and flow direction. The original data was simulated using MathCAD software.

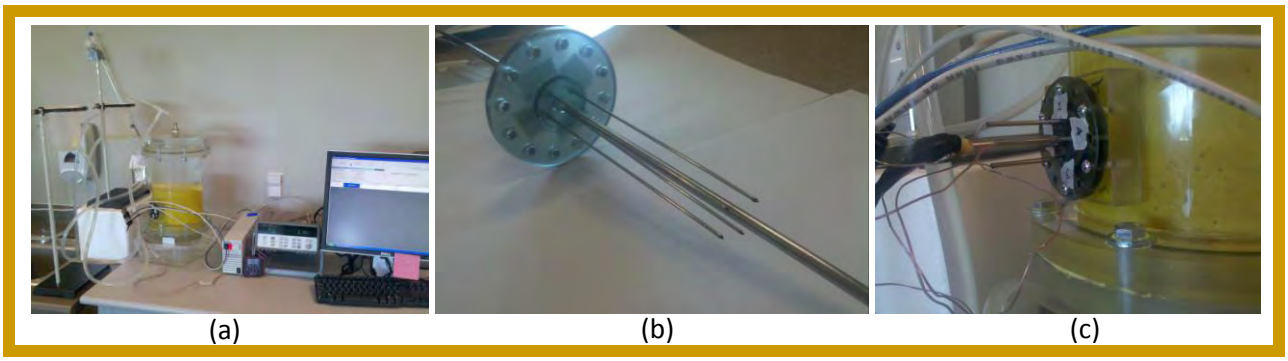


Figure 2. (a) Experimental setup. Left to right: Elevated flow control beakers, flow cell with yellow glass, constant current power supply (ZUP36-12), DAQ (Agilent 34970A), logging computer. (b) Robust SPI probe. The center probe provides heating as well as a temperature response, and the four off set probes record temperature. The tip of the center probe is inserted 7" horizontally into the flow cell. (c) SPI probe inserted into the flow cell. The probe may be rotated and re-inserted to verify the flow direction calculation.

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.

Effects of Groundwater-Surface Water Interactions on Instream Temperatures in High-Gradient Mountain Streams

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***State:*** *Dan Christensen/UDWR*

Project Description

- **Need and Purpose:**

  There are many physical processes that influence pollutant transport in a river or stream. One of the greatest challenges associated with predicting and modeling mass and energy movement accurately is quantifying each of these processes individually. A better understanding leads to appropriate management practices and protecting our source water.

  Curtis Creek, UT was used in a case study for advancing the development of a data-centric modeling method over a broader range of conditions. The results can be used to understand and quantify energy and mass fluxes in river systems. This study system was highly influenced by groundwater exchange and first required the estimation of a water balance in terms of gains and losses before a Two-Zone Temperature and Solute transport model could be used and tested.

- **Benefits to State:**

  The State of Utah will benefit from this project by having a Two-Zone Temperature and Solute Transport model that has been applied and tested within Utah. These modeling applications provide more accurate heat and solute predictions that can assist in more informed surface water management for a larger portion of the watersheds within the state. Additionally, effects of management decisions involving channel alterations and beaver dam removal are presented in this study. This leads to better source water protection and reduction of management costs.

- **Geographic Areas:**

  Study Area: Curtis Creek, Hardware Ranch, Cache County, Utah.

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

- **Accomplishments**:

  Findings: Overall, this data collection effort and the newly developed strategies have provided great insight into a number of research topics. We have been able to expand on methods of determining gains and losses occurring within streams by providing the corresponding uncertainty of these methods. We have also developed new methods to collect sediment temperature data representing the effects of bed conduction. The results have provided reliable estimates of sediment thermal diffusivities using conduction models. Additionally, the use of sediment temperature time-series to determine more accurate seepage rates is being developed using these sediment thermal properties.

  Results: Different data types were initially collected within Curtis Creek from May – October of 2008, many of which have continued to date. These data have led to further studies and proposals

related to the influence of the newly established beaver dams within our study reach. The study reach was found to have complex surface water-groundwater interactions as described in Schmadel et al. (2010). This research and the resulting data have provided for many opportunities to collaborate with others. One of the newly established collaborations is with Dr. Anders Worman of KTH Royal Institute of Technology in Stockholm, Sweden. Noah Schmadel will be working as a Ph.D. student with Dr. Worman to incorporate heat into another solute transport model developed at KTH. An additional collaboration with the College of Natural Resources has resulted in the development of a joint NSF proposal regarding the influence of beaver dams on streams in Utah that will be submitted in 2011. Lastly, this research has led to an Inland Northwest Research Alliance project using the methods developed in Curtis Creek in an Arctic stream as well as two NSF Polar Program proposals to continue this work.

Work Plan FY 10/FY11

This project is complete.

Informational Resources

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

Publications:

Schmadel, N.M., B.T. Neilson, and T. Kasahara (In review). Investigation of Data Collection Techniques Used for Estimating Stream Water-Groundwater Interactions. *River Research and Applications*.

Lyman, C., B.T. Neilson, and N.M. Schmadel (2010). Effects of Beaver Dams on Curtis Creek Temperature and Flow. *Utah State University Spring Runoff Conference 2010*. Logan, UT, April.

Schmadel, N.M., B.T. Neilson, and D.K. Stevens (2010). Approaches to Estimate Uncertainty in Longitudinal Channel Water Balances. *Journal of Hydrology*, 394:357-369.

Bingham, J.D. and B.T. Neilson (2009). Data Collection and Modeling for Determining Stream Bed Conduction Parameters. *Utah State University Spring Runoff Conference 2009*. Logan, UT., April.

Bingham, J. D. (2009). *Comparison of Data Collection and Parameter Estimation Techniques for the Approximation of Streambed Thermal Properties*. M.S. Thesis, Utah State University, Logan, UT, 108pp.

Schmadel, N.M. (2009). *Quantifying Surface Water and Groundwater Interactions in a High-Gradient Mountain Stream for Solute Transport*. M.S. Thesis, Utah State University, Logan, UT, 189pp.

Evaluation of Best Management Practices for Sustainable Groundwater Protection at Biosolids Land Application Sites

Principal Investigators:
Michael McFarland

Partners/Collaborators:
- ***Local:*** *Karthik Kumarsamy, Utah State University; Dan Olson, Tooele City Wastewater Treatment Plant*
- ***State:*** *Mark Schmitz, Utah Division of Water Quality*
- ***Business/Industry:*** *Alan Hais, Water Environment Research Foundation*
- ***Federal:*** *Robert Brobst, US EPA Region 8 Denver, CO*

Project Description

- **Need and Purpose:**

  With increasing demands for residential and commercial land use, as well as the increasing costs associated with achieving new wastewater treatment standards, there is an urgent need for the Utah Department of Environmental Quality (UDEQ) to establish scientifically defensible options for the beneficial use of biosolids generated within the state. In addition, the UDEQ, the Utah Department of Natural Resources, and the Utah Department of Agriculture and Food are considering best management practices aimed at restoring disturbed Utah landscapes. The objective of this study is to evaluate the effectiveness of currently implemented biosolids land application best management practices (BMPs) to mitigate the potential risk of groundwater contamination by regulated pollutants associated with land applied biosolids.

- **Benefits to State:**

  The information generated from this project will be important to Utah land managers, municipal wastewater treatment plants, biosolids generators, biosolids land appliers, and to Utah agricultural producers in identifying sustainable methods for utilizing biosolids (Figure 1). It is anticipated that the results of the research will lead to biosolids management practices that will help improve Utah landscapes as well as the agricultural economy while minimizing any adverse ecological and/ or environmental impacts.

Figure 1. Biosolids Land Application for Rangeland Restoration in Tooele County, Utah.

- **Geographic Areas:**

  Study Area: The study area is national in scope, but the specific counties in Utah that have directly benefited from this research include Salt Lake County and Tooele County.

  Areas Benefited: The areas that most directly benefit from this effort include disturbed and/ or marginal agricultural land located in Tooele county where significant amounts of biosolids are being recycled.

- **Accomplishments:**

  Findings: Current best management practices established by the US Environmental Protection Agency for protection of groundwater quality at biosolids land application sites are sufficiently conservative to minimize the risk to public health from groundwater consumption. These findings were determined by the development of a risk characterization screening tool (RCST) that utilized the EPA's Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment (3MRA) technology as its computational framework.

  Results: The primary result from this effort was the refinement of the risk characterization screening tool (RCST). The RCST is now able to account for the impact of irrigation practices and other supplemental hydraulic loadings on the leachability of biosolids pollutants to groundwater. The RCST can also alert the user when the biosolids land application rate is limited by the background soil nutrient levels.

Work Plan FY 10/FY11

To improve the RCST usability, a number of refinements will be made in next FY including the following:

- Modify the RCST software to characterize the potential human health risks associated with land applied biosolids microconstituents (e.g., pharmaceuticals, personal care products, detergents, fragrances, etc.) on groundwater quality.

- Modify the RCST software to account for the impact of global climate change on the precipitation patters affecting biosolids land application activities.

Informational Resources

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

The Fate of Pharmaceuticals and Personal Care Products Associated with Northern Utah Wastewater Treatment Effluents

Principal Investigators:
William J. Doucette
Joe Stewart

Partners/Collaborators:
- ***Local:*** *Clint Rogers, Carollo Engineering and Michael Luers, Snyderville Basin Water Reclamation District*

Project Description

- **Need and Purpose:**

  The potential human and ecological impacts (i.e., hormone disruption, increased microbial resistance to antibiotics) of pharmaceuticals and personal care products (PPCPs) introduced into the environment has lead to an increased interest in their distribution, environmental fate, and bioavailability. One of the main pathways that PCPPs enter the environment is through the effluents of wastewater treatment plants (WWTPs). PCPPs often pass through WWTPs untreated or partially treated. There is little information regarding the identity, distribution and fate of PPCPs discharged from WWTPs in Utah. The focus of this project is to conduct a preliminary survey of Northern Utah WWTP effluents to determine the identity and concentrations of PPCPs.

- **Benefits to State:**

  Results from this preliminary survey will help determine whether PPCPs are being discharged into the environment from effluents originating from Northern Utah municipal wastewater treatment plants. This information will be compared to similar observations in other areas of the United States and used to determine the effectiveness of wastewater treatment facilities in removing PPCPs and to assess the potential impact of these compounds on the surface and groundwaters within the State of Utah.

- **Geographic Areas:**

  Study Area: Cache, Box Elder, Morgan, Sanpete, Summit and Utah Counties.

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

- **Accomplishments**:

  Findings: Methods utilizing solid phase extraction and liquid chromatography/ mass spectrometry (LC/ MS) were used to tentatively determine the identity and concentration of PPCPs in effluents from several wastewater treatment plants in Northern Utah, including those located in Park City, Price, Brigham City, Fairview, Spanish Fork, Oakley, Moroni and Wellsville.

  Results:

  - PPCPs that were tentatively identified include acetaminophen, sulfamethoxazole, carbamazepine, DEET, fluoxetine, estrone, B-estradiol, and progesterone.
  - Estimated concentrations were typically in the pg to ng/ L range.

Work Plan FY 10/FY11

This project is completed.

Informational Resources

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

Figure 1. Synderville WWTP

Figure 2. Solid Phase Extraction

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 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 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 and surface-groundwater zone 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.

  Results: Analytical solutions of two-zone solute transport have been developed with the use of Laplace transforms and 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 1 shows example predictions of the movement of a short duration pollutant spill through a river or stream.

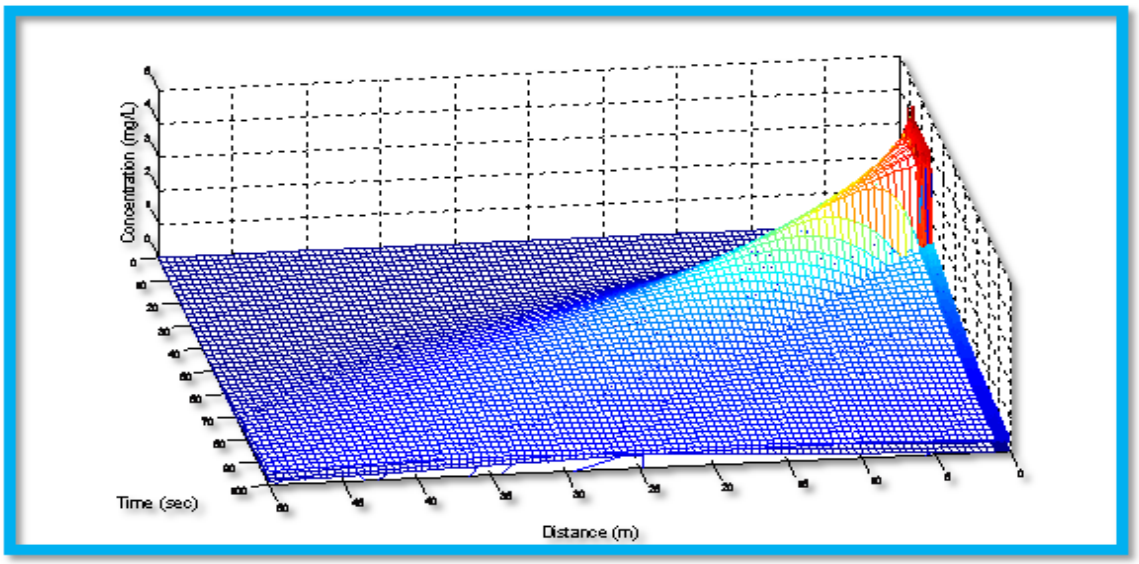


Figure 1. Example of using analytical solutions to predict the transport of a pollutant spill through a river or stream.

Work Plan FY 10/FY11

The two-zone heat transport model equations have been partially solved analytically and will be completed and further tested with observed temperature data. Additionally, effects of surface water-groundwater interactions will be introduced into the model to better account for all transport processes. Using observed data, temporal moments will be calculated to represent varying residence time distributions of solute and heat. 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.

"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 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 are 1) Ion sensor arrays 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 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.

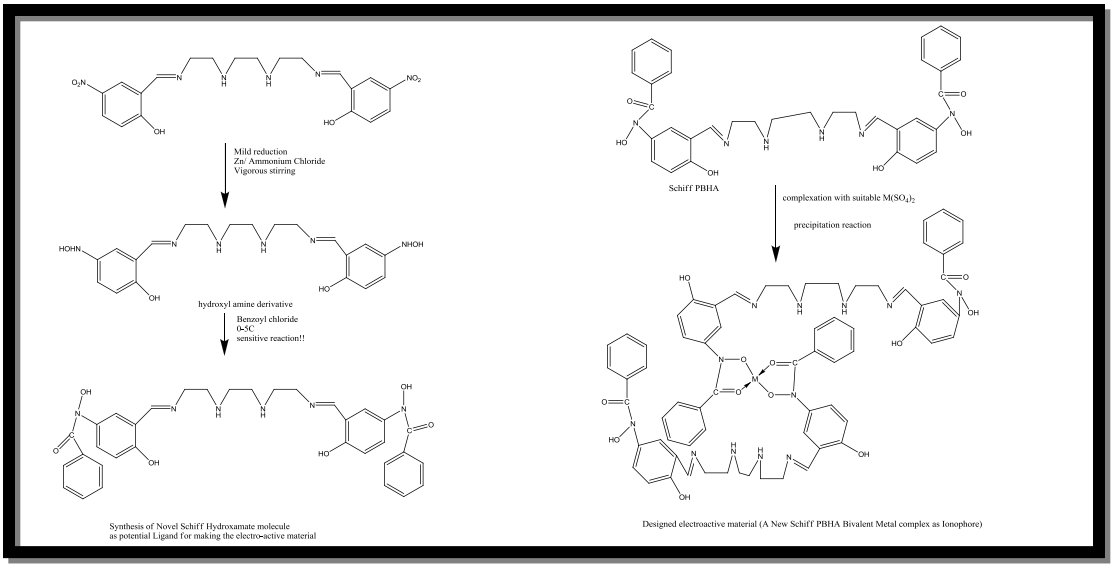
- **Accomplishments:**

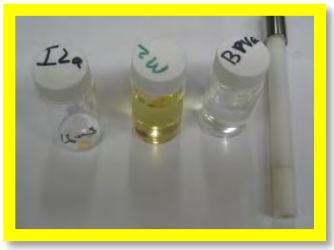
  Findings: We have been working with USU Technology Commercialization Office to complete two significant revisions submitted to the U.S. Patent Office for our pending patent (see below). Meanwhile, we have improved the selectivity and sensitivity of our previously constructed sulfate ion selective electrode probe by designing a new ionophore (II) with two optional synthesis routes (see below) and optimized by a using molecular dynamic modeling.

  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 atomistic simulation to optimize the geometry and calculate Molecular Orbital (MOs) structure of the newly designed and synthesized ionophore molecules.
  3. Explored initial investigations utilizing ionic liquids as plasticizers with the synthesized ionophore molecules to further improve the selectivity of sulfate ion probe sensor.

4. Explored preliminary molecule dynamic modeling to increases understanding of the ionophore-sulfate ion recognition mechanism.





USU synthesized new ionophore compounds that can be potentially used to build highly sensitive sulfate ion selective probe.

USU's proprietary sulfate ion selective electrode (bottom is the sensing area).

Patent activity: Anhong Zhou, Huifang Dou (2007). Electrochemical Chip with Miniaturized Sensor Array", U.S. Patent Application No. 11/ 761,916, filed by Utah State University (June 12, 2007). We have submitted two revisions of this pending patent as requested. On Aug 2nd, the potential examiner from U.S. Patent allowed our new claims in our revision submitted 06/ 30/ 2010. We await resolution of the final issue of this pending patent. Dr. Zhou is working with the TCO office to prepare the filing of new potential patents derived from this parent patent.

Work Plan FY 10/FY11

- Recruit a research scientist or postdoc to join in this team in 2010-2011 to synthesize new candidate ionophores for detection of sulfate ions and other salinity ions at Utah sites.
- Identification of the chemical structures by a variety of instrumental analysis techniques (NMR, MS, FTIR, XRD, etc).
- Work with USU TCO office to complete 1~2 provisional patent applications derived from our pending parent patent and the new patent for the new synethesized ionophore compounds.

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/ waterquality/ labonachip.html.

Modeling Stream Flow Surface Water/Groundwater Interactions to Improve Water Management

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***State:*** *Dan Christensen/UDWR*

Project Description

- **Need and Purpose:**

  Many physical processes influence pollutant transport in a river or stream. The key components to understanding the fate and transport of pollutants are the gains and losses to and from the stream. Curtis Creek, Utah was used in a case study for advancing the development of a various approaches to quantifying surface water-groundwater interactions in river systems. A better understanding leads to appropriate management practices and protects our source water.

- **Benefits to State:**

  Various methods of quantifying water exchanges have been applied and tested in a typical Utah mountain stream. These methods can be used in modeling and data collection efforts around the state to provide a better understanding of heat and solute fate and transport. This will in turn facilitate more informed surface and groundwater management. Additionally, effects of management decisions involving channel alterations and beaver dam removal may be illustrated by past and future information provided by this study. Recent data collected within the portion of the study reach that now has 5+ large beaver dams will provide information regarding the impact of beaver dams on surface water-groundwater interactions. This will also provide insight into the impacts of recent guidance promoting the use of beavers for stream management and restoration within the State of Utah.

- **Geographic Areas:**

  Study Area: Curtis Creek, Hardware Ranch, and Cache County, Utah.

  Areas Benefited: The current applications of the data collection can be applied to streams within the entire State of Utah.

- **Accomplishments:**

  Findings: Through the development of a detailed error analysis methodology for dilution gaging, the 95% confidence bounds of gains and losses were established. Overall, the data collection efforts and newly developed strategies have yielded methods for determining stream sections where significant gains and losses are occurring within streams.

  Results: Data collected from May to October 2008 showed that Curtis Creek has complex surface water-groundwater interactions (within lengths ranging from 80 to 240 m). Gains and losses were quantified and shown to be significant in most of the sub-reaches (Figure 1).

