MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2014

for

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

by

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Foreword

The Utah Water Research Laboratory (UWRL) located at Utah State University (USU) has been a leader in water and environmental research for over 50 years. The UWRL receives 2¼% of all deposits made to the Mineral Lease Account, "to be used for activities… having as a purpose the development and exploitation of water resources in the State of Utah."

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

1. Actual expenditures for FY 2014

2. Budgeted expenditures for FY 2015

3. Planned expenditures for FY 2016

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

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

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

Mac McKee
UWRL Director

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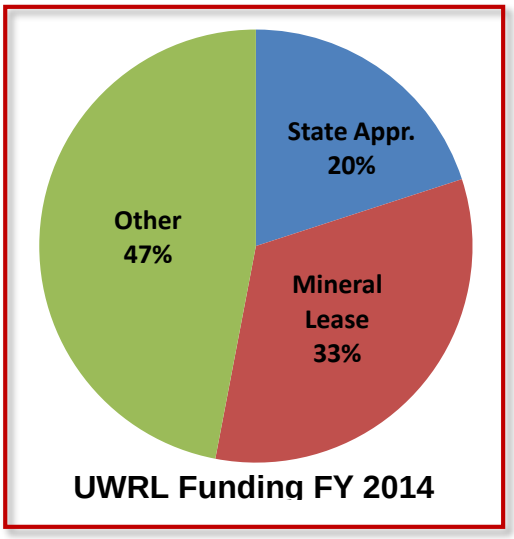
Introduction

Role of the Utah Water Research Laboratory

Research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and are also recognized throughout the nation and the world. The State of Utah provides state-appropriated funds (SAF) and mineral lease funds (MLF) for research support at the UWRL. These funding sources directly target problems facing the State of Utah. In FY 2014, MLF funding of over 3 million accounted for 33% of total UWRL expenditures. With additional funding from federal, private, and other state sources (as shown in the pie chart), the total UWRL expenditures for FY 2014 were almost $ 10 million.

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

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



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

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

A brief summary of the ongoing work in each of the six research areas is presented at the end of this 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 UWRL is involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships, as well as public and professional service, technology and information transfer, and public education. Almost all research and applied projects include graduate student involvements, and result in masters or doctoral degrees. Undergraduate student involvement in UWRL projects for the purpose of student education and training is also integrated into the basic and applied research programs.

UWRL Student Involvement FY 2014

Graduate Students Supported	(FY 14)	67
Undergraduate Students Supported	(FY 14)	110

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

History of the Utah Water Research Laboratory

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

In 1964, Congress approved the Water Resources Research Act that created a water research institute in every state. The Utah institute, known as the Utah Center for Water Resources Research (UCWRR), was established at the UWRL as part of a national network of water research institutes. With total research funding through the UWRL of nearly $10 million, it is one of the largest institutes in the nation. As shown in the table below, it is also highly productive in terms of research publications and graduate student education.

There are currently 36 faculty and 31 support staff at the UWRL. During FY 2014, 29 master's students, 42 doctoral students, and 3 hourly post-doctoral fellows received support from UWRL projects. An additional 110 undergraduate students assisted with UWRL research. UWRL faculty collaborate with colleagues from other USU departments, faculty from other institutions, professionals form the private sector, and government agencies in Utah and elsewhere. Several of our faculty members, including the former UWRL Director, have been awarded the Utah Governor's Medal for Science and Technology. In addition, our faculty have received many national honors and recognitions, and served on national and international engineering and science panels and committees

UWRL Financial/Academic Summary (FY 2014)

Research Products (FY13)	
Number of Active Projects	257
Dollar Value of Active Projects	9,558,374
Scholarly Publications in Peer-Reviewed Journals	95
Scholarly Presentations at Professional Conferences	147
Outreach Products (FY13)	
Short Courses and Field Training	16
Degrees Granted	
Ph.D.	8
MS	24
ME	6

Management of USGS 104 Program for State Benefit

The Water Resources Research Act of 1964 created a national network of Water Resources Research Institutes (WRRIs) in the United States and an allotment program providing funds for the institutes, called the Section 104 Program. The Utah Institute, known as the Utah Center for Water Resources Research (UCWRR), is located at the Utah Water Research Laboratory (UWRL). Currently, the Section 104 Program is funded at an annual level of approximately $92,000 of federal funds through the U.S. Geological Survey (USGS). This year, the base grant in combination with MLF directly benefit the State of Utah in areas of (1) developing a capability to evaluate and implement drought indices on a spatial basis for inclusion in a National Integrated Drought Information System (NIDIS) pilot study creating a drought early warning system for the Upper Colorado River Basin; (2) developing a framework for estimating crop water use using remote sensing through a standardized approach, thus providing guidelines and specifications for applying certain evapotranspiration (ET) models and producing ET products that are acceptable to the USGS WaterSmart program and the scientific and user community; (3) investigating the value of using AggieAir, a low-cost, high-resolution multispectral remote sensing platform, as a tool to provide accurate and quality spatial data for municipal applications to help manage water and environmental issues in wetland and riparian areas, landfills, and parks and recreation areas; (4) determining the impact of dissolved oxygen depletion from coarse particulate organic material in the Jordan River and determining the impact of dissolved organic material loading on the oxygen demand and subsequent oxygen depletion within the lower Jordan River (5) using an inexpensive unmanned aerial vehicle (UAV) to provide high resolution, up to date aerial imagery in support of restoration schemes ongoing in the San Rafael River in South Central Utah and determining the accuracy and limitation of this platform for providing digital elevation and terrain models in place of more conventional, and more expensive, approaches. In the future, the USGS 104 Program will continue to be used to support applied research tools and accomplish information and technology transfer to address Utah's water quantity and quality problems, other source water protection strategies, and development of tools and programs across the State of Utah.