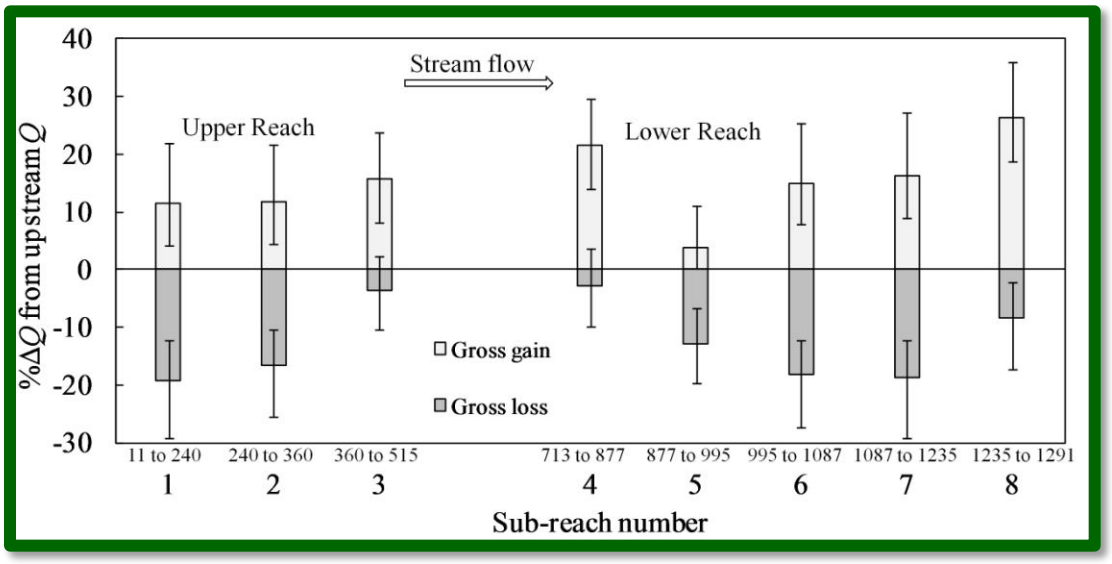


Figure 1. Upper and lower reach %gross loss and %gross gain from upstream flow with 95% prediction intervals. Distances are in meters.

Work Plan FY 10/FY11

Continued research will address the significance of the ways surface water-groundwater interactions fluctuate temporally throughout seasonal changes and varying flow conditions. This will provide information regarding the impacts of a wide range of source water management planning. For example, our understanding will expand regarding the ways that stream diversions, irrigation, and drought may significantly influence these complex interactions. Additionally, the Lower Reach shown in Figure 1 has at least 5 large beaver dams that have drastically altered stream flow patterns, gains and losses to and from the stream, and instream temperatures. Further research is planned to compare surface water-groundwater interactions pre- and post-beaver dam construction and provide insight into the pros and cons of beaver activity in our Utah streams. This includes analyses of how stream alterations affect the fate and transport of heat and water constituents.

Informational Resources

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

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

Principal Investigators:
David K. Stevens
R. Ryan Dupont
Darwin L. Sorenson
Joan E. McLean
Ana Ovalle (student)
Ruba Momammed (student)

Partners/Collaborators:
- ***Local:*** *Issa Hamud, City of Logan; James Milleson, UWRL*

Project Description

- **Need and Purpose:**

This project provides water quality monitoring in five rivers draining into Cutler Reservoir and at five locations in the reservoir itself. Measurement includes the loading of nutrients and suspended sediments, and general water quality as measured by temperature, dissolved oxygen, turbidity, and total dissolved solids. Additional data related to sediment samples and the nutrient and oxygen fluxes from the sediments into the overlying water was also obtained. 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, the following sampling program is ongoing to develop baseline information regarding nutrient loading and water quality in Cutler:

1. Spring Creek (at Mendon Road).
2. Logan River (near Mendon Road).
3. Little Bear River (at Mendon Road) (monitoring using existing UWRL funds).
4. Swift Slough near Cutler.
5. Bear River into Cutler.
6. Five locations within Cutler to include:
   - Station 590098 (Non Impaired).
   - Station 590099 (Temp & DO Impairment).
   - Station 590100 (Temp & DO Impairment) (Benson Road).
   - Station 490506 (Temp & DO Impairment).
   - South of Valley View Highway (DO Impairment).
7. Eighteen stations 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.

The river and reservoir sampling locations have been sampled monthly beginning November 1, 2008 using grab sampling, vertical profiling, and manual field and laboratory analyses to aid in placement of continuous probe measurement stations. Flow estimates are also required in order to determine load. This means establishing a datum at each location and measuring the water surface elevation relative to that datum using a staff gauge. Also, six rainfall events will be targeted for sampling over a 24-month period. In addition, the well and lysimeter stations have been sampled since April 2010.

- **Benefits to State:**

  The project benefits the state by estimating a full accounting of total phosphorus loading into Cutler Reservoir and how conditions in the reservoir the 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 help 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: We have installed three automated flow and water quality monitoring stations on the Logan River, Spring Creek, and the Bear River, in addition to an existing monitoring station on the Little 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. The data through October 2010 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, the data will be made available to the public via the Bear River Watershed Information System (http:/ / bearriverinfo.org).

Work Plan FY 10/FY11

Data collection is ongoing. A first year report was filed in January 2010. A second year report will be filed in January 2011. Monitoring is scheduled to be completed in June 2011, although 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 Wet 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:**

  Municipalities across Utah are mandated by the Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) water pollution control program to install structural stormwater Best Management Practices (BMP) as a means of reducing polluted runoff from major industrial facilities, large and medium city storm sewers, and construction sites that disturb five or more acres of land. Stormwater basins are commonly used in response to this federal mandate. This progressive program is aimed at minimizing pollutants and discharge volumes from urbanized areas into receiving water bodies and begins to address the serious 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 aims to measure biomass production and water quality improvement effectiveness in a controlled laboratory environment and in a field demonstration site study. The laboratory scale study is designed to produce controlled, laboratory scale replicates of on-site stormwater basins in which biomass production, total nutrient and metal removal, and water uptake can be quantified for four individual vegetative species under simulated (frequency and duration) rainfall events. The field demonstration study is designed to produce quantitative data for the water quality improvement effectiveness of three species compared with voluntary weed species and non-vegetated control plots under actual field conditions existing in Northern Utah. The field site study will extend preliminary laboratory data to an existing subdivision stormwater detention area in the Logan, Utah area and will determine plant production and contaminant removal improvements that might occur in response to periodic plant harvesting.

- **Benefits to State:**

  This study will provide Utah municipalities with the stormwater nutrient and metal removal effectiveness of species found and planted locally and will result in data specific to Utah's climate and geologic conditions. Logan City officials intend to utilize this information in the upcoming TMDL regulations which target reductions in the nutrient loading (particularly phosphorous) of discharges into Cutler Reservoir. Additionally, the results of this rigorous quantitative study 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. The laboratory study will be conducted in the Utah State University Research Greenhouse. The field demonstration study will be conducted in the Green Meadows Subdivision detention basin, located on 600 South and 800 West in Logan.

  Areas Benefited: All counties in the state would potentially benefit from quantitative data regarding growth, survival, and pollutant removal performance of local vegetative species that could be utilized within their stormwater management systems.

- **Accomplishments**:

  Findings: Greenhouse studies initiated in the late spring of 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 are being carried out through FY10. Final design of the field demonstration site at Green Meadows is complete, and construction and planting of this field site is planned for the end of summer 2010.

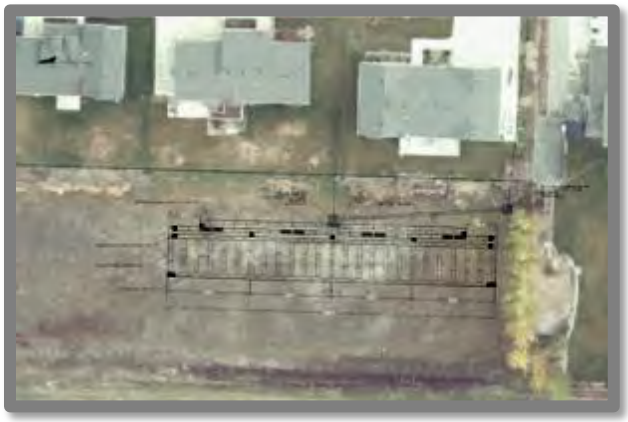
  Results: Four plant species have been successfully propagated and are growing under simulated stormwater wetting and drying cycles in the University greenhouse. Methods and procedures to load and sample simulated stormwater and collect groundwater infiltration for analysis of nutrient, solids, and metal removal potential as a function of species type have been finalized.

Work Plan FY 10/FY11

Construction of the field demonstration site is to be completed early in FY11; fall planting and initial data collection are to take place shortly after site completion. Operation of the field demonstration site will continue through FY11 to capture runoff input and contaminant removal performance data during the spring and summer of 2011. Simulated contaminated stormwater application and quantification of the contaminant removal potential of the four species being used in the greenhouse study will be conducted through the end of 2010 to complete a 6-month loading cycle. At the end of the 6-month loading period, both soil and plant material will be harvested and analyzed for nutrient and metal composition to evaluate the mechanism of contaminant removal and sequestration observed during the study.

Informational Resources

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



Plan View of the Green Meadows Stormwater BMP Field Demonstration Site.

Location of Future Green Meadows Stormwater BMP Field Demonstration Site.

Precipitation/Weather Monitoring in the Little Bear River

Principal Investigators:
David K. Stevens
Bethany Neilson
Jeffrey Horsburgh

Partners/Collaborators:
- ***Local:*** *City of Logan*
- ***Business/Industry:*** *Twin Lakes Canal Company*

Project Description

- **Need and Purpose:**

  Non-point loadings in watersheds are related to watershed hydrology in terms of runoff and stream flow. The Bear River basin is critically lacking in hydrologic information systems, including stream flow, water quality, and basic climate data collection facilities. The lack of data collection facilities limits the capability to assess basic water and pollutant mass balances.

  Some observations in Cache Valley, and in other Utah watersheds, indicate that the precipitation is highly location-specific, particularly for single storms in which one subdrainage in a watershed receives heavy rainfall and an adjacent subdrainage receives next-to-none. Contaminant loading into water courses is even more site-specific because the impact that a particular storm event will have depends on whether the precipitation falls directly on or immediately upstream of a contaminant source. So a parcel of land supporting an animal management operation that receives heavy precipitation may be adjacent to another pristine parcel that receives light precipitation, and contaminant loading will be over or under estimated.

- **Benefits to State:**

  As part of several ongoing efforts, the equipment installed under this project will ultimately provide real time data for better management of the Bear River Basin Watershed and the Great Salt Lake.

  - The USU Water Initiative has invested in real time monitoring equipment for the Logan River as part of the Bear River Monitoring Network. This project will extend the capabilities of the Bear River Monitoring Network.
  - The EPA Targeted Watersheds grant is funding the development of an Internet Based Watershed Information System (WIS) for the Bear River Basin.
  - Equipment for two monitoring stations in the Little Bear River to collect continuous, real time measurements of stream flow and turbidity with telemetry equipment to connect these monitoring stations to the Bear River Monitoring Network. The downstream monitoring station will also support more accurate estimates of flow to Cutler Reservoir and will improve the overall water balance and management of this reservoir. Both of the proposed sampling locations in the Little Bear River coincide with Utah DWQ long-term monitoring stations and will provide important flow and water quality observations that will be of interest to DWQ.
  - Water management and research institutions are working to establish a CUAHSI Hydrologic Observatory in the Great Salt Lake Basin. This effort will leverage existing monitoring infrastructure in the Great Salt Lake Basin, of which the Bear River Basin is a major part.

- **Geographic Areas:**

  Study Area: Little Bear/ Bear River Basin, Cache County.

Areas Benefited: Watersheds statewide.

- **Accomplishments**:

  Findings: We have installed the two weather stations – one in the East Fork of the Little Bear River and one at the USU Experimental Farm in Wellsville, and telemetry networks are operational. The third and fourth will be used at the UWRL for testing purposes.

  Results: The outcome of this project is a large and growing weather data set for public and research use. The data are accessible via the Bear River Watershed Information System (http:/ / bearriverinfo.org).

Work Plan FY 10/FY11

The work was completed in FY 09. Data collection using the instrumentation is ongoing.

Informational Resources

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

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

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 are 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 salt produced by agriculture and natural sources.

- **Benefits to 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.

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 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.

Work Plan FY 10/FY11

- Improve the reliability of salt source identification, and subsequently, the quantification of salt loading in the Desert Lake watershed from anthropogenic and natural sources.
- Evaluate the extension of the procedures used and lessons learned on the Desert Lake watershed to other areas in Utah that contribute salt to the Colorado River.
- 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 (MS student)
Xianyu Meng (PhD 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 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 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: The arsenic in groundwater and subsurface sediments collected from locations around the City of Logan Landfill were from geologic sources.

  Results: The concentrations of arsenic in groundwater at many locations throughout Cache Valley exceed the drinking water limit (Figure 1). The geologic material of Cache Valley contains arsenic minerals, and although landfills are potential sources of arsenic, the highest concentrations of arsenic from wells around the City of Logan landfill are located up-gradient of the landfill (Figure 2).

Laboratory microcosm studies demonstrated that the subsurface sediments have the potential to release arsenic to the groundwater. The extent of release was dependent on the sediment type and input of organic carbon.

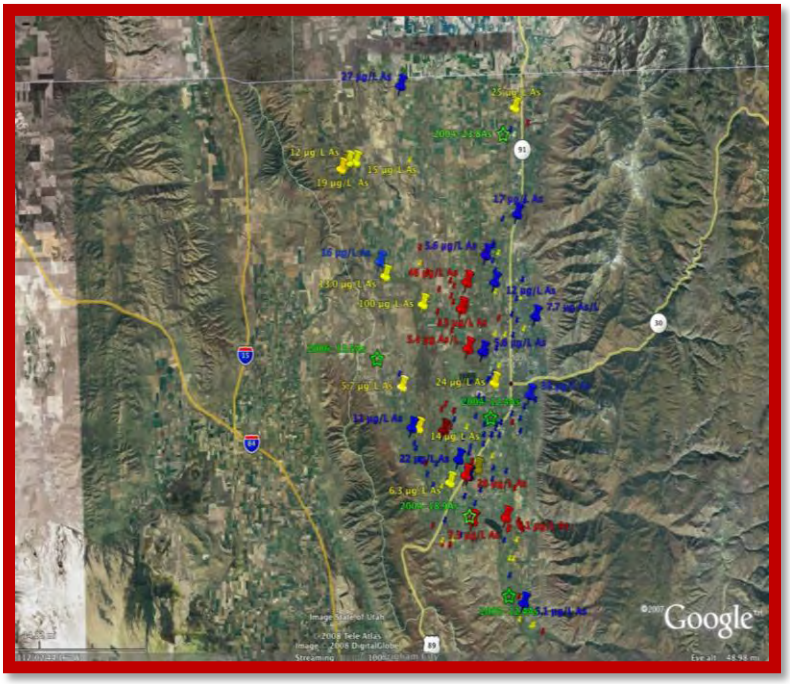


Figure 1. Distribution of groundwater wells sampled for arsenic (µg As/ L). Well samples identified using small symbols were below 5 µg/ L arsenic. Arsenic concentrations above 10 µg/ L were found in 27 out of 161 wells tested. Color denotes: yellow for shallow wells (<100 ft), blue for wells from 100-200 ft, and red for wells deeper than 200 ft; green denotes no well depth given. Elevated As concentrations were found throughout the valley and at all depths. Pinhead symbols are for data from the UGS (2003) and stars from UDAF (2004).

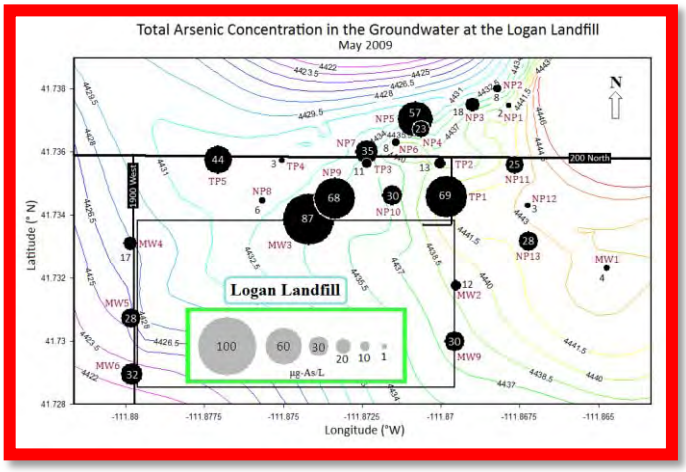


Figure 2. Arsenic concentration in groundwater (µg/ L) from sampling locations around the Logan City Landfill for May 2009. Arsenic concentrations in the surface water samples were below 2 µg/ L (data not shown). A total of 18 wells out of the 24 sampled had arsenic concentrations in excess of 10 µg/ L. The highest concentrations of arsenic were found north of the landfill at sampling locations MW3B, NP9 and TP1. These concentrations were greater than the arsenic concentrations in wells west of the landfill (MW4, 5 and 6B).

Work Plan FY 10/FY11

We will continue to investigate the biogeochemical factors that lead to the release of arsenic to groundwater from native geologic materials. This year will focus on the role of microorganisms in arsenic release.

Informational Resources

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

Technical Support for Bear River System Data Acquisition

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

Partners/Collaborators:
None

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.

- **Benefits to State:**

  Specific benefits to the State of Utah of the modeling work ongoing at the UWRL 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. Beginning of a 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, 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 gather remotely sensed data which can then be processed for distribution to researchers in Mud Lake, north of Bear Lake. Field vegetation mapping was collected in 2009/ 10, with additional data collection planned for 2011 for ground-truthing of the remotely sensed data.

Results:

- Programmable intelligence to fly a pre-determined flight path.
- Acquisition and storage of high-resolution images in the visual and near-infrared spectral bands.

The remote sensed image processing capabilities include:

- Location of images with respect to ground coordinates.
- Transformation of the resulting images into GIS-compatible formats.

The fiber optic temperature measurements include:

- Spatial resolution of 1-2 cm.
- Temporal resolution of < 2 seconds.

Work Plan FY 10/FY11

- Investigate ground-truthing of remotely sensed data.
- Correlation of remotely sensed data with results from field campaigns.
- Integration of UAV-gathered data into sediment dynamic models in the Bear River Basin.
- Continued use of fiber optic temperature sensors in UT river basins to collect data for temperature model support.

Informational Resources

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

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

Temperature and Solute Model for the Virgin River

Principal Investigators:
Bethany T. Neilson

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

Project Description

- **Need and Purpose:**

  Water shortages and drought result in low stream flows that are commonplace in Utah. In Washington County, rapid population increase and the associated water requirements are the drivers for a number of water development projects (e.g., Sand Hollow Reservoir and the proposed Lake Powell pipeline). Although water quantity is usually the focus of efforts to cope with low flows, the effects on instream temperatures are also important because of endangered species that are unique to the Virgin River: the Virgin River Chub (Gila seminuda) and woundfin minnow (Plagopterus argentissimus). Under the Clean Water Act, states must establish water quality standards for temperature that meet the needs of sensitive species. Once these standards are set, states must understand when these limiting conditions occur, what caused the impairment, and which management options will remedy the impairment.

  In this project, a Two-Zone Temperature and Solute model is applied to the Virgin River for use as a management tool for the diverse stakeholders. Data representing specific processes have been collected to ensure appropriate representation of heat sources and sinks in the model. To assist in these efforts, further research has been conducted to determine data types that will provide for better model population and calibration in order to make more confident management decisions. This includes the use of pyranometers in the water column to quantify radiation behavior, remotely sensed thermal infrared and multispectral image data to assist in parameter estimation, dye tracer studies to test the conservativeness of Rhodamine WT, and the use of a variety of other data types for model calibration and corroboration.

- **Benefits to State:**

  Utah has a number of temperature impaired streams. The ability to quantify the importance of different heat fluxes and model a broad range of heat transfer processes within natural systems will guide management and decision making processes throughout the state. The benefit of these capabilities is already being utilized in the Jordan River Temperature TMDL.

- **Geographic Areas:**

  Study Area: Washington County

  Areas Benefited: Primarily Washington County, although the data collection and modeling capabilities can be implemented in any watershed in the state.

- **Accomplishments:**

  Findings:

  - The Two-Zone Temperature and Solute (TZTS) model has been successfully applied to the Virgin River during a number of time periods. It accurately reproduces mass balance and heat behavior in the main channel, dead zones, and even the subsurface conditions. These modeling results provide insight into thermal refugia that will lead to better river management for the endangered fishes.
  - The effects of turbidity on shortwave radiation reflection off the water surface and attenuation through the water column have been quantified for two different sediment types found in Washington County. The relationship for both reflection and attenuation is linear for certain ranges of turbidity. The results of this project provided information regarding the interaction between sediment and instream temperature management in the Virgin River.

  Results:

  - Three different applications of the TZTS model and real-time modeling capabilities in the Virgin River.
  - Estimates of thermal heterogeneity and its influence on thermal refugia for endangered species during low flows.
  - Information regarding the utility of thermal imagery in estimating model parameters.
  - Relationships to predict the amount of radiation penetrating the water column and how it behaves in the water column given a measure of instream turbidity.
  - Calculations and a report regarding the influence of turbidity on the fate of radiation in a water column

Work Plan FY 10/FY11

This project is complete.

Informational Resources

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

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

Principal Investigators:
William J. Doucette
Joe Stewart

Partners/Collaborators:
- ***Local**: Clint Rogers, Carollo Engineering and Michael Luers, Synderville Basin Water Reclamation District*

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 lead to an increased interest in their environmental distribution and bioavailability. PPCPs can enter the environment by passing untreated or partially treated through wastewater treatment plants (WWTPs) or septic systems, during the land application of WWTP biosolids containing PPCPs, or after the disposal of unused PPCPs in sanitary landfills. 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 examining the environmental fate of nonylphenol.

  One of the most important processes impacting the environmental transport and bioavailability of PPCPs is sorption to environmental solids such as soils, sediments, and biosolids. The rate and extent of sorption depends on the physical and chemical properties of both the solids and the specific PPCPs of interest. Most information on the sorption of organic contaminants and its impact on bioavailability have been generated for relatively hydrophobic non-ionizable industrial or agricultural organic chemicals. Much less is known about more polar PPCPs that can also exist in ionized forms at environmentally relevant pHs. Recently completed research at the UWRL indicates that polar organic compounds are more likely to be taken up by plants (Dettenmaier et al., 2009). A better understanding of the sorption behavior of these compounds is needed to adequately predict the environmental mobility and bioavailability of PPCPs for surface and ground water protection in the state of Utah and the nation. An improved understanding of the sorption process may also help evaluate the potential effectiveness of activated carbon as a water and wastewater treatment option.

- **Benefits to State:**

  Results from this study will contribute to our basic understanding of the sorption, mobility, and bioavailability of PPCPs and will help facilitate comprehensive modeling efforts for the protection of surface water and groundwater resources from wastewater and septic tank effluents. This project will have a direct and positive impact on citizens throughout the state of Utah because of the high level of septic tank use within the state and the increasing importance of maintaining high quality groundwater resources for our increasing state population. An improved understanding of the sorption and mobility of PPCPs 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: East Canyon Creek, including Morgan and Summit Counties.

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

- **Accomplishments**:

  Findings/Results: Preliminary plant uptake/ bioavailability studies were conducted using a pressure chamber method for the following five PPCPs previously identified in wastewater: sulfamethozazole (antibiotic), fluoxetine (antidepressant), carbamazepine (anticonvulsant), tris(2-chloroethyl) phosphate (flame retardant), and progesterone (steroid). Root zone and xylem concentrations of the compounds, determined using high performance liquid chromatography/ mass spectrometry (LC/ MS), were used to calculate transpiration stream concentration factors (TSCFs) as an expression of plant uptake. Values of TSCF as high as 0.8 for carbamazepine were obtained, suggesting that plant uptake of these compounds can be significant and should be further evaluated.

Work Plan FY 10/FY11

Development of methods for the extraction and analysis of the following PPCPs in water and environmental solids will continue: DEET, acetaminophen, gemfibrozil, estrone, and ibuprofen. Additional plant uptake and sorption studies will also be conducted for these compounds.

Informational Resources

Contact: Dr. 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

Weber Basin Decision Support System (DSS) Modernization

Principal Investigators:
David K. Stevens

Partners/Collaborators:
- ***Local:*** *Scott Paxman, Weber Basin Water Conservancy District*
- ***Federal:*** *Steve Noyes, USBR*
- ***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 State:**

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

  Significant progress has been made to:

  - Convert the model interface to Visual C#.Net 2005.
  - Modify the Weber Basin mass balance model and database to include new flows into Park City from above Rockport.

Results:

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

Work Plan FY 10/FY11

Finish conversion of model interface to Visual C#.net 2005 and integrate the hydrology model and the water quality model.

Informational Resources

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

Water Conveyance, Distribution, and Control

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

Project Name	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
Accuracy of In-Service Water Meters at Low and High Flow Rates	$18,377.52	$24,000.00	$0.00
Acoustic Canal Flow Measurement	$16,719.60	$0.00	$0.00
Dam Failure Life-loss Estimation	$10,033.39	$28,000.00	$0.00
Dam Safety Risk Analysis Computations	$10,033.38	$32,500.00	$5,000.00
Dam Safety Risk Management	$10,033.39	$27,000.00	$0.00
Determining Accuracy of Flow Measurements Below USBR Dams and State of Utah Dams	$32,313.81	$39,000.00	$0.00
Development of Flow Measurement Procedures for Pipe Installations with Non-Ideal Conditions	$12,866.21	$10,000.00	$2,000.00
The Effects of Pipe Aging on Headloss and Water Quality	$6,687.60	$6,888.23	$3,444.11
Engineering Analysis of Sprinkler Irrigation Systems for Agriculture and Landscapes	$2,989.52	$0.00	$0.00
Hydraulic Structures for Flood Control and Flood Bypass	$17,534.49	$29,000.00	$0.00
Labyrinth Weir Research	$73,912.11	$68,000.00	$0.00
Low-Level Outlet Air Vent Sizing for Small to Medium Sized Embankment Dams	$9,353.14	$9,633.73	$9,922.75
Metering of Secondary Irrigation Water Systems	$5,920.47	$0.00	$0.00
Open Channel and Closed Conduit Field Flow Measurement, Maintenance, and Upgrade for the State of Utah	$33,703.33	$34,714.43	$0.00
Open-Channel Unified Flume Calibrations	$43,712.05	$25,000.00	$0.00
Sediment Management for Small Reservoirs: Logan First Dam Study	$11,706.88	$12,000.00	$0.00
Sediment Transport and Flood Control	$17,534.50	$26,000.00	$0.00
The Transfer of Agricultural Water to Municipal and Industrial Uses	$5,635.00	$0.00	$0.00
Designated Projects		$156,792.00	$0.00
Undesignated Projects		$0.00	$50,000.00
Total	**$339,066.39**	**$528,528.39**	**$70,366.86**

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

Principal Investigators:
Steven L. Barfuss
Michael C. Johnson

Partners/Collaborators:

- ***State:*** *Fourteen utilities within the U.S. are formally participating on this project, including four from the State of Utah. They include: 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:*** *The primary funding agency is the Water Research Foundation*

Project Description

- **Need and Purpose:**

  This project is evaluating 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 is also investigating 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 are being accuracy-tested over the project period. In addition, both historical and current metering standards are being researched and documented.

- **Benefits to 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 compliance 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, and there were 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 FY 10/FY11

- Project testing was completed April 2010.
- Final report is due Oct 2010.
- Publish the project results.
  - Three journal papers have been written as follows:
    - 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.

Informational Resources

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

WRF Project Website:
http:/ / www.waterresearchfoundation.org/ research/ TopicsAndProjects/ projectSnapshot.aspx?pn=4028

Acoustic Canal Flow Measurement

Principal Investigators:
Todd Moon
Brent Carruth
Mac McKee

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Irrigation systems throughout the state of Utah, and indeed throughout the world, use open canals for irrigation. Water flow rate measurement in canals is a critical need for canal companies and their customers. Accurate measurement can ensure that shareholders receive their due share of water, and appropriately spaced measurement stations can provide valuable information on location and amount of water seepage along the canal that is vital to protecting resources, property, and life. In addition, measurement of water flow rate, or gaging, in rivers and streams is a similarly critical need in water resource management.

  Traditional methods for measuring water flow rate in small open channels include simple staff gages and costly weirs and flumes that channel the water through them. These methods have been used for centuries. Presently, for most canals, water masters measure the water level once a day with a staff gage at a very few points along the canal then determine the volumetric flow rate from empirical tables. More technologically advanced methods place velocimeters with rotors or acoustic doppler velocimeters with no moving components into the moving water itself to measure the flow rate. Such methods are comparably accurate, simpler to implement and less expensive than weirs and flumes; however, the instruments suffer adverse effects from the harsh environment and require frequent maintenance or replacement.

  Noncontact methods of water flow rate measurement have been investigated by scientists over the past decade. Progress has been made toward implementing acoustic and electromagnetic sensing methods to measure water flow rate, but more work is required. This research investigates the use of ultrasound for noncontact measurement of water flow rate in small open canal flows.

- **Benefits to State:**

  Open channel irrigation systems would benefit from an inexpensive noncontact water flow rate measurement method. Most canals in Utah are privately owned and operated and are cash poor. Some are over one hundred years old and need costly maintenance and improvements. A simple, inexpensive noncontact measurement device would greatly benefit these companies.

  A manufacturing industry to construct these devices would bring outside dollars into local communities with jobs in the manufacturing plant and into the state through taxes.

- **Geographic Areas:**

  Study Area: The investigative research occurs at Utah State University.

  Areas Benefited: Most counties in the state have open irrigation systems that would benefit.

- **Accomplishments:**

Findings: Noncontact water flow measurement with radar was first reported ten years ago by University of Washington and U.S.G.S. scientists. They found such measurements agreed closely with traditional measurements on the Skagit River in Washington State. The 183-m wide river at the Mount Vernon gaging station has enough surface turbulence to provide radar echoes to measure surface velocity. In contrast, the Cache County 5-m wide (or less) irrigation canals have relatively smooth surfaces that present a unique challenge to measuring surface velocity.

On the basis of observed rocket propellant surface acoustic waves, we hypothesize that water surface acoustic waves may also be observed in stationary and flowing water. This new approach uses the equipment shown in Figures 1, 2 and 3.

Figure. 1. Two 20KHz acoustic transducers inside flume with flowing water at the Hydraulics Lab, Utah State University.

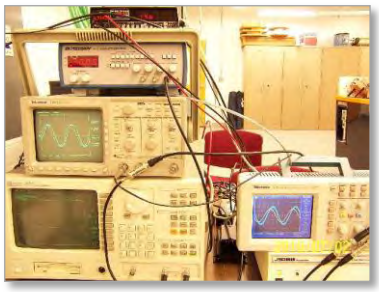


Figure. 2. 20KHz signal generator, oscilloscopes, spectrum analyzer, volt meter, and pulser.

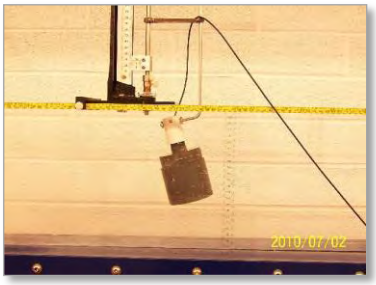


Figure. 3. Closeup view of 20KHz acoustic transducer mounted at 11 degree angle from vertical above the water surface.

The transducers operate as a transmitter and receiver pair. The transmitter launches a wave presumed to travel along the surface of the water that is detected by the receiver located 1m away. Conditions within the flume made the intended effect difficult to observe. This prompted the setup of a portable station operating on battery power as shown in Figure 4.
The equipment is sensitive enough that even a small amount of air motion is readily observed. The next step will be to position this equipment over a canal and perform measurements there.

Results: This phase of the research has made advances toward observing water surface acoustic waves, and work continues to complete the desired measurements.

Figure. 4. Demonstration of a battery operated station with transducers mounted on tripods and other instruments on cart.

Work Plan FY 10/FY11

- Acoustic phase shift measurements performed during the draining and filling of a canal will provide an opportunity to learn whether the proposed phenomena are observable with the present instruments.
- Future work is proposed to design and test a radiowave tomography system to measure the channel cross section of a canal.

Informational Resources

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Dam Failure Life-loss Estimation

Principal Investigators:
David S. Bowles

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

Project Description

- **Need and Purpose:**

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

- **Benefits to 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 and 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 comprises the following internal modules: 1) Loss of Shelter, including prediction of building performance; 2) Warning and Evacuation, including a dynamic transportation model component; and 3) Loss of Life, in which empirical fatality-rate probability distributions, developed by McClelland and Bowles (1999) in the first phase of this project, are 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 Plan FY 10/FY11

The proposed focus will be on developing guidance for the assignments of values to parameters in LIFESim and other guidelines for setting up LIFESim applications. In addition, cooperation with USACE and USBR and researchers in The Netherlands, Canada and the UK will be pursued.

Informational Resources

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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 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 and are being applied by federal dam safety agencies such as the US Army Corps of Engineers (USACE), the US Bureau of Reclamation, the Department of Homeland Security and the Federal Energy Regulatory Commission. 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 a 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.

Results: 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 applying DAMRAE to individual dams, it 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.

Work Plan FY 10/FY11

DAMRAE is undergoing continuous improvement of user interface features and computational and post-processing functions. Proposed improvements will focus on continuing the development database capabilities of DAMRAE to facilitate an expansion of functionality in the following ways:

- Continued increase in 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 increase in the computation rates.
- Link to a portfolio risk management system.
- Generalize the applicability to long dams, levees or canal embankments.
- Uncertainty analysis.
- 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 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 and 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, and justification of dam safety risk reduction measures.

- **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.

Work Plan FY 10/FY11

1. Portfolio Risk Assessment: Continue advances in portfolio risk assessment, including development of procedures for large portfolios in which screening is needed and for owners that have limited resources, such as those regulated by the states.

2. Tolerable Risk Evaluation: Further develop practical approaches to using information from tolerable risk evaluation for making dam safety decisions on individual dams and portfolios of dams. Topics include 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, dam safety regulatory impact analysis, and 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. 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.

4. Guidance on Dam Safety Risk Management: Technical advice is available through the Institute for Dam Safety Risk Management at USU.

5. Seminars and Workshops: Further develop and present briefings, seminars, and workshops to professional groups in the United States and overseas.

Informational Resources

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

Determining Accuracy of Flow Measurements Below USBR Dams and State of Utah Dams

Principal Investigators:
Steven L. Barfuss

Partners/Collaborators:
- ***State:*** *Matt Lindon, 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 manufacturer design 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 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: Ninety-eight flow measurement devices have been assessed as of July 27, 2010. These devices include seventy-three Parshall flumes, five ramp flumes, one cutthroat flume, four weirs, two rated sections, three sluice gates, five ultrasonic meters and five magnetic meters. Only twenty-eight percent of the tested devices measured flow within manufacturer design specifications. The remaining seventy-two 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 theoretical measurements that prevent water users from receiving their true water allocations.

Results:

- A list of all sites visited, their locations, measurement device type, 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 10/FY11

- Continue to locate flow measurement devices throughout the State of Utah.
- Visit flow measurement device sites and 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

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Examples of Flow Measurement Devices Tested in Utah.

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

Principal Investigators:
Steven L. Barfuss

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 for applications in which 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 indicated flow reading of the meter.

  An example of poor approach conditions 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 State:**

  The improved accuracy of flow measurements resulting from this study will ultimately improve the allocation of water rights, 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: The CFD software package, Fluent, is very capable of modeling fluid flow and mapping fluid velocity vectors and contours downstream of flow disturbing piping scenarios. As expected, the preliminary CFD models have been made to show that the velocity profiles are quite non-uniform within ten pipe diameters downstream of a 90-degree elbow.

  Results: Further refinement is necessary in order to correctly compare the CFD results with laboratory and field data. The final CFD model results will be used to determine the effects of the flow disturbances on ultrasonic flow meter accuracy. Once the inaccuracies are verified to be similar between the CFD models and actual laboratory measurements, procedures for flow measurement correction or modified ultrasonic flow meter installation can be developed.

Work Plan FY 10/FY11

- Conduct laboratory point velocity measurements in disturbed flow conditions in order to determine and map the fluid velocity profiles at various downstream locations within the non-uniform flow regions. The velocity profiles measured in the laboratory will be a sort of "fingerprint" for a given flow rate and piping scenario.
- 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.
- Refine CFD models using Fluent to better represent the actual non-ideal velocity profiles and flow conditions seen in the laboratory and in the field.
- Compare physical data to CFD results for the same piping configurations.
- 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 procedures for installation or flow measurement correction.

Informational Resources

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Devin M. Stoker, (435) 797 3231, Email: devin.stoker@aggiemail.usu.edu.

The Effects of Pipe Aging on Headloss and Water Quality

Principal Investigators:
Steven L. Barfuss

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Pipes are commonly used in a variety of engineering applications for the purpose of transporting fluids. For example, water distribution networks provide water for the majority of the people in Utah. In many cases, conditions within the pipes of distribution networks are favorable for corrosion and other types of degradation. Furthermore, many pipes currently in use in distribution networks, some installed in the 19th century, are significantly affected by age related degradation. The buildup that can form as pipes age significantly impacts the flow dynamics of degraded pipes.

  Widely-used models that describe distribution system flow have been applied to varied processes such as chlorine decay and distribution system hydraulics. The overall goal of this project is to better understand the changes that can take place in aged pipes in order to determine methods for minimizing the errors those changes introduce in network modeling. To this end, aged pipes have been gathered and tested in a laboratory setting. Further testing has consisted of application of the laboratory results to a pipe network along with the computational fluid dynamics modeling of two of the aged pipes.

- **Benefits to State:**

  The overall goal of the project is to further understand the ways that the degraded interiors of aged pipes affect the modeling of conditions within the pipes. Improving the accuracy of network models will allow distribution system managers to better meet the present and future needs of water users.

- **Geographic Areas:**

  Study Area: Aged pipe sections from Centerville City, Kaysville City, and the Weber Basin Water Conservancy District (along with pipes from a few cities outside of Utah) have been studied during the course of this project. The specific results from each aged pipe section have been provided to the applicable city.

  Areas Benefited: All cities use pipes for the conveyance of potable water, and the results of this testing have the potential to improve the accuracy of distribution network modeling. In particular, cities with a significant portion of aged pipe have the most to gain from this research.

- **Accomplishments**:

  Findings: Using the results from the laboratory and network testing, a method has been developed for correcting the diameters of aged pipes. Computational fluid dynamics (CFD) testing has also shown that Reynolds averaged Navier-Stokes (RANS) turbulence modeling and large eddy simulation are capable of providing highly descriptive flow data for small sections of aged pipes.

Results:

Specific to the network modeling:

- The method developed for correcting pipe diameters is convenient to apply.
- Not accounting for age related changes in pipe diameter was shown to result in errors of up to 10% in modeling the water age of a pipe with a Hazen-Williams C of 65.
- Because water age is an important factor in water quality, changes in pipe diameter are an important consideration in modeling water quality.

Specific to CFD:

- Though difficult to apply, CFD testing provides a wealth of flow information.
- The k-ε-v2-f model was found to give the best results of the turbulence models considered.
- Large eddy simulation is useful for resolving turbulence but does not give more accurate prediction of headloss than the RANS models.

Work Plan FY 10/FY11

- Project has been completed
- Publish the project results.
  - Three journal papers have been written as follows:
    - Improving Water Quality Modeling in Systems Containing Tuberculated Pipes, submitted to the Journal of American Water Works Association.
    - Application of Three RANS Turbulence Models to Aged Water Transmission Pipes, accepted for publication in the ASCE Journal of Hydraulics.
    - Application of Large Eddy Simulation to Aged Water Transmission Pipes, accepted for publication in the Journal of Engineering Applications of Computational Fluid Mechanics.

Informational Resources

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Engineering Analysis of Sprinkler Irrigation Systems for Agriculture and Landscapes

Principal Investigators:
Gary Merkley
Zhang Lin

Partners/Collaborators:
- ***Local:*** *Utah Agricultural Experiment Station*
- ***Foreign:*** *Northwest A&F University, Yang Ling, China*

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 is to improve the efficiency and uniformity of water delivery in drip and sprinkler irrigation systems design and operation. This requires hydraulic measurements and analysis of data for characterizing some components of irrigation systems and sprinklers. From this study, we will have better capability to advise farmers about irrigation operations and to provide higher-quality technical designs (and re-designs) of irrigation systems in Utah. We will also be able to do the same for irrigated lawns and landscapes, leading to improved water management in the state. We are testing only sprinklers that are commonly used in Utah for agriculture and for landscapes.

  The experimental design was completed in the autumn of 2009, and the equipment and facilities were set up at the Utah Water Research Lab in the winter and spring of 2010. Tests began in early May, 2010, and have been on-going from that time until mid-August.

- **Benefits to 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 will be able to 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 will also be able to provide the same for some sprinklers that are used to water lawns and landscapes in Utah.

- **Geographic Areas:**

  Study Area: Logan, 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: Most of the data have already been collected during the spring and summer of 2010. A great deal of data exists because flow rate, pressure, air temperature, and relative humidity samples were collected every 5 seconds during each of over 100 tests, in addition to uniformity data. Analysis of the data is ongoing.

Results: Most of the tested sprinklers provide approximately the same application uniformity over a range of pressures within their recommended operating range, but the uniformity drops quickly when the pressure is outside that range. This is important because it allows us to answer the question: "What are the water management consequences if my sprinkler pressure is too low or too high?" Previously, there were no specific answers to this question.

Testing a Rainbird sprinkler at theUtah Water Research Laboratory.

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

Work Plan FY 10/FY11

- Over 100 one-hour tests have been conducted, and the data are now being analyzed. Additional tests will still be conducted to fill in some gaps in the data and to verify some data that seem questionable.
- A computer program will be developed to apply the data to analysis and design applications so that practical results can be produced for farmers and other sprinkler irrigators.
- This project will be completed in April 2011.

Informational Resources

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

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

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 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 costs and design parameters associated with the rehabilitation. Utah will be better suited 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 included the use of stair stepped spillways, auxiliary spillways, submerged tainter or radial gates, side channel ogee crests, and control structures in high velocity approach channels. All of these concepts offer alternative solutions for flood control in Utah that will be more economical and sustainable and will have less environmental impact than the currently used types of spillways. Current studies utilize auxiliary spillways to increase the capacity of flood control structures. A number of possible applications of these types of auxiliary spillways could be used in Utah.

Results: Work was completed and information prepared on:

- Eliminating Vortices at the Proposed Folsom Dam Auxiliary Spillway.
- Physical Modeling to Evaluate Spillway Performance for the Modern-Day PMF.
- 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 FY 10/FY11

- 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-fit of dams for drought control and storage; rehabilitation and retro-fit 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.

Labyrinth Weir Research

Principal Investigators:
Blake P. Tullis

Partners/Collaborators:
- ***Local:*** *Everett Taylor, DNR-Water Rights*

Project Description

- **Need and Purpose:**

  Due to revisions in probable maximum flood flows and a greater emphasis on dam safety, many spillways will require rehabilitation or replacement. Labyrinth weirs are often a favorable design option because they 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. Furthermore, current information and data available for labyrinth weir design and evaluation are incomplete.

  The study objectives include: 1) improving the design and analyses of labyrinth weir spillways by consolidating available data sets and information, 2) assimilating and expanding current design methodologies, and 3) 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 are a modified version of traditional labyrinth weirs designed specifically to increase discharge capacity of spillways with a limited footprint atop narrow concrete gravity dams. The PK weir footprint constitutes a rectangular labyrinth shape but with the wall cantilever in the up and/ or downstream directions, increasing the weir crest length. Because a literature review revealed very little published information regarding PK weirs, an experimental study was conducted to evaluate various PK weir design options.

  An oblique weir, which is essentially half of a triangular labyrinth weir cycle, can be installed in canals as flow measurement or flow diversion structures. Traditional linear weirs are installed normal to the flow direction. Oblique weirs are installed at some angle, other than 90 degrees, from the channel centerline. Smaller angles result in longer weir lengths and higher discharge capacity for a given upstream flow depth, which makes them ideal for canals with limited free board upstream of the flow control structure.

- **Benefits to State:**

  The results of this labyrinth weir study may increase the sustainability of existing dams with undersized spillways. Labyrinth weirs are a commonly used alternative over linear weirs for increasing spillway capacity without increasing the width of the spillway apron. Insufficient data are currently available for the range of labyrinth weir design alternatives.

- **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, three separate experimental studies were carried out in FY10, including a labyrinth weir study, a piano key weir study, and an oblique weir study. The

results are still being analyzed and will be included in a PhD dissertation, two MS theses, and several peer-reviewed journal articles on these topics.

Findings/Results: More than 25 different laboratory-scale physical models of various labyrinth, PK and oblique weir geometries (sidewall angle and crest shape) were evaluated for discharge coefficients, nappe stability and aeration characteristics, and local submergence effects. Weirs were tested for both channel and reservoir applications. The study also included rectangular labyrinth weir testing with a crest length and layout consistent with the PK weir for comparison. Another objective of the study was to determine if labyrinth weir data could be used to estimate oblique weir performance.

Work Plan FY 10/FY11

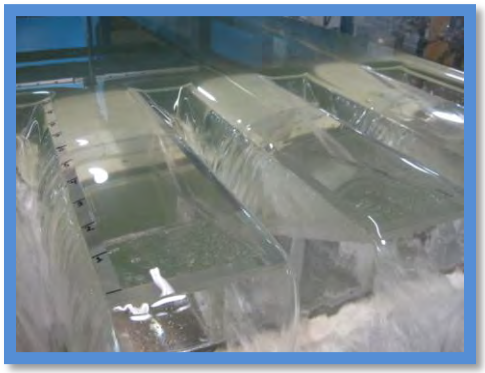
Additional laboratory work will focus on size-scale related issues associated with labyrinth weirs. A series of geometrically similar labyrinth weirs, of varying size scales, and some non-geometrically similar labyrinth weirs will be tested to evaluate the influence of the model size on the hydraulic performance. The ultimate question will be whether it is appropriate to apply lab-scale design data to prototype structures. Additional work will also include more reservoir labyrinth weir testing; the influence of abutment wall geometry on weir discharge capacity will represent a key component. A labyrinth weir design/ analysis spreadsheet program will be developed and made available on the UWRL website in an effort to move this research into practice.

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.

Labyrinth Weir Study (UWRL).



Piano Key Weir Study (UWRL).

Oblique Weir Study (UWRL).

Low-Level Outlet Air Vent Sizing for Small to Medium Sized Embankment Dams

Principal Investigators:
Blake P. Tullis
Jason Larchar

Partners/Collaborators:
- ***Local:*** *Everett Taylor, DNR-Water Rights*

Project Description

- **Need and Purpose:**

  State regulators who approve dam designs often have little or no information regarding requirements for sizing air vents for low-level outlet works. Some work has been done by the US Army Corps of Engineers (USACE) in conjunction with air vent sizing for vertical slide gates in outlet tunnels. Limited amounts of field data were used to validate the model. The gate/ intake geometries for small to medium sized dam low-level outlet works typically do not feature a vertical slide gate but rather have slide gates mounted on the sloping upstream face of an earth fill dam, followed by a mitered elbow transition.

  The USACE method uses water flow rate through the gate as an independent variable. No information, such as discharge coefficient data (with or without air venting), has been found related to inclined slide gates. Consequently, water flow rates through such control structures cannot be determined conveniently. In an effort to develop a better understanding of air demand in low-level outlet works and verify the accuracy of the USACE and provide improvements where possible, this study will include a laboratory testing, a CDF modeling, and a field data collection effort. The results of this study should be beneficial to all parties involved in dam safety (designers, regulators, and owners).

- **Benefits to State:**

  Using the results of this study, the Utah Office of Dam Safety (DNR-Water Rights) will be able to specify air vent sizes associated with new dam construction and dam improvement projects. Adequate air vent capacity is critical to the safety and longevity of the low-level outlet, which facilitates reservoir releases once the reservoir level falls below the spillway elevation.

- **Geographic Areas:**

  Study Area: State wide

  Areas Benefited: Reservoir use is common throughout the State (e.g., municipal and industrial, irrigation, and hydropower uses) so all counties in the state would potentially benefit.

- **Accomplishments**:

  Findings/Results: An air vent sizing algorithm was developed using the data obtained in this study to allow designers/ regulators to determine the appropriate air vent size for small to medium sized embankment dams, featuring either a round or rectangular control gate installed on the upstream face of the dam. This work was presented at the Association of State Dam Safety Officials (ASDSO) 2009 conference and a paper published in the conference proceedings. In 2010, two additional

manuscripts related to this study were submitted to peer-reviewed journals [Journal of Irrigation and Drainage (ASCE) and Journal of Dam Safety]. The manuscripts are currently under review

Work Plan FY 10/FY11

Additional funding is anticipated through DNR-Water Rights to collect air vent flow rate data on various dams around the State during the 2011 irrigation season in an effort to verify the laboratory results.

Informational Resources

Contact: Dr. Blake Tullis, 435-797-3194, E-mail: blake.tullis@usu.edu.
Website: http://www.neng.usu.edu/uwrl/www/faculty/btullis.html.

Slide gate (Uinta Mountains, UT).

Air vent intake & gate control (Woodruff, UT).

Lab-scale low-level outlet model.

Metering of Secondary Irrigation Water Systems

Principal Investigators:
Michael C. Johnson
Steven L. Barfuss
Gregory L. Richards

Partners/Collaborators:

- ***State**: Todd Adams, Water Resources, Eric Klotz, Water Resources*

Project Description

- **Need and Purpose:**

  Many cities and suppliers of water in the State of Utah are using secondary water for irrigation purposes. Secondary water contains debris that has made it impractical in the past to meter its use. Because many secondary systems do not provide for metering, users often waste water by using more than is needed. In order to provide user accountability, secondary providers need to accurately account for water use and bill accordingly. The purpose of this study is to identify possible technologies to accurately meter secondary water.

- **Benefits to State:**

  The results of this project will enable water suppliers in the State of Utah to understand the various technologies available to them to meter secondary water. High quality potable water is best used for indoor purposes, while secondary water is well suited for irrigation. If feasible means are available for secondary water providers to monitor and bill for irrigation use, more potable water is made available for cities to grow and serve more residents without the need to develop more sources or increase treatment costs on existing sources to meet the demand.

- **Geographic Areas:**

  Study Area: Weber Basin, Spanish Fork, Grantsville, Draper.

  Areas Benefited: The project information is applicable to any irrigated residential and commercial area in the State of Utah. The technology is applicable to all areas in the world that use secondary irrigation and need to measure its use.

- **Accomplishments:**

  Findings: Several means for metering secondary irrigation water are available, including centralized filtration, local filtration, and some newly emerging metering technologies. The recommended technology to be implemented is system dependent.

  Results: Two papers have been published in the Journal AWWA, which is a peer reviewed journal that benefits water users in the State of Utah as well as water users across the world.

Work Plan FY 10/FY11

The project was completed October 31, 2009.

Informational Resources

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

Richards, G.L., Johnson, M.C., and Barfuss, S.L. (2009). Revenue Losses Due to Water Meter Inaccuracies at Ultra-Low Flows. Accepted for publication in *Journal AWWA*.

Richards, G.L., Johnson, M.C., and Barfuss, S.L. (2009). Metering Residential Irrigation Water: Technological Approaches and Cost Estimation. *Journal AWWA*, 101(6):52-63.

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

Principal Investigators:
Steven L. Barfuss

Partners/Collaborators:
- ***State:*** *Matt Lindon, Utah DWR*

Gertrudys Adkins, Utah DWR Business/Industry

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 manufacturer design 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 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: Ninety-eight flow measurement devices have been assessed as of July 27, 2010. These devices include seventy-three Parshall flumes, five ramp flumes, one cutthroat flume, four weirs, two rated sections, three sluice gates, five ultrasonic meters and five magnetic meters. Only twenty-eight percent of the tested devices measured flow within manufacturer design specifications. The remaining seventy-two 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 theoretical measurements that prevent water users from receiving their true water allocations.

Results:

- A list of all visited sites, 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 10/FY11

- Continue to locate flow measurement devices throughout the State of Utah.
- Visit flow measurement device sites and 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

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Devan J. Shields, (435) 797 3231, E-mail: dev.j.shields@aggiemail.usu.edu.

Examples of Flow Measurement Devices Tested in Utah.

Open-Channel Unified Flume Calibrations

Principal Investigators:
Gary Merkley
Sathaporn Temeepattanapongsa

Partners/Collaborators:

- ***Local:*** *Several canal companies, and the Utah Water Research Laboratory*

Project Description

- **Need and Purpose:**

  Over the long term, water shortages and water quality issues in Utah will continue to increase and 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 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: The work began in June 2010, but the model is already set up for all different standard flume sizes, and simulations have begun.

Results: The preliminary results show good agreement with the experimental data that was previously taken. More results are coming soon.

Work Plan FY 10/FY11

- Three-dimensional mathematical modeling of various Cutthroat flume sizes has begun and will continue for the next several months. Data analysis will occur in tandem with the modeling to ensure correct results. This analysis will include comparisons with existing laboratory measurements.
- After sufficient data are generated for the first standard flume size, a software package will be used to generate a unified free- and submerged-flow calibration.
- This project will be completed in June 2012.

Informational Resources

Contact: Dr. Gary P. Merkley, Phone (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, Stan Kane, and 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 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, so the potential benefit is statewide.

- **Accomplishments**:

  Findings: Several things have been learned 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, periodically examine available river flow forecasts to better anticipate future flow conditions and regulate hydraulic operations at the dam.
- Monitor outflows from the hydraulic structures on the dam 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.

Work Plan FY 10/FY11

Researchers at the UWRL will assist the operators of First Dam in conducting a sluicing event during spring runoff in 2011 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.

Sediment Transport and Flood Control

Principal Investigators:
William J. Rahmeyer

Partners/Collaborators:
- ***Local:*** *Salt Lake and Davis counties*
- ***Federal:*** *U.S. Army Corps of Engineers*

Project Description

- **Need and Purpose:**

  Utah streams and rivers formed under unique geologic and climatic conditions. Understanding sedimentation and erosion processes is important. How is sediment produced in our watersheds? How is it transported in the streams and rivers? What is the balance between erosion and deposition in our floodplains? The sedimentation process affects most man-made activities including agriculture, urbanization, reclamation, and mining. Short-term and long-term changes in climate and precipitation interact with the sedimentation process to cause flooding and debris flow problems in Utah. The effect of the sedimentation process on flooding and flood routing in floodplains is of major interest to the State of Utah and other Western States.

  Knowledge of sediment transport has been developed for climates and geology different from those in Utah. Our research objectives are as follows: 1) continue developing prediction methods and models of sedimentation and scour, 2) conduct basic and applied research to solve specific sediment problems that affect Utah, and 3) work with local and state agencies to provide education and support in the area of sedimentation.

- **Benefits to State:**

  Direct benefits to the State of Utah will flow from the knowledge and methodology gained from Utah specific research in sedimentation and erosion. Almost all areas of agriculture, mining, forestry, reclamation, and transportation should benefit directly from this research. The Division of Oil, Gas, and Mining; Division of Water Quality; Division of Water Resources; Utah Department of Transportation; and water conservancy districts will be informed of project results. A better understanding of this research and how it applies to Utah may positively impact federal guidelines and the requirements for sedimentation and erosion control in Utah.

- **Geographic Areas:**

  Study Area: All counties and cities in Utah.

  Areas Benefited: All counties and cities in Utah.

- **Accomplishments:**

  Findings:

  - An understanding of the fundamental hydraulics of sedimentation and erosion for the semi-arid regions of Utah.
  - The methods and equations for transporting sediment through culverts in the semi-arid regions of Utah.
  - The effect of wave oscillation from bridge columns on channel bank erosion.

Results:

- The first of a kind circular water tunnel for studying sediment transport in a culvert was developed and fabricated. The tunnel included a 20-foot length of 12-inch diameter clear PVC pipe. Incipient motion, flow resistance, and sediment transport have been studied for several gravel and sand sizes. The formation and classification of bed forms in culverts has also been conducted.
- Completed work on sediment transport impacts upon culvert hydraulics including the reduction of culvert capacity due to the sediment transport.
- Presentation of findings on the impact of culvert sedimentation on floodplains to Utah floodplain and storm water management professionals.

Work Plan FY 10/FY11

- Study the fundamental hydraulics of sedimentation and erosion.
- Develop equations and methodologies to predict the sediment transport in steep mountain streams and closed conduits.
- Develop sediment transport equations and methods for UDOT.
- Study and develop methodology for the transport of sediment through culverts.
- Study and develop methodology for the flow resistance of sediment through culverts.
- Study and develop methodology for the incipient motion of sediment through culverts.
- Gain an understanding of the effect of vegetation on the sediment transport in floodplains.
- Continue research and publish journal articles on flood plain resistance and the effect of vegetation on flow resistance.
- Study the effect of the sedimentation process on erosion and deposition at culverts and road crossings.

Informational Resources

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

The Transfer of Agricultural Water to Municipal and Industrial Uses

Principal Investigators:
Michael C. Johnson, Ph.D
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 State:**

  The results of this study will provide information regarding the accuracy of the existing water rights recording system. The study will also identify water rights that are inaccurate or that do not have up-to-date information. Having a comprehensive set of records on the use and status of each water right will be of significant value to the State of Utah. More information on actual water right status leads to better informed decisions in terms of water allocation and management.

- **Geographic Areas:**

  Study Area: Major cities across the State of Utah.

  Areas Benefited: Same major cities.

- **Accomplishments:**

  Findings:

  - A survey was sent to 80 major cities in Utah to identify municipal behavior associated with obtaining and using water rights in the city. 36 of 80 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.
  - Additionally, each of these 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.
- 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.

Further results will be available in the completed report once a final draft has been submitted.

Work Plan FY 10/FY11

- Submit final draft to State of Utah, Department of Water Resources for approval.
- Submit report as a completed thesis to committee at Utah State University for review and defense.

Informational Resources

Contact: Dr. Michael 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	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
Agricultural Water Resources Management Training	$17,134.01	$0.00	$0.00
Development and Maintenance of the Bear River Watershed Information System	$4,707.93	$4,849.17	$4,994.64
High Speed River Dynamics Modeling Using Graphics Processor	$47,559.98	$9,178.29	$2,000.00
Information Transfer in Support of the Utah Center for Water Resources Research (UCWRR)	$21,902.92	$0.00	$0.00
Instrumentation to Support a Center for Hydrologic Information Systems	$97,857.77	$0.00	$0.00
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$1,000.00	$1,030.00	$0.00
Real Time Monitoring Internet Portal for the UWRL	$10,680.31	$0.00	$0.00
Salt Lake Valley Solid Waste Management Council	$2,491.42	$2,566.16	$0.00
State of Utah Solid Waste Control Board	$2,491.41	$2,566.15	$2,643.14
Support for State Watershed Modeling and TMDL Plans	$30,552.87	$31,469.46	$0.00
Utah On-Site Wastewater Treatment Training Program	$14,799.89	$15,243.89	$2,500.00
Designated Projects		$47,729.00	$0.00
Undesignated Projects		$0.00	$18,000.00
Total	**$251,178.51**	**$114,632.12**	**$30,137.78**

Agricultural Water Resources Management Training

Principal Investigators:
Gary Merkley
Mohammed Shaban

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  As in many places in the USA and around the world, Utah has experienced water shortages that, in the long term, tend to become increasingly problematic. Water quality problems are also becoming more prominent with time. Much of the emphasis in dealing with water scarcity and quality problems has been directed toward infrastructure and technological improvements. Very 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 irrigators and the difficult operational decisions they face with respect to water management. In fact, many of the problems related to water delivery (canal and or pipeline) design and operation for agricultural irrigation are due to a lack of understanding of agricultural irrigation by policy makers, administrators, and operational personnel.

  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 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 statewide, so all counties in the state would potentially benefit.

- **Accomplishments:**

  Findings/Results: The study has not yet been completed and there are no findings/ results to date. However, one conference presentation has already been given on the program design, and the poster was awarded the first prize. Another conference paper has been accepted and will be presented at the USCID meeting in September 2010.

Work Plan FY 10/FY11

This project will be completed in December 2011. The modeling work will continue as the initial design is modified and developed in greater detail. After an operational version of the model is completed, it will be tested in a workshop with various potential members of the target audiences. Using feedback from workshops, the model will be further modified and expanded.

Informational Resources

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

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

Development and Maintenance of the Bear River Watershed Information System

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

Partners/Collaborators:

- ***Local:*** *Jim Bowcutt, USU Extension*
- ***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 this project is continuing to support the partnerships and collaborations that have resulted in the current WIS.

- **Benefits to 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 FY 10/FY11

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.

Informational Resources

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

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

The Bear River Watershed Information System.

High Speed River Dynamics Modeling Using Graphics Processor

Principal Investigators:
Dr. Koushik Chakraborty (Electrical and Computer Engineering)
Yiding Han (student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  High bandwidth computation is an essential requirement in modeling river dynamics. Typical fluid dynamics modeling involves extensive numerical computation to solve Partial Differential Equations (PDE) from the Navier-Stokes model. Utah Water Research Laboratory uses this approach to model the Logan River using very large 2D meshes that span the river length. Currently, a desktop machine based on a general purpose microprocessor (also known as CPU) is used for the numerical computation. Unfortunately, the computation bandwidth of the CPU greatly limits the level of details that can be modeled.

  In this proposal, we seek to implement the river dynamics model in a high-end graphics processor (GPU) based machine to gain substantial performance improvement over the CPU based solution.

- **Benefits to State:**

  A substantial increase in the speed of the model will lead to several benefits. It will allow for more detailed modeling techniques that can investigate several other interesting properties of aquatic life in the Logan River. In the future, the model can be extended to three dimensions (3D).

- **Geographic Areas:**

  Study Area: Logan, Cache County, Utah.

  Areas Benefited: All possible river systems with aquatic life, both within the state and nationwide.

- **Accomplishments**:

  Findings: The starting point for this investigation is the river dynamics modeling software developed at the US Geological Survey. The software is used extensively at the Utah Water Research Laboratory. The software was re-written for parallel processing and also porting to the GPU model execution.

  Long data chains of dependent operations required a CPU implementation, and the GPU was used to execute the code that could be parallelized. Several optimizations were used to further improve the performance, such as coalesced memory access in the GPU to fully exploit its memory bandwidth page-pinned host memory to reduce the GPU-CPU traffic.

  Results: Two benchmark programs given by the USGS were tested for implementation: [i] Evola and [ii] Mar07trans, as well as two different machine setups: (a) High-end GPU machine consisting of a Tesla (C1060) GPU card from NVIDIA. This machine also has a very fast CPU (server class Nehalem processor); (b) Low-end GPU machine consisting of G92 graphics card from NVIDIA. The table

below compares the execution time of the GPU implementation with the original code running on a CPU.

Benchmark	GPU (s)	CPU (s)	Speedup
Evola (G92)	10.9553	36.80441	3.36X
Evola (Tesla)	8.9906	27.02389	3.01X
Mar07trans(G92)	40.8128	110.5842	2.71X
Mar07trans(Tesla)	29.2046	86.34587	2.96X

The high-end machine achieves the lowest execution time, and overall a 3X speedup was observed.

Work Plan FY 10/FY11

Develop and incorporate three-dimensional modeling, as well as appropriate models for biological systems.

Informational Resources

Contact: Koushik Chakraborty, (435) 797-2840, E-mail: koushik.chakraborty@usu.edu.

Information Transfer in Support of the Utah Center for Water Resources Research (UCWRR)

Principal Investigators:
Mac McKee
R. Ivonne Harris

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  The Water Resources Research Act of 1964 established the Utah Center for Water Resources Research (UCWRR). The Center is housed at Utah State University in Logan, Utah. The general purposes of the UCWRR are to foster interdepartmental research and educational programs in water resources; administer the State Water Research Institute Program funded through the U.S. Geological Survey at Utah State University for the State of Utah; and provide university-wide coordination of water resources research.

  The center plays a vital role in the dissemination of information. Utah is home to approximately 50,000 miles of rivers and streams and 7,800 lakes. This water is an essential resource for the economic, social, and cultural well being of the State of Utah. As one of 54 water research centers, the UCWRR works to "make sure that tomorrow has enough clean water."

  A major component of the information transfer and outreach requirements of the UCWRR is the development of appropriate vehicles for dissemination of information produced by research projects conducted at the Center. This project provides on-going updates of the UCWRR web page, with information transfer specifically identified as the key objective. A recent project objective has been the dissemination of semi-annual newsletters for the Utah Center that feature research projects and their findings, water-related activities in the state, and on-going work by researchers affiliated with the Center.

- **Benefits to State:**

  A vital objective in the dissemination of information for the UCWRR has been the development of an up-to-date web page. The UCWRR web pages were developed to make information available and provide a tool wherein interested parties can find solutions to water problems.

- **Geographic Areas:**

  Study Area: State of Utah

  Areas Benefited: All areas of the state of Utah and others

- **Accomplishments**:

  Findings/Results: Web pages have been developed for the Utah Center for Water Resources Research. The pages can be found at <http://uwrl.usu.edu/partnerships/ucwrr/>. "The Water bLog" page contains links to electronic copies of current and past issues of the UCWRR Newsletter. The "Water blog" is disseminated electronically via email and the UCWRR website. The newsletter is sent to approximately 350 readers through e-mail. The main purpose of the newsletter is to highlight research projects and their findings. These will be of great interest and value to the State of Utah, as

well as the national and international community. Figure 3 shows the first page of the "Water blog." An electronic copy can be viewed at <http:/ / uwrl.usu.edu/ partnerships/ ucwrr/ newsletter/ >

Work Plan FY 10/FY11

The web pages for the UCWRR are a work in progress and will be updated periodically. "The Water bLog" Newsletter is published twice a year.

Informational Resources

Contact: Ivonne Harris, 435-797-3693, E-mail: ivonne.harris@usu.edu.

Websites: http:/ / uwrl.usu.edu/ partnerships/ ucwrr/
http:/ / uwrl.usu.edu/ partnerships/ ucwrr/ newsletter/

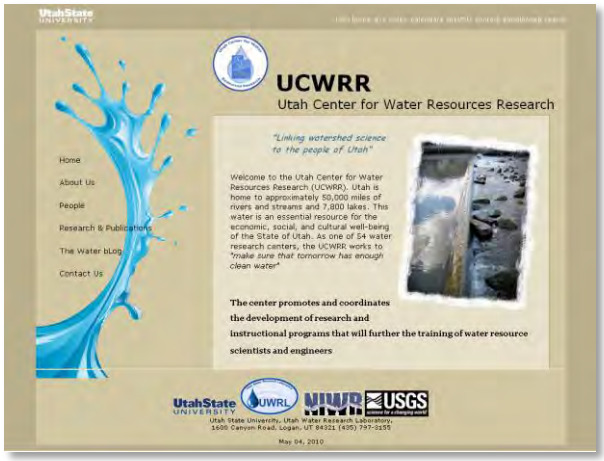


Figure 1. Home page of the UCWRR.

Figure 2. Research and Publications Page.

Figure 3. UCWRR Online Newsletter, The Water bLog.

Instrumentation to Support a Center for Hydrologic Information Systems

Principal Investigators:
Jeffrey Horsburgh

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Cyberinfrastructure is a new term that is being used for the computer hardware, software, and environmental sensor systems that are being developed to support data intensive science. With the huge growth of data collection over the past 10 years, particularly associated with high-frequency data streams and high resolution spatial datasets, new computer infrastructure is needed to enable scientists and water resource managers to handle the ever growing volume of environmental data that are becoming available. This project establishes a state-of-the art research platform for developing cyberinfrastructure to support data-intensive synthetic research in the area of hydrology and water resources. This new infrastructure has incredible potential for enabling new studies into watershed processes. The new process knowledge gained may enable new breakthroughs in water management strategies. Additionally, the data management techniques and software tools that are being developed using this new infrastructure will be made generally available.

- **Benefits to State:**

  The establishment of a state-of-the-art cyberinfrastructure research platform at the UWRL will have the following benefits to the state:

  1. Demonstrate how high-volume, continuous datasets from environmental sensors can be managed using robust software and database tools that are generally available (applicable to state environmental data managers).
  2. Demonstrate the value of high frequency, continuous datasets in hydrology and water resources management. Example applications include total maximum daily load (TMDL) water quality studies and canal/ irrigation diversion management (applicable to state water quality and water resource managers).
  3. Develop general methods for anomaly detection within continuous data streams, diagnose environmental sensor malfunctions, and design algorithms for remediating these problems with continuous data collection.
  4. Continue to host and develop watershed and hydrologic information systems in collaboration with state agencies, including the Bear River Watershed Information System (http://www.bearriverinfo.org) and the Great Salt Lake Information System (http://www.greatsaltlakeinfo.org).

- **Geographic Areas:**

  Study Area: All counties of the state of Utah, and data intensive science nationwide.

  Areas Benefited: All counties of the state of Utah, and data intensive science nationwide.

- **Accomplishments**:

  Findings: A new era of science is emerging in which new datasets with high spatial and temporal resolution are being collected to enable studies generating new hydrologic and watershed process understanding. In many cases, scientists are combining existing datasets in new ways using cyberinfrastructure to generate new knowledge. The research platform established by this project is being used to develop new cyberinfrastructure that supports synthetic research using new and existing datasets.

  Results: This project has advanced or established the following capabilities:

  - A high-frequency, continuous monitoring research platform within the Little Bear River of Cache Valley. Continuous monitoring sites include stream hydrology and water quality as well as weather stations with soil moisture monitoring.
  - A robotic discrete analyzer for processing large volumes of water quality samples to support ongoing sampling and data collection efforts within the state of Utah.
  - A robust set of computer servers comprising an advanced data center with high capacity Internet capabilities for development of new cyberinfrastructure.

Work Plan FY 10/FY11

This project has established the instrumentation capabilities described above. Although not directly supported by continuing funds from this project, it is anticipated that a variety of ongoing UWRL research projects focused within the state of Utah will be supported by the infrastructure that has been established.

Informational Resources

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

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

Principal Investigators:
Laurie 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 State:**

  This committee provides three scholarships to students who will benefit the field of water quality, supply, and treatment in the Intermountain West (Utah and southern Idaho). These three scholarships include: undergraduate ($1,000), graduate ($1,500), 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 at Utah State University during the Fall 2009 semester.

Work Plan FY 10/FY11

Participation in IMS-AWWA meetings and activities will continue. Three scholarships will again be awarded in Fall Semester 2010. 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 McNeill, (435) 797-1522, E-mail: Laurie.McNeill@usu.edu.

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

Real Time Monitoring Internet Portal for the UWRL

Principal Investigators:
Jeffrey Horsburgh
Chris Chapman (student)
Ben Morris (student)
Amber Spackman (student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  There is a growing trend within hydrology, water quality research, and water management for collecting continuous, real-time streamflow, water quality, and climate data. Efforts at the UWRL alone include streamflow, water quality, soil moisture, and climate monitoring in the Little Bear River and other tributaries to Cutler Reservoir; turbidity, discharge, water temperature and climate variables at the Bear Lake National Wildlife refuge; streamflow and water quality monitoring in the Logan River; streamflow and water quality monitoring in the Virgin River; and continuous temperature and streamflow data collection in Curtis Creek. The continuous data collection efforts generate large volumes of data that present challenges for data management, visualization, analysis, and publication. This project has created an Internet-based portal for real time monitoring data being collected by individuals or groups at the UWRL as a demonstration of innovative technologies for management of continuous, real time data streams from environmental sensors. The portal integrates these efforts and provides access to the data to users over the Internet. All functionality is server based, and the only client software needed by users is a web browser.

- **Benefits to State:**

  Numerous projects ongoing at the UWRL or at USU collect real time or continuous data. Due to the volume of data generated by real time monitoring, computer infrastructure is needed to support real time data collection. This project has developed tools and technologies that can be used to support management of continuous and real time data collection. River systems within the State of Utah that are already benefiting from this work include the Virgin River, the Little Bear River, the Bear River, Curtis Creek, the Cub River, and the Logan River. These data can be useful for individuals, classes, researchers, and managers who analyze and operate these water systems. Part of this project has developed techniques and technologies that can be used to support watershed and hydrologic information systems. This project benefits the State of Utah not only by making these data available, but also by contributing technologies that are supporting watershed information systems for rivers within the state, including the Bear River Watershed Information System (http://www.bearrriverinfo.org) and the Great Salt Lake Information System (http://www.greatsaltlakeinfo.org) currently under development at the UWRL.

- **Geographic Areas:**

  Study Area: Generalized tools have been developed that could be applied to data collection efforts within all counties of the state of Utah

  Areas Benefited: Specifically, the tools advanced by this project have benefitted data collection efforts throughout the state, including ongoing efforts within the Logan River, Bear River, Little Bear

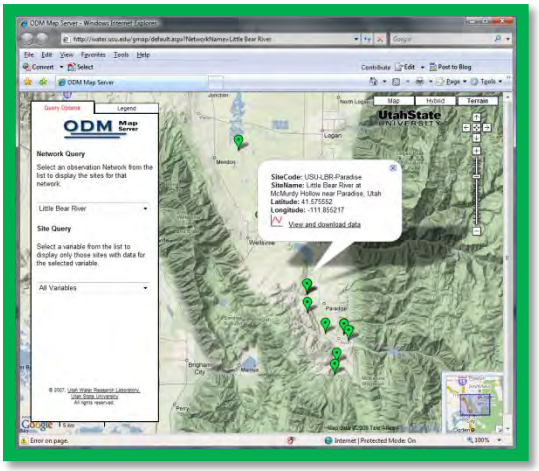
River, Curtis Creek, T.W. Daniels Experimental Forest, and soil moisture monitoring efforts near Delta.

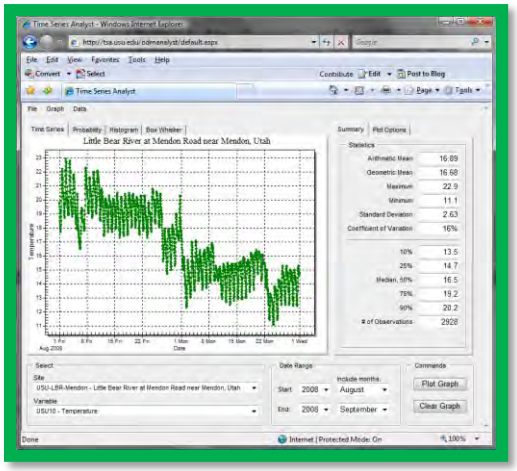
- **Accomplishments**:

  Findings: Continuous and real time datasets are incredibly useful for studying environmental processes, understanding the way watersheds function, and informing water management decisions. Collection and management of these datasets, however, are difficult, and there are relatively few freely available software tools for doing this. On this project, we have advanced the development of a set of software tools for managing, visualizing, analyzing, and publishing continuous water quality related datasets.

  Results: The software tools that have been advanced as part of this project include:

  - A relational data model for storing environmental observations data.
  - Tools for automatically loading streaming data from environmental sensors.
  - A set of Internet applications for publishing and providing access to real time, continuous and streaming datasets, including:
    - A map server application based in Google Maps.
    - A Time Series Analyst application for data visualization and analysis.
    - Web services for publishing the data on the internet.





Examples of systems that are using the tools supported by this project include http://littlebearriver.usu.edu, http://mudlake.usu.edu, http://icewater.usu.edu, http://www.bearriverinfo.org, http://www.greatsaltlakeinfo.org.

Work Plan FY 10/FY11

This project is complete.

Informational Resources

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

Salt Lake Valley Solid Waste Management Council

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***Local:*** *Linda Hamilton, Salt Lake County Public Works; Rick Graham, Salt Lake City Public Works; Brian Bennion, Salt Lake County Health Department; Russ Willardson, Council of Governments, 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 solid waste. The landfill facility operates a citizen's unloading facility, provides recycling of 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 funds. 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 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 investigating the impact of mandating green waste recycling on a County-wide basis on the SLVSWMF's carbon and energy footprint.

- **Geographic Areas:**

  Study Area: Salt Lake City and Salt Lake County.

  Areas Benefited: Salt Lake City and Salt Lake County.

- **Accomplishments**:

  Findings/Results: The PI attended all regularly scheduled SLVSWM Council meetings throughout FY10 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 throughout Salt Lake County.

Work Plan FY 10/FY11

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.

Websites: http://www.slvlandfill.slco.org/
https://public.me.com/rdupo/UWRL.

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 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, and removers, as well as requiring the registration of underground tanks. Each owner or operator of an underground tank must register the tank with the Executive Secretary of the Waste Control Board.

- **Benefits to 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:**

  Areas Benefited: All affected parties state-wide.

- **Accomplishments**:

  The PI attended all regularly scheduled Waste Control Board meetings and facility tours throughout FY09 and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY 10/FY11

Continue involvement in decision-making through attendance at monthly Waste Control Board meetings and associated facility tours and providing 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, 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 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 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:

  <u>Jordan River TMDL Model Review:</u>

  - Worked with the Utah DWQ over the past year reviewing documents, giving presentations, and attending meetings in order to provide guidance as to how best to proceed in the TMDL process.
  - Reviewed the Linkage Documentation for the Jordan River and provided insight into the linkage between dissolved oxygen and temperature at the Jordan River Linkage Symposium.
  - Completed calculations regarding the possible change in oxygen saturation and other coefficients (e.g., BOD decay coefficients and reaeration coefficients) given differences in temperature.
  - Participated in the collaborative QUAL2KW model calibration that provided information to conclude that nutrients are not the primary cause of low instream dissolved oxygen. Sediment oxygen demand and loads of organic matter have become the new focus of the TMDL and decisions made using QUAL2KW are now limited.

  <u>Salt Lake County Watershed Modeling:</u> Assisted Stantec as expert reviewer for the Watershed Model that is being developed for Salt Lake County. 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. A model development plan has been reviewed and completed, data to force and calibrate the model have been gathered, and the hydrology calibration is complete and a review has been provided. Currently, the review of the water quality calibration is being completed.

Jordan River Temperature Modeling: Contracted with the Utah DWQ and South Valley Water Reclamation Facility to complete the instream temperature modeling to assist in determining whether a site specific temperature standard is necessary for the upper portion of the Jordan River. We are in the initial phases of this study, but we have conducted a seepage study to support the understanding of water movement within this portion of the Jordan River.

Statewide Wasteload Allocation Study: Contracted with the 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. We are in the initial phases of this study, but we have been collecting data in streams below various wastewater treatment plants throughout the state.

Results:

Jordan River TMDL Model Review: After the Linkage Symposium, a temperature monitoring strategy to support model population and calibration was developed. Temperature is being considered simultaneously with dissolved oxygen, which resulted in the Jordan River Temperature Modeling study described above.

Salt Lake County Watershed Modeling: The BASINS/ HSPF model has been calibrated for hydrology, and the water quality calibration will be complete soon. Once complete, Salt Lake County can use this model to make decisions regarding stormwater and flood control, along with the ability to quantify the impacts of development on instream water quality.

Jordan River Temperature Modeling and Statewide Wasteload Allocation Study: Both of these studies are just beginning and there are no results at present.

Work Plan FY 10/FY11

Over the next year, continue to support both the Jordan River TMDL process and the Salt Lake Watershed Model development as part of the Jordan River TMDL Technical Advisory Committee and Salt Lake County Watershed Model Advisory Committee, respectively; continue to act as an independent model reviewer for both of these efforts; 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.

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 depends on having 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 housing developments will continue to expand into current open space. Such development 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 State:**

  As population growth and associated housing developments continue to threaten the preservation of agricultural lands in Utah, there is 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 was introduced and passed as House Bill 14s during the 2001 Legislative Session to develop 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 Department of Environmental Quality, 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:

  - Level 1: Soil Evaluation and Percolation Testing.
  - Level 2: Design, Inspection, and Maintenance of Conventional Systems.
  - Level 3: Design, Operation, and Maintenance of Alternative Systems.

  Workshops are also provided for renewal of certification, as Level 1 and Level 2 certification expires after 5 years and Level 3 certification expires after two years.

  Results: During FY 2009/ 2010, 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.

Work Plan FY 10/FY11

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.

Sims, J.L., Cashell, M., Cowan, B., and Jex, R. (2009, 2010). *Course Manuals for Levels 1, 2, and 3 Certification*. Utah Water Research Laboratory, Utah State University, Logan, UT.

Sims, J.L. (2010). Partnerships and Training to Advance Decentralized System Management: The Utah Certification Program. Invited Speaker, *Annual Meeting, Colorado Professionals in Onsite Wastewater*, Denver, CO, January 27 – 29, 2010.

Water Resources Planning and Management

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Water Resources Planning and Management

Project Name	FY 2010 Actual Expenditures	FY 2011 Budgeted Expenditures	FY 2012 Planned Expenditures
Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake	$23,016.05	$42,219.13	$34,000.00
Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties	$50,728.19	$0.00	$0.00
Analyzing the Spread of *Phragmites Australis* Over Short Time-Scales Using Spatial and Genetic Tools	$2,309.18	$23,400.00	$25,000.00
Curtis Creek: A 3-Dimensional Flow and Contaminant Transport Model to Estimate Stream and Groundwater Exchange and Water Quality Changes	$32,821.30	$33,805.94	$34,820.12
Eliminating the Division Between Ecosystem Engineers and Biologists	$27,969.61	$28,808.70	$29,700.00
Estimating Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated systems at Different spatial scales	$17,459.85	$25,000.00	$27,000.00
Finding Appropriate Complexity for Distributed Hydrologic Models	$46,317.06	$0.00	$0.00
Flood Potential Due to 100-Year Storm Events for Small Utah Cities	$3,571.38	$3,678.52	$3,788.88
Habitat Monitoring of the Bear River	$10,394.91	$0.00	$0.00
Improving Hydrologic Model Predictions to Land Use and Climate Change	$25,370.87	$27,600.00	$29,000.00
Improving the Accuracy, Reliability, and Accessibility of Irrigation Flow Measurements	$41,164.53	$0.00	$0.00
Interstate Movement of Bonneville Cutthroat Trout	$215,499.35	$40,000.00	$11,000.00
Investigating Turbidity and Sediment Transport Dynamics in the Little Bear River Using Continuous Monitoring Data	$88.30	$0.00	$0.00
Lake Fork/Uintah River System Optimization Review	$10,713.75	$0.00	$0.00
Multispectral Image Processing for Water Management and Other Agricultural Applications	$17,645.31	$18,174.67	$18,719.91
Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment	$112,466.37	$165,500.00	$170,465.00
Optimal Merging of Different Scale Soil Moisture Measurements into Land Surface Modeling Systems	$0.00	$0.00	$0.00
Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology	$193,648.41	$137,000.00	$46,000.00
Real-Time Management of Irrigation Systems in the Sevier River Basin	$111,461.97	$87,300.00	$75,800.00
Restoration of Interstate Migration Routes for Bonneville Cutthroat Trout	$6,418.10	$6,610.64	$6,808.96
Stream Restoration in Boulder Creek, Utah: Effects of Increased Stream Discharge and Non-native Fish Removal	$20,859.32	$24,500.00	$23,000.00
Treated Wastewater Use in Agricultural Irrigation	$15,370.04	$0.00	$0.00
UAV Remote Sensing Service Center	$119,676.61	$84,600.00	$72,300.00
Water Conservation and Drought Planning with Reservoir Carryover Storage	$44,999.87	$25,500.00	$14,000.00
Dedignated Projects		$849,387.00	$0.00
Undesignated Projects		$130,000.00	$201,000.00
Total	**$1,149,970.33**	**$1,753,084.60**	**$822,402.87**

Advanced Statistical Learning Techniques for Predicting Water Levels in the Great Salt Lake

Principal Investigators:
Gilberto E. Urroz
Niroj K. 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. Modern statistical techniques known as Statistical Learning Techniques can be used for GSL level predictions using data from the last 100+ years.

- **Benefits to State:**

  Accurate prediction of Great Salt Lake (GSL) levels would help GSL stakeholders, such as the Utah Division of Water Resources, municipal and County governments in the counties of the Great Salt Lake Basin (Box Elder, Weber, Davies, Salt Lake, and Tooele), as well as industries in the shoreline, in terms of planning, development, and emergency response.

- **Geographic Areas:**

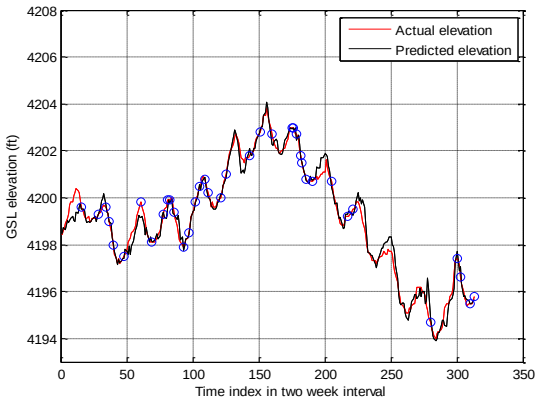
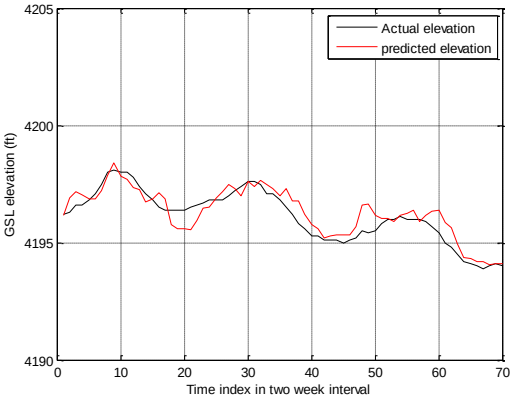
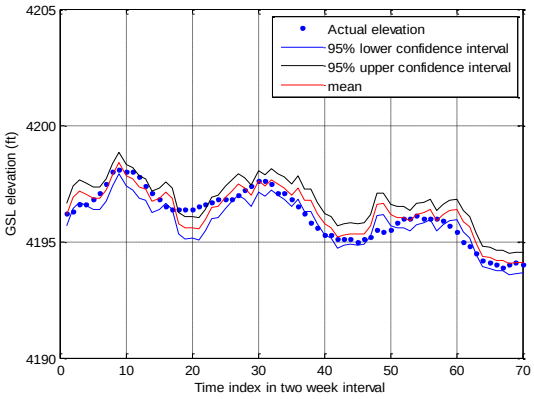
  Study Area: Great Salt Lake Basin.

  Areas Benefited: Great Salt Lake Basin, Box Elder, Weber, Davies, Salt Lake, and Tooele Counties.

- **Accomplishments:**

  Findings:
  - Statistical techniques were used to predict GSL levels by "training" computer models using long-term data provided by the Utah Division of Water Resources. Earlier model applications used Artificial Neural Networks (ANN), Support Vector Machines (SVM), and Relevance Vector Machines (RVM). The FY 09-10 work concentrated on Multivariate Relevance Vector Machines (MVRVM).
  - All statistical and simulation techniques produce good "training" GSL level trends, as illustrated in the following figures.
  - All statistical and simulation techniques produced accurate predictions for the testing period (2000-2007), both in the testing phase (with feedback) and the blind iterative testing (new predictions), as shown in the figures.

  Results: The training period is used to prepare the model for predicting water elevations. The testing graph shows predictions beyond the training period. The predictions (red line) are compared with the actual data (blue line). Notice the agreement between prediction and observation. The last graph shows predicted data with 95% probability confidence intervals.

Training	Testing
	
Training bias = 0.0001 Testing bias = -0.171 Training RMSE = 0.326 Test RMSE = 0.478	

Work Plan FY 10/FY11

- Complete analysis using MVRVM for GSL level prediction.
- Extend use of MVRVM to other hydrological data

Informational Resources

A primitive tool for prediction is available at the following web site:
http://www.neng.usu.edu/cee/faculty/gurro/GSL_w/stand%20alone%20application.htm.

Contact: Dr. Gilberto E. Urroz, Ph.D., P.E., Phone (435) 797-3379, E-mail: gilberto.urroz@usu.edu.

Website: http://www.neng.usu.edu/cee/faculty/gurro/GLS_/index.htm.

Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties

Principal Investigators:
David E. Rosenberg
Omar Alminagorta
Melina Santos Vanderlinder
Karin M. Kettenring
Christopher Neale

Partners/Collaborators:

- ***Local:*** *Al Trout, Friends of Bear River Refuge*
- ***Federal:*** *Bob Barrett and Sharon Vaughn, 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 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. Beyond contributing new information, 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 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, Utah.

  Areas Benefited: Utah wetlands.

- **Accomplishments:**

Findings:

- Developed the wetlands systems model user interface using HydroPlatform (Figure 1).
- Programmed hydrological and ecological components of the systems model.
- Presented modeling work at World Environmental & Water Resources Congress in Providence, RI, May 16-20, 2010.
- Mapped flight paths over the Refuge in 1991 – 1992 recorded on video tapes.
- Spoke with former refuge managers to learn where and when Phragmites first appeared at the refuge. Started subsequent plant coverage classification efforts there.
- Flew over and photographed BRMBR in May, 2010; geo-rectified and tiled images taken.
- Ground-truthed at 63 waypoints; photographed and classified plant coverage (Figure 2).

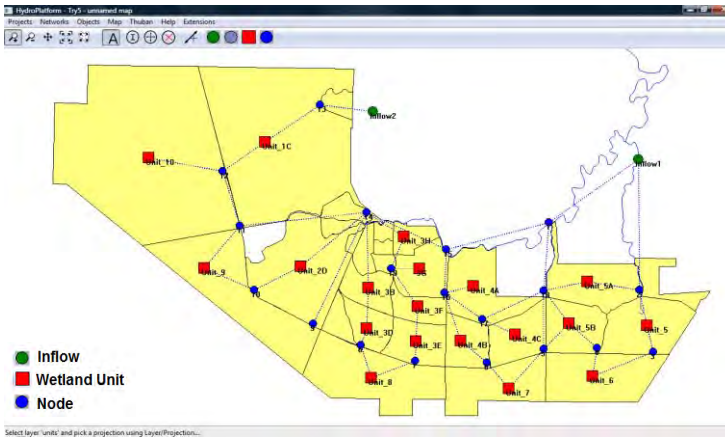


Figure 1. HydroPlatform User interface for the wetlands systems model for the Bear River Migratory Bird Refuge, Utah.

Work Plan FY 10/FY11

- Finish developing the systems optimization model for the BRMBR.
- Conduct sensitivity analysis—identify ecological parameters to which model results are most sensitive.
- Run the systems model. Report recommended water allocations and work collaboratively with BRMBR managers to verify that model recommendations are reasonable.
- Complete the database of water levels and plant coverage back through time.

Figure 2. Google Earth map with numbered-color markers indicating plant presence at ground-truthed waypoints.

- Submit proposal to National Science Foundation program "Dynamics of Coupled Natural and Human Systems" to extend work to include ecological uncertainties.

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/drosenberg/projects.htm.

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

Principal Investigators:
Dr. Karin M. Kettenring
Dr. David Rosenberg

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

Project Description

- **Need and Purpose:**

  Phragmites australis is an invasive grass that is rapidly taking over wetlands in northern Utah and other areas across the US. The invasion of this grass has resulted in substantial loss of quality wetland habitat, especially in areas heavily used by highly valued migratory birds. The state of Utah has recognized the natural resources problem that *Phragmites* presents by directing and funding State Waterfowl Management Area managers, under the direction of Randy Berger, to embark on a long-term, large-scale *Phragmites* control program.

  To aid in control efforts, managers need efficient and accurate ways to assess *Phragmites* cover before and after herbicide spraying and to monitor its spread. The recent development of remote sensing technologies and UAVs (unmanned aerial vehicles) by USU's Utah Water Research Laboratory allows us to evaluate this technology for wetland applications. We expect to be able to assess fine-scale changes in *Phragmites* cover over the course of the growing season because of the high resolution the UAVs allow for remote sensing imaging.

  We also need to be able to assess the method of spread of *Phragmites*, whether by seed or clonally by rhizomes (underground stems). The method of spread will help guide the type and timing of *Phragmites* control efforts. The use of UAV-based remote sensing will help assess the rate of spread and the results of *Phragmites* management actions.

- **Benefits to State:**

  This technology potentially has broad applications for use in agricultural and natural resource management situations. Furthermore, having an understanding of how Phragmites spreads will be important given the widespread nature of this plant and the need to best match control efforts with the biology of the plant to maximize the effectiveness of control measures.

- **Geographic Areas:**

  Study Area: Bear River Migratory Bird Refuge (BRMBR), Brigham City, UT.

  Areas Benefited: The BRMBR will directly benefit from the research, as well as anyone working in agricultural or natural resource management settings.

- **Accomplishments**:

  Findings: UAV flights have been conducted to test the capability of the aircraft in acquiring imagery that can be used to automatically identify *Phragmites*. Software is under development that will be able to locate *Phragmites* at very high resolutions (approximately 25 cm), determine whether it has spread, and evaluate its growth condition.

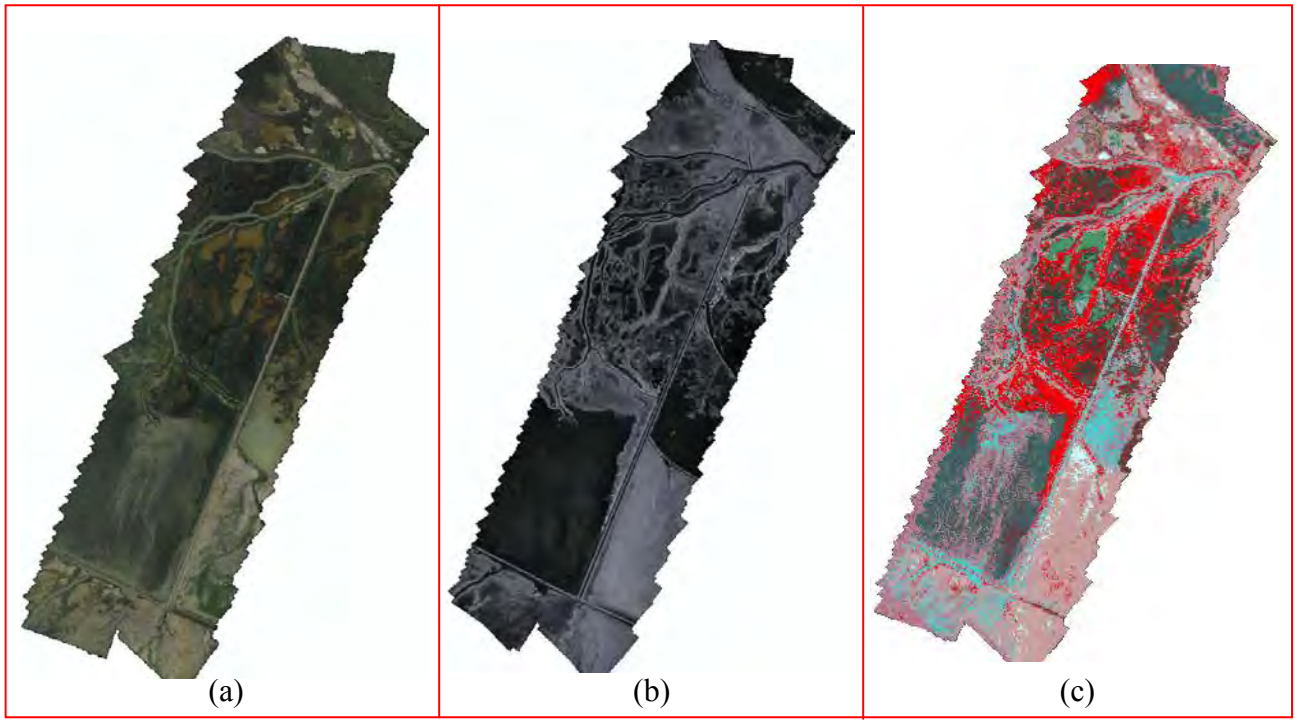
Results: Preliminary results of the UAV remote sensing work show that *Phragmites* identification using the UAV imagery can be accomplished cheaply and effectively at very high resolution.

Work Plan FY 10/FY11

Work in the coming year will focus on combining the results of the DNA analyses (which are underway now) with the aerial imagery analyses to (1) quantify both the agents and rates of how *Phragmites* spreads, (2) develop methods to assess the effects of alternative *Phragmites* control mechanisms.

Informational Resources

Contact: Dr. David Rosenberg, (435) 797-8689, E-mail: david.rosenberg@usu.edu.



Computer Identification of Phragmites Across 4 Square Miles of the Bear River Migratory Bird Refuge: (a) Visual Spectrum Imagery; (b) Near-Infrared Imagery (in False Grey-Scale); (c) Computer Identification of Phragmites (in Bright Red)

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 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 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.
  - Sources of uncertainties:
    - Heterogeneity of the physical system.
    - Many flow paths, including long surface-groundwater exchanges, are not captured by MODFLOW but are very well-estimated by dilution gauging.
    - Model discretization (cell size and layers).
  - More investigation on the level of uncertainty for each method is needed.

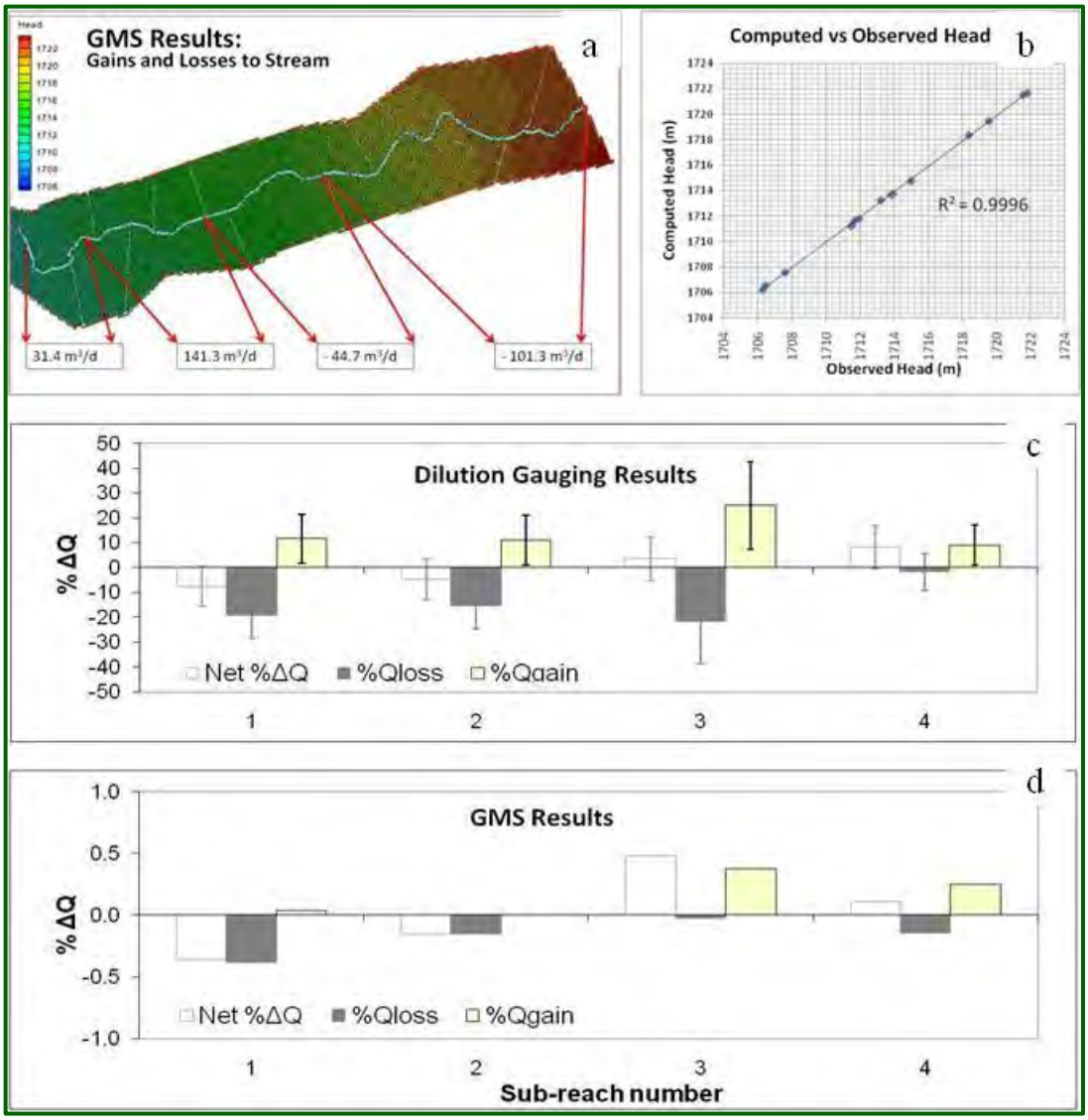


Figure 1: a) groundwater model results of gains and losses; b) groundwater model calibration results; c) % gains and losses by dilution gauging method; and d) % gains and losses by groundwater model.

Work Plan FY 10/FY11

- Reduce the modeling and data collection uncertainty.
- Incorporate the impact of flow exchanges on water quality of the stream.
- Publish the results

Informational Resources

Contact: Dr. Said Ghabayen, (435) 797-7176, Email: s.ghabayen@aggiemail.usu.edu.

Characterization of Groundwater-Surface Water Interactions Using GMS and Dilution Gauging Approaches: Curtis Creek, Northern Utah. *Proceedings of AWRA 2009 Annual Water Resources Conference*. Nov 9 - 12, 2009. Seattle, WA.

Eliminating the Division Between Ecosystem Engineers and Biologists

Principal Investigators:
Casey Williams

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Water supply and the lack thereof is one of the largest problems in America today, 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 many times are actually at odds with one another. This disagreement often leads to conflicting information that causes confusion. Very few individuals or groups are trained to work with 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 State:**

  This project directly benefits the state of Utah by improving analytical methods for complex water related issues of 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 is currently being developed in cooperation with the Utah Division of Wildlife Resources, Bureau of Land Management, and Emery County Water Conservation District.

- **Geographic Areas:** Boulder Creek in Garfield County, Bear River in Cache County, and San Rafael River in Emery County.

  Study Area: Garfield, Cache, and Emery counties.

  Areas Benefited: Garfield, 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 the 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 their ability to communicate the findings of their research.

Work Plan FY 10/FY11

Additional modeling will be conducted and a final report detailing all collaborative efforts will be written.

Informational Resources

Contact: Dr. Casey Williams, (435) 797-1184, E-mail: casey.s.williams@aggiemail.usu.edu.

Estimating Real-Time and Seasonal Crop Evapotranspiration of Large Irrigated Systems at Different Spatial Scales

Principal Investigators:
Christopher M. U. Neale

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 for water rights adjudication and control. Improved and timely estimates of irrigation water demand can help water managers understand 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 estimates is needed.

- **Benefits to State:**

  Improved water management can lead to water savings and potentially 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:**

  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: Irrigated agricultural areas and systems of Utah in all counties.

- **Accomplishments:**

  The remote sensing methodology has been applied to the water balance of two large irrigation systems, namely the Bear River Canal Company (BRCC) in northern Utah and the Palo Verde Irrigation District (PVID) in southern CA, and will allow the policy makers to analyze potential changes in water management strategies to improve water use efficiency.

  Findings: The SETMI modeling approach was developed to estimate spatial ET from satellite and airborne remote sensing using both the energy balance approach (Two-source model and SEBAL) and the reflectance-based crop coefficient approach. The model is written in Visual Basic and operates within an ArcGIS environment, easily manipulating and displaying spatial data.

Results: GIS databases containing the layout of canals and drains, turnouts, and hydraulic structures were developed for both the BRCC and PVID irrigation systems. A complete water balance was conducted on the Palo Verde Irrigation District using satellite based remote sensing and the SEBAL model for estimating ET and irrigation water demand and measuring inflows and outflows to the system. A new method of processing and correcting measured scintillometer data for estimating sensible heat fluxes and derive ET was developed. Scintillometers allow for the estimation of ET over large spatial scales.

Work Plan FY 10/FY11

The field data collection has ended, and the focus is now on analyzing the results.

Informational Resources

Contact: Dr. Christopher Neale, (435) 797-3689, E-mail: christopher.neale@usu.edu.

Geli, H.M.E., C.M.U. Neale, D.R. Watts, J. Osterberg and S.I. Sritharan (2010). Improved Scintillometer-Based Estimates of Latent and Sensible Heat Fluxes Over Naturally Vegetated Heterogeneous Semi-arid Areas Using LIDAR Data. *Second State of the Art Conference: Remote Sensing of Evapotranspiration*. Desert Research Institute (DRI), Las Vegas, NV, August 16-18.

Taghvaeian, S., C.M.U. Neale, C.A.C. dos Santos, D. Watts, J. Osterberg, and S.I. Sritharan (2010). Studying Water Balance Components at the Palo Verde Irrigation District, Using Remote Sensing, GIS and Hydroclimatological Data. *Second State of the Art Conference: Remote Sensing of Evapotranspiration. Desert research institute (DRI.* Las Vegas, NV. August 16-18.

Lecina, S., C.M.U. Neale, G.P. Merkley, and C.A.C. dos Santos (2009). Increasing Field Work Productivity in Irrigation Evaluation Processes Through the Use of Combined Irrigation Models. *ASCE World Environmental and Water Resources Congress 2009: Great Rivers*. Conf. Proc. 342, 428 (2009), DOI:10.1061/ 41036(342)428.

Finding Appropriate Complexity for Distributed Hydrologic Models

Principal Investigators:
Luis Bastidas

Partners/Collaborators:
Federal: *National Weather Service, Colorado Basin River Forecast Center*

Project Description

- **Need and Purpose:**

  This project is exploring the use of Statistical Learning Theory and Fractional Calculus as ways 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 are developing 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 aims to reconcile two constraints in hydrologic modeling due to lack of information and huge computational requirements: 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.

  The study is currently being carried out using 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 State:**

  The study focuses on mountainous areas with snow cover, which includes a significant part of the western United States and, in particular, the State of Utah. Once the testing procedures are finished they will 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 the radar coverage over the Utah area, and as a first approximation, we are currently testing 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: So far 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.

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 are concurrently evaluating the discharge at various points, together with the snow water equivalent and snow cover values derived from satellite and gage observations.

Work Plan FY 10/FY11

A paper on the theoretical development of the complexity measure with simple hydrologic and water resource models and one on the application and numerical estimation of the complexity measure are to be submitted before of the end of 2010. Two presentations will be made at the AGU Fall Meeting 2010. A presentation was made at the IAHS Symposium in India (September, 2010).

The main goals of the project are close to being reached and we are currently looking for opportunities for further testing and application.

Informational Resources

Contact: Dr. Luis Bastidas, (435) 797-8228, E-mail: luis.bastidas@usu.edu.

Flood Potential Due to 100-Year Storm Events for Small Utah Cities

Principal Investigators:
Dr. Michael C. Johnson
Mr. Marshall W. Saunders

Partners/Collaborators:
- ***State**: Todd Adams, Water Resources*
- ***Business/Private:** Matt Stayner, Bowen Collins*
- ***Federal:** Edward Clark, CBRFC*

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 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 hiring 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 water 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.

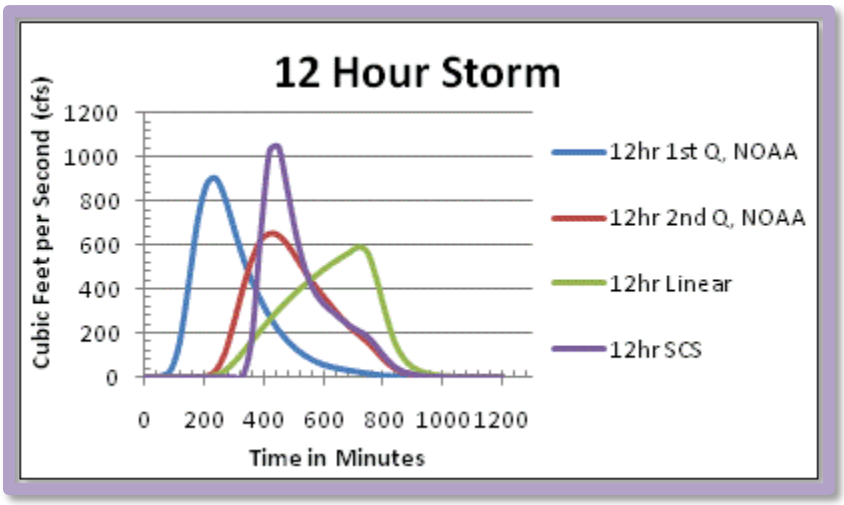
- **Geographic Areas:**

  Study Area: The study area includes all basins in the state 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 study sites in each county: Box Elder 5, Cache County 17, Carbon County 9, Davis County 18, Juab County 2, Juab County 4, Millard 1, Morgan County 11, Salt Lake County 17, Sanpete County 3, Summit County 6, Tooele County 2, Utah County 18, Weber County 13, Wasatch County 3, and Washington County 5.

  Areas Benefited: This project will benefit all cities in the state that are experiencing growth.

- **Accomplishments:**

  Findings: The figure below is an example of a hydrograph showing the peak runoff flood water in Hyde Park Canyon for a 12-hour storm. Similar hydrographs are being created for many other basins for 1-, 2-, 3-, 6-, 12-, and 24-hour storms. The different lines represent different ways to distribute rainfall during the length of the storm. Each line has a different peak value, but the volume of runoff is the same for a given timeframe. 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.



Results: The results indicate that there is a high probability of flooding in areas of sub basins that do not contain a natural stream, and this presents a potential hazard for the citizens in the path of the flood waters. This study also recognized that the State of Utah has very limited rainfall curve information, and that some curves differ widely. We recommend that rainfall curve distributions 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.

Work Plan FY 10/FY11

- Identify the research that has already been done in the state and determine if the study is needed.
- Identify the study areas and perform a 100-year storm event analysis for each study area.
- Assemble all data into a report that is organized to easily identify 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, thus affecting cutthroat trout populations in Utah. The proposed dam would inundate approximately five 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 focuses 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 State:**

  The information from this study can be used as a basis for predicting macroinvertebrate assemblage changes due to reservoir construction and the resulting changes in cutthroat trout assemblage. Specifically, it 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.

- **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: Seasonal macroinvertebrate samples have been collected from five study reaches of the Bear River in southern Idaho and Utah. All samples have been sorted and are currently being identified.

  Results: Although samples are still being processed and have yet to be analyzed, a longitudinal pattern of macroinvertebrate density appears to be present in the Bear River. Greater densities in upstream areas compared to downstream areas are most likely correlated to changes in physical and chemical habitat characteristics.

Work Plan FY 10/FY11

All samples will be identified and analyzed. A more detailed report will be submitted during FY2010/ 2011.

Informational Resources

Contact: Dr. Casey Williams, (435) 797-1184, E-mail: casey.s.williams@aggiemail.usu.edu.

Collection of Drift Samples.

Collection of kick samples for Benthic Macroinvertebrates.

Improving Hydrologic Model Predictions to Land Use and Climate Change

Principal Investigators:
David G. Tarboton
Ibrahim Mohammed (student)
Teklu Tesfa (student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Land cover and climate change, along with their associated impacts on hydrology, 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 also addresses impacts of land use and climate change on 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.

  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 through computer programs that use parallel processing, and 2) understanding the dynamics of the Great Salt Lake. We address each of these in the results below.

  Results: One approach to improving the predictions of hydrologic models is to take advantage of more detailed spatial information in their inputs. Soil depth is one such input, better knowledge of which has the potential to improve hydrologic model predictions. A PhD Dissertation (Tesfa, 2010) examined this question by first developing methods to map soil depth from topographic inputs, then using parallel computing to more rapidly evaluate topographic variables from digital elevation models for extensive areas, then using these detailed inputs in a distributed hydrologic model to simulate streamflow.

Fluctuations in the level of the Great Salt Lake have impacts on lake resources, so understanding these fluctuations is important. A paper examining preferred lake level states and their underlying causes was written and submitted for publication in Water Resources Research (Mohammed and Tarboton, submitted 2010). This paper explained how preferred lake levels are related to the lakes bathymetric form as expressed in the relationship between level, volume, and area interacting with water inputs to the lake.

Work Plan FY 10/FY11

Work is ongoing in the application of distributed models to quantify the impacts of changes in land use, land cover, and climate on the watershed hydrology. Work this year will focus on application of the RHESSys model because it provides a detailed representation of snow, runoff, soil, and vegetation processes important for addressing key questions. This physically-based modeling will help us better understand and quantify the sensitivity of watersheds to changes in individual input factors. This is needed to complement and integrate with prior and ongoing 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.

Informational Resources

Contact: Dr. David G. Tarboton, (435) 797-3172, Email: david.tarboton@usu.edu.

Publications:

Mohammed, I.N. and D.G. Tarboton, (submitted 2010), On the Interaction between Bathymetry and Climate in the System Dynamics and Preferred Levels of the Great Salt Lake. *Water Resour. Res.*

Tesfa, T. (2010). *Distributed Hydrological Modeling Using Soil Depth Estimated from Landscape Variables Derived with Enhanced Terrain Analysis*. PhD Dissertation, Civil and Environmental Engineering, Utah State University, Logan, UT, 222 p. http:/ / digitalcommons.usu.edu/ etd/ 616/ .

Improving the Accuracy, Reliability, and Accessibility of Irrigation Flow Measurements

Principal Investigators:
Blake P. Tullis
Mac McKee

Partners/Collaborators:
- ***Local:*** *Aaron Hunt, DNR-Water Rights, Matt Lindon, State Engineer*

Project Description

- **Need and Purpose:**

  Effective management of a water resource requires accurate, reliable, and accessible flow measurement data. State Distribution Systems in Utah make critical decisions regarding water diversions, exchanges, and ultimately delivery of the proper quantity to the end-user. Real-time accurate flow measurement data should provide guidance for sound decision making and for meeting water delivery obligations. Most Distribution Systems have some means of flow measurement (flumes, weirs, etc.); however, many of those structures are constructed incorrectly (e.g., out-of-level, incorrect dimensions, and/ or incorrectly located staff gages) or suffer maintenance deficiencies that affect calibration (e.g., excessive sediment build up in a flume or upstream of a weir). A lack of communication also exists between those who develop the head-discharge relationship and those who apply it, all of which can result in flow measurement errors. The objective of this project is to inspect flow measurement structures, identify and correct deficiencies, where possible, check the flow calibration, and add an automated data collection and telemetry system to make the data available real-time.

  The Upper Bear River Distribution System in Woodruff, UT participated in this study. Nine flow measurement structures in the system were evaluated and calibrated. A report contains the findings of the study, including a list of corrective actions recommended/ implemented for the flow measurement structures, a summary of the training provided to the River Commissioner (or other responsible parties) on maintenance and operational deficiencies impacting flow measurement accuracy at specific structures, and recommendations for additional work.

- **Benefits to State:**

  Improved (or verified) flow measurement accuracy improves the confidence in and effectiveness of the water distribution decision making. Having the data available real-time via a telemetry system and website facilitate real-time decision making with respect to water allocation and management.

- **Geographic Areas:**

  Study Area: Woodruff, UT (Upper Bear River Distribution System).

  Areas Benefited: Irrigation flow measurement is common throughout the State so all counties in the state could potentially benefit, either through increased awareness of the problem (current study results) or through participation in future studies.

- **Accomplishments:**

  Findings/Results: Nine ramped-flume flow measurement structures were evaluated and calibrated. In many flumes, the water level and/ or flow rate staff gages had been installed at incorrect elevations. The variation between the field calibration and the standard head-discharge relationship (as determined by the WINFLUME software developed by the USBR) for three of the ramped flumes was significant (50 – 80% errors were observed between the field measured and the predicted head-discharge data). New head-discharge relationships were provided for these flumes along with a recommendation that a more thorough calibration effort may be warranted. The other six ramped flumes had accuracies between the various staff gages and the field calibration that ranged from approximately 5 to 20%. This information was provided to the river commissioner in a project report so that, where it was determined to be prudent, the staff gages could be adjusted to improve the flow measurement accuracy.

Work Plan FY 10/FY11

At present, no additional funding has been made available for additional work on this project.

Informational Resources

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

Examples of ramped flume flow measurement structures in the Upper Bear River Irrigation System.

Interstate Movement of Bonneville Cutthroat Trout

Principal Investigators:
Casey Williams
Thomas B. Hardy

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 migration routes and distribution of Bonneville cutthroat trout across the Utah/ Idaho border, thus affecting cutthroat trout populations in Utah. The proposed dam would inundate approximately five 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 of both Utah and Idaho.

  This project focuses 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, are being conducted throughout the study area. In addition, a survey of current fish assemblage structure and Bonneville cutthroat trout distribution and migration patterns are being conducted using accepted methods of fish collection and biotelemetry.

- **Benefits to State:**

  The information from this study can be used as a basis for conservation efforts toward Bonneville cutthroat trout throughout its range. Specifically, it 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 the conservation efforts of Trout Unlimited. This study will provide explicit information concerning migrations and conservation of the genetic diversity of interconnected local cutthroat trout populations within 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 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 are being analyzed in order to predict future changes to the aquatic resources of Utah.

  Results: Fish surveys indicate a small population of Bonneville cutthroat trout exists in the Bear River around the Utah/ Idaho border. The telemetry study has verified interstate migration of Bonneville cutthroat trout along the Bear River and suggests an intact genetic connection with cutthroat trout in the Cub River.

Work Plan FY 10/FY11

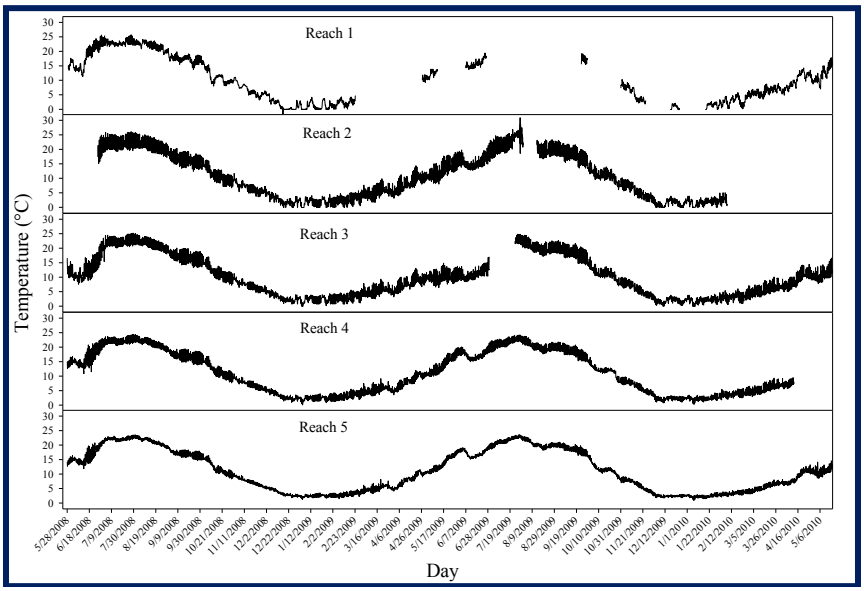
Additional telemetry tracking will continue through December 2010. Habitat and fisheries data will be analyzed and predictions made using various statistical and modeling methods. All study components will be combined into a final written report and submitted to state and federal officials.

Informational Resources

Contact: Dr. Casey Williams, (435) 797-1184, E-mail: casey.s.williams@aggiemail.usu.edu.

Electrofishing the Bear River.

Bear River Bonneville cutthroat trout.



Temperature Data for the Bear River, Idaho and Utah.

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

Principal Investigators:
Jeffery S. Horsburgh
Cody Allen (student)
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 solids 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 aims to 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 general methods to better quantify the sources, timing, and magnitude of sediment fluxes.

- **Benefits to State:**

  Because the analysis and monitoring techniques that we are developing provide information about the timing, magnitude, and potentially 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 preliminary 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 sort of rapid response is poorly characterized by traditional water quality sampling techniques, and traditional techniques provide no information at all about sources of sediment.

  Results: This work is just beginning and will continue through FY10/ FY11.

Work Plan FY 10/FY11

For this project we will use existing data collection and turbidity sensor infrastructure at several monitoring sites within the Little Bear River to assemble and examine high frequency turbidity data as a surrogate for total suspended solids (TSS). We will couple the turbidity data with much lower-frequency grab sampling of total suspended solids concentrations to create relationships between turbidity and TSS at each monitoring site so that high-frequency estimates of TSS concentrations can be derived from the turbidity measurements. We will collect new TSS 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 potential effects of particle size distribution on the relationship between TSS and turbidity. 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 TSS 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.

Continuous monitoring site on the Little Bear River.

Lake Fork/Uintah River System Optimization Review

Principal Investigators:
Dr. Mac McKee

Partners/Collaborators:
- ***State:*** *Dex Winterton, Duchesne Water Conservancy District*

Project Description

- **Need and Purpose:**

  Advances in data-driven modeling techniques applied to the management of water resources systems have been pioneered at the Utah Water Research Laboratory in recent years. These are being applied to the operation of several of the large irrigation systems in the Sevier River Basin, contributing to the achievement of greater efficiency in the delivery and use of large quantities of irrigation water. The purpose of this project is to extend the application of data-driven modeling approaches for better forecasting of canal and stream flows in a new area of the state: the Lake Fork Irrigation System in Duchesne County.

- **Benefits to State:**

  Application of data-driven modeling techniques in the Sevier River Basin in the past several years have already shown a dramatic increase in the efficiency of basin-wide water management. Similar results are expected for the Lake Fork System and potentially for every river basin in Utah, especially those with substantial irrigated agriculture. The short-term forecasting methods developed by this project can provide system managers with information necessary to more precisely control the operation of large and complicated irrigation systems such as those found in the Lake Fork System, thereby saving water and increasing the overall productivity of the system.

- **Geographic Areas:**

  Study Area: Lake Fork Irrigation System, Duchesne, UT.

  Areas Benefited: The Lake Fork System will have a direct benefit from our research, but the applications of our findings could benefit anyone working in agricultural or natural resource management settings who might use this remote sensing technology.

- **Accomplishments**:

  Findings: Preliminary findings indicate that real-time operations of portions of the Lake Fork System, especially the Sand Wash reservoir, can be substantially improved by subjecting the available operations data to analysis with data-driven methods. We expect that these findings could be extended to the entire system if sufficient process-based model results can be coupled with data-driven modeling techniques.

  Results: Analyses conducted to date indicate that the Sand Wash reservoir releases can be operated in real time so as to achieve stable downstream water levels in critical system, reservoir, and canal components.

Work Plan FY 10/FY11

Work in the coming year will focus on extending the data-driven analyses to make system-wide corrections in real time on the outputs of the River Ware model, which is now under development by others who are working for the Duchesne Water Conservancy District.

Informational Resources

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

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. Monitoring evapotranspiration (ETa) and 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 for the analysis of water content over large crop fields and rangelands. However, due to low spatial resolutions of images and practical temporal limits, as well as weather related obstructions (like clouds), accurate forecast of daily agricultural water consumption using remote sensing is not a trivial 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 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. Also, this research program will 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: After comparing different types of classification algorithms, Support Vector Machines (SVMs), one type of learning algorithms, were found to be the most effective and efficient approach. The advantages of SVMs are their strong predictive capability, automatic estimation of nuisance parameters, and the flexibility to use arbitrary basis functions.

  Results: In this study, data collected in SMEX02 were used to test the algorithm. The model inputs are Leaf Area Index (LAI), obtained from remotely sensed images, soil temperature, air temperature, and precipitation. The output is surface soil moisture content (0-6cm). Different kernel functions with

different width parameters were tried and compared. Some results are exhibited in Table 1.The results indicate that the Cauchy kernel function gives the best estimation of soil moisture content, as shown in the following figure.

Table 1 The Mean Absolute Error (MAE) between predicted soil moisture contents and measured soil moisture contents under different kernel functions and width parameters

Kernel Function/ Width	Gaussian	Cauchy	Cubic	Distance
1	0.0356	0.0284	0.1410	0.0322
2	0.0298	0.0280	0.0367	0.0322
3	0.0302	0.0325	0.0377	0.0322
4	0.0323	0.0332	0.0376	0.0322
5	0.0414	0.0291	0.0384	0.0322

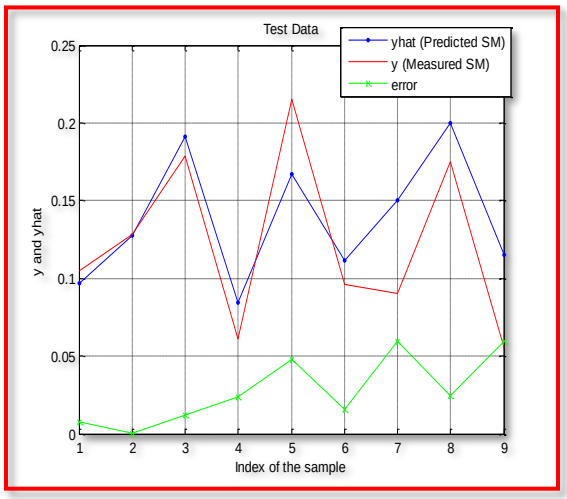


Figure 1 Comparison of predicted and measured soil moisture contents with Cauchy kernel function and width = 2

Work Plan FY 10/FY11

The Year-4 research effort includes the following: Based on remotely sensed multispectral images real-time acquired from Unmanned Autonomous Vehicles (UAV), develop and implement signal processing algorithms for crop and forage classifications, growth status estimation, as well as water management by monitoring, evaluating, and predicting ETa and 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. Attention will be given to testing of algorithms using actual field data.

Informational Resources

Contact: Huifang Dou, (435) 797-2858, Email: douhf@engineering.usu.edu.

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 low cost and 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 diverted to other, higher valued uses, such as municipal supply.

- **Benefits to 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 allocated 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 equipments, and gather remotely sensed data which can then be processed for distribution to water managers and farmers.

  Results: 1) A team of several working, fully open-source UAVs have been flown for various mission scenarios such as irrigation water management and ecological assessment, 2) patent disclosures have been filed, and 3) UAV-based services are now being offered.

Work Plan FY 10/FY11

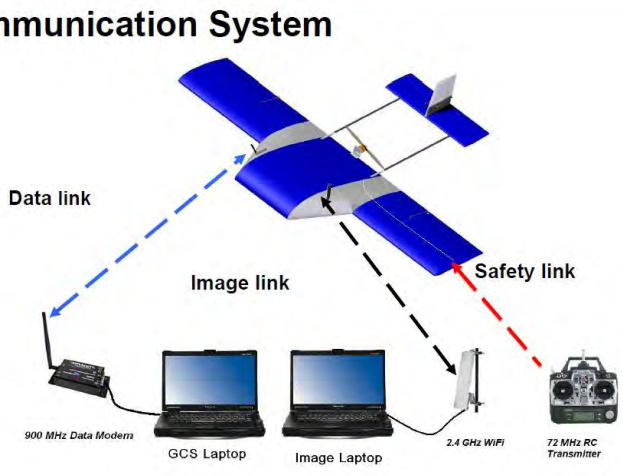
- Make Boomtail-2 (BT2) platform manufacturable
- Research and prototype a 100 mile platform
- Design a portable passive UAV launcher
- Explore thermal infrared (TIR) capability on BT2 platform
- Test flight control tuning methods
- Further develop protocols for information sharing among multiple UAVs
- 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://yangquan.chen.googlepages.com/ 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.
Publication list 2009-2010: http://mechatronics.ece.usu.edu/yqchen/paper/09/ and http://mechatronics.ece.usu.edu/yqchen/paper/10/.
News paper story: http://yangquan.chen.googlepages.com/Scan08062009_160254.pdf.
News release: http://www.usu.edu/ust/index.cfm?article=37983.

AggieAir-2



Optimal Merging of Different Scale Soil Moisture Measurements Into Land Surface Modeling Systems

Principal Investigators:
Luis A. Bastidas

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  The project is a theoretical study that explored an optimal way to incorporate/ assimilate non-synchronous different scale observations into a land surface modeling system: point in situ measurements – discrete in space, continuous in time; satellite remote sensing observations – discrete in time, continuous in space; and small aircraft remote sensing observations – discrete in time, ~~"~~semi-continuous" in space.

- **Benefits to State:**

  The study focused on semi-arid environments, which make up a significant part of the western United States and the State of Utah, in particular. The results from this study, especially those regarding the inferior performance of the models in semi-arid environments, will help to improve simulations and forecasts of the turbulent heat and water fluxes.

  The theoretical foundations developed for the assimilation of the non-synchronous different scale observations will surely help in addressing the deficiencies found.

- **Geographic Areas:**

  Study Area: Theoretical models.

  Areas Benefited: All semi-arid regions of the United States, particularly Utah.

- **Accomplishments**:

  Findings/Results: The main accomplishment of this project has been the development of an appropriate framework for the assimilation of non-synchronous different scale observations. Thus, the main purpose of the study has been achieved. A project proposal has been developed for submission to a Federal Funding Agency in order to further test the procedure and develop applications with real data.

  Simultaneously, a study about the effect of land surface model parameter uncertainty and its assessment has been carried out. This complementary effort mainly compared the ability of the land surface models to properly simulate the moisture and temperature state variables in semi-arid areas as opposed to tropical forest environments. The models tend to perform well in the latter because they were designed with those environments in mind. The performance of the models was found to be inferior for the semi-arid environments. A paper detailing these findings is in process and should be ready by the end of the year. A presentation was made about the findings at the AGU meeting, and a student obtained a master's degree with the study.

Important findings include the conclusion that the models have serious problems representing the runoff generation in arid areas and that an inclusion of the soil respiration process is needed for proper simulation of the carbon fluxes. The parameters are not easily transferred and further classification of the semi-arid systems is required.

Work Plan FY 10/FY11

The main goal of the project has been achieved and a proposal and a paper will be submitted soon. The project is considered finished.

Informational Resources

Contact: Dr. Luis Bastidas, (435) 797-8228, E-mail: luis.bastidas@usu.edu.

Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology

Principal Investigators:
Darwin L. Sorensen
Lindsey DeBoer (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:**

  Algae and cyanobacteria blooms are generally linked to high concentrations of phosphorus. Current Total Maximum Daily Load (TMDL) determinations required under the Federal Clean Water Act for reservoirs with these kinds of problems often list the reservoir as ~~"i~~impaired" relative to its designated uses and call for reductions in nutrient loads. Managing the watershed to reduce phosphorus loads can have socioeconomic consequences that are difficult for land users to accept. Nuisance blooms of algae and cyanobacteria occur annually in Pineview Reservoir, Weber County, Utah. Weber Basin Water Conservancy District (WBWCD) personnel who are involved in the operation of the reservoir and in monitoring its water quality have hypothesized that the present mode of reservoir operation contributes substantially to conditions that trigger blooms and that a more complete understanding of how these conditions develop could inform decisions about reservoir operation so that blooms could be avoided.

  The major objective of this project is to describe the microbial and non-living components of Pineview Reservoir ecology and how the operation of the reservoir affects these components.

  The complex interactions of microbial communities and their non-living environment are not well understood. The results of the project will provide scientific insight into the microbial ecology of reservoirs in the intermountain region.

- **Benefits to 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. Knowing the microbial ecology of the reservoir and the phytoplankton response to nutrients and other physical and chemical conditions can inform reservoir and watershed managers' decisions so that the quality of the reservoir can be protected.

- **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 watershed and reservoirs in Utah and the intermountain west.

- **Accomplishments:**

  Findings: The reservoir is thermally stratified during summer months. Surface water nutrient loading is relatively low, and 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. Nutrient loads contributing to primary production in the reservoir are from multiple sources including irrigation return flows through groundwater; internal cycling from iron-rich reservoir sediments; and tributary streams.

Results: The bottom-draw, high flow operation of the reservoir in the summer and early fall results in a substantial fraction of the phosphorus loaded to the reservoir being exported when anoxic, nutrient laden water is withdrawn for irrigation and other uses.

Work Plan FY 10/FY11

In-reservoir process monitoring will continue at a reduced level. Efforts to describe and evaluate watershed processes that contribute phosphorus and nitrogen to the reservoir will increase. High frequency monitoring instrumentation on the South Fork of the Ogden River will continue to operate. A similar instrument package will be installed on the North Fork of the Ogden River. Grab sampling on other major tributaries will be conducted. Ground water quality monitoring near the reservoir will be expanded.

Informational Resources

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

Figure 1. Groundwater monitoring.

Figure 2. Instruments on the south branch of the south fork of the Ogden River.

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 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 State:**

  Application of this and related technologies in the Sevier River Basin in the past several years have already shown a dramatic increase in 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 and experiments are on-going to use this imagery to provide estimates of soil moisture everywhere in the Canal B command area.

Work Plan FY 10/FY11

- 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 the use of UAVs.
- 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 Williams

Partners/Collaborators:
- ***State**: Roger Wilson– Utah Division of Wildlife Resources*
- ***Business/Private:** Warren Colyer, Kirk Dahle – 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 State:**

  The information from this study can be used as a guide for conservation efforts in the State of Utah and reconnection of Bonneville cutthroat trout habitat throughout their current range. Specifically, it 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 the conservation efforts of Trout Unlimited. This study will provide explicit information concerning migrations and conservation of interconnected cutthroat trout populations within 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. Tracking has been conducted on a weekly basis.

  Results: Initial tracking efforts have helped identify spawning areas of migratory Bonneville cutthroat trout in the Cub River.

Work Plan FY 10/FY11

Additional tagging efforts (20 Bonneville cutthroat trout) will be conducted during the downstream migration period in fall, 2010. Tracking efforts will continue on a weekly basis through 2010 and into the spring and summer of 2011.

Informational Resources

Contact: Dr. Casey Williams, (435) 797-1184, E-mail: casey.s.williams@aggiemail.usu.edu.

Bonneville cutthroat trout implanted with a telemetry tag during early March on the Bear River.

The same Bonneville cutthroat trout 4 months after the surgery was conducted.

Stream Restoration in Boulder Creek, Utah: Effects of Increased Stream Discharge and Non-native Fish Removal

Principal Investigators:
Casey 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 is evaluating realistic quantifiable objectives for instream flow restoration associated with hydropower operations. Population response of the Colorado Cutthroat Trout within the main stem Boulder Creek, as well as the East and West Forks of Boulder Creek, is being monitored in order to assess the impact of both non-native trout removal and restoration of bypass flows below the East Fork Diversion structure.

  Quantitative assessments of proposed mitigation actions associated with non-native fish removal and bypass flow releases 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 State:**

  This research will inform resource managers in the State of Utah on 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, Garfield County.

  Study Area: Garfield County, Utah.

  Areas Benefited: Garfield County 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 age structure. These baseline data have been used to establish control sites and sampling sites throughout the system for use in long-term monitoring. Fish barriers have been established and the initial eradication of non-native trout has been completed.

  Results: An assessment of 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 FY 10/FY11

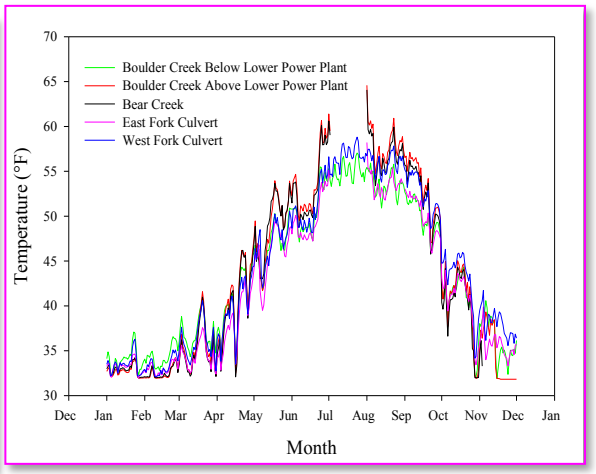
Additional monitoring of flow, temperature, macroinvertebrates, and fisheries resources will be undertaken throughout the spring, summer, and fall of 2010/ 2011. In addition, UWRL personnel will participate in the fall 2010 non-native fish removal activities.

Informational Resources

Contact: Dr. Casey Williams, (435) 797-1184, E-mail: casey.s.williams@aggiemail.usu.edu.

Hardy, T.B., C.S. Williams, and C.W. Thomas (2010). *Trout population monitoring in Boulder Creek: 2009*, Utah Water Research Laboratory, Utah State University, Logan, UT.

Macroinvertebrate Sampling.



Temporal Temperature Profile.

Colorado River Cutthroat Trout.

Treated Wastewater Use in Agricultural Irrigation

Principal Investigators:
Gary Merkley
Leila Ahmadi

Partners/Collaborators:
- ***Local:*** *Cache Valley municipalities and 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 very well compensate for the ~~"l~~oss" 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 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 augmented wastewater volumes 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: The data collection is mostly completed, and the modeling work continues; however, there are no findings to date.

  Results: The study has not yet been completed and there are no results to date.

Work Plan FY 10/FY11

This project will be completed in December, 2010. Data collection will be completed, and the modeling work continues. Various operating scenarios for treated wastewater usage in irrigated agriculture will be developed and compared, and conclusions and recommendations will be made about the feasibility of each scenario.

Informational Resources

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

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

UAV Remote Sensing Service Center

Principal Investigators:
Thomas 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 low-cost, 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 continue 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 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 with the service center. 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 get some 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). 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 for these applications.

A new workshop was equipped with tools, workbenches, shelving, and enough materials to build nine aircraft. Of the nine aircraft, two have been built and are fully functional. Enough equipment, including a ground station, was also acquired to support three crews in the field.

In the past year, the AggieAir Flying Circus has provided support to research contracts in five 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 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 a Certificate of Authorization (COA) from the US Federal Aviation Authority (FAA) in this past year that certifies the AggieAir platform as being airworthy and authorizes 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.

Work Plan FY 10/FY11

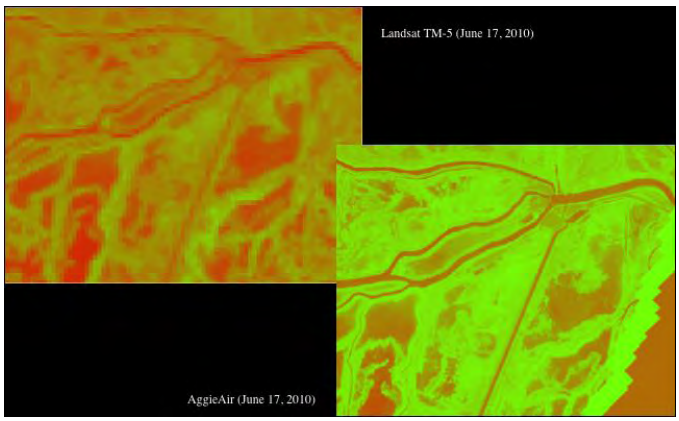
- Complete work on training manuals.
- Hire and train more crew members to handle a larger workload.
- Expand the AAFC business base through acquisition of more research contracts.
- Develop and license a spinoff company to market AggieAir technology, both aircraft and downstream services.

Informational Resources

Contact: Mr. Austin Jensen, Phone (435) 797-3315, E-mail: austin.jensen@aggiemail.usu.edu.
Website: http://aggieair.usu.edu/

Niobrara River (overlain on a Google Earth image), in support of a research contract on in-stream flow management for the University of Nebraska.

As-build Aerial Images of a portion of the Southern Parkway Highway, in Washington County, Utah, for the Utah Department of Transportation.



Comparison of NDVI Satellite Imagery (left, from Landsat 5), with 30-meter resolution, and imagery from the AggieAir Flying Circus (right), with 1-foot resolution, Bear River Migratory Bird Refuge.

Water Conservation and Drought Planning with Reservoir Carryover Storage

Principal Investigators:
David E. Rosenberg

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*
- ***State:*** *Scott Adams, Scott Stonely, David Cole, UDWR; Jim Wells, Utah Water Rights*
- ***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, technology, 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 with the need to coordinate with 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 help simulate water availability and plan for and respond to droughts.

- **Benefits to State:**

  The 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). The value landscape engineering project has also made analysis tools and information available to landscapers, home and business owners to help them identify the lifecycle financial costs, labor requirements, water use, and energy use of their landscaping choices. This information can help owners select water- and energy-efficient landscapes. 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 to better help plan drought responses, estimate runoff and flows to the Great Salt Lake, and estimate flows required for environmental purposes. Using and extending the tools can reduce drought coping 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 Area:

  - Indexing water conservation project: Detailed end-use data was collected by Aquacraft, Inc. in Oakland, CA; Seattle, WA; and Tampa, FL. The approach and findings, however, are applicable in Utah, and, Aquacraft is completing an end-use study for Salt Lake City, UT which may be available for further study.
  - Intervening to encourage water conservation project: currently with the Cities of Logan, St. George, and Cedar City, we expect to add more cities along the Wasatch Front.
  - Value landscape engineering project: Utah-statewide. The tool is generic and allows users across the state to modify inputs specific to their local growing conditions.
  - 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:

  - Both technology and behavioral factors influence water savings indoors from retrofits.
  - Households with more occupants and that used toilets, showers, and faucets more frequently saved the most water from retrofits.
  - Replacing typical cool-season turfgrass (such as Kentucky Bluegrass) with warm-season turf (such as Bufallo grass) can synergistically save water, money, labor, and fertilizer.
  - Property owners can realize substantial savings if they mow, edge, trim, and maintain turf and other landscape features at recommended frequencies.

  Results:

  - Completed the spreadsheet tool and user's guide for the value landscape engineering analysis. Submitted paper to Journal of the American Water Resources Association.
  - Presented estimating and verifying work at World Environmental & Water Resources Congress in Providence, RI, May 16-20, 2010.
  - Interviewed 24 managers and conservation coordinators throughout the state.
  - Held 5 water-conservation oriented focus groups with 30 people.
  - Cities of Logan, St. George, and Cedar City agreed to participate in 5-year study.

Work Plan FY 10/FY11

- Complete recruitment testing and then submit proposal to NSF Environmental Sustainability program to fund subsequent, 5-year water conservation study.
- Build a systems model including water and energy conservation actions for Salt Lake City.
- Build a reservoir simulation model for the Weber Basin using either WEAP or RiverWare.

Informational Resources

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