Mineral Lease Fund Expenditures

The table at the beginning of the next section summarizes the actual, budgeted, and planned expenditures of MLF allocated to the UWRL for FY 2014 and FY 2015 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 11% of total MLF budgeted and planned expenditures in FY 2014 and FY 2015.

Relevancy and Benefits of the Mineral Lease Fund

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

Research Program

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

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

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

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 website: http://uwrl.usu.edu.

Utah Department of Natural Resources Division of Water Resources State Engineer – Division of Water Rights	**Utah Department of Environmental Quality** Air 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 Utah Governor's Unmanned Aerial Systems Test Site Advisory Board	**State Water Associations and Organizations** Utah Center for Water Resources Research (UCWRR) Utah Division of Air Quality Utah Rural Water User's Association Water Environment Association of Utah Utah League of Cities and Towns Utah On-Site Wastewater Treatment Association
Professional Organizations and Associations American Water Resources Association American Society of Civil Engineers American Water Works Association Water Environment Research Foundation (WERF)	**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) Water Environment Research Foundation (WERF)

Public Service

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

- Drinking Water Board
- Water Treatment Operators Certification Commission
- Salt Lake County Solid Waste Management Council
- Utah State Solid and Hazardous Waste Control Board
- Cache County Solid Waste Advisory Board
- Jordan River Water Quality Technical Advisory Committee (Utah DEQ)
- Willard Spur Science Panel, a panel formed by the Utah Division of Water Quality
- Utah Division of Water Quality, Department of Environmental Quality, Task Force Member, R317-4 Onsite Wastewater Systems Stakeholders Workgroup

- Water Environment Association of Utah, Board of Directors and Biosolids Committee
- Logan City Air Quality Task Force
- Bear River Health Department's Air Task Force
- Governor Herbert's Unmanned Aerial Systems Test Site Advisory 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, and national and international organizations engaged in financing water developments, such as the World Bank.

Information Dissemination and Technology Transfer

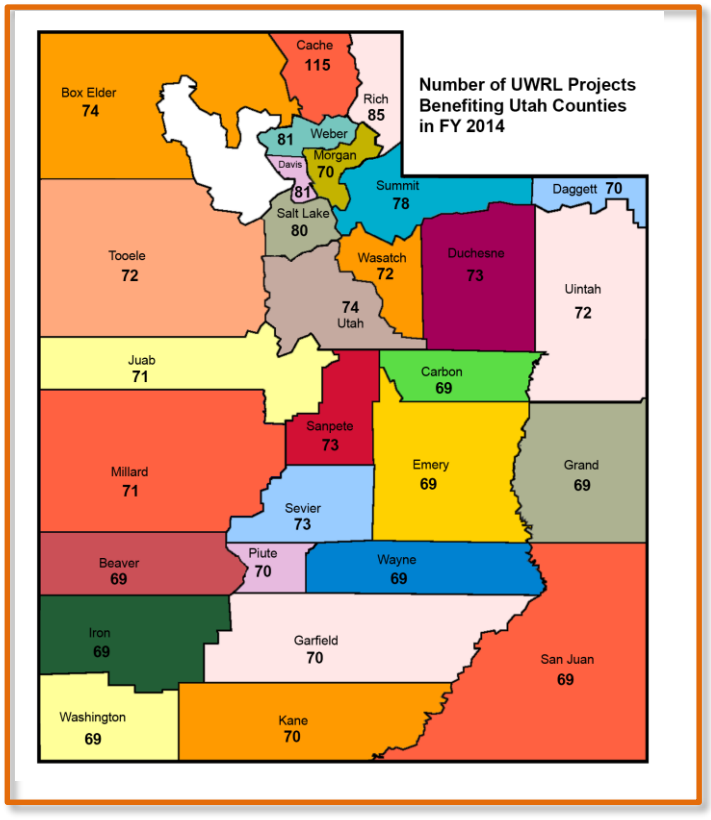
UWRL information dissemination, outreach, and technology transfer activities include the publication of research results in professional journals, distribution of information on various UWRL and UCWRR web pages and newsletters, presentations before various professional societies at organization and association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

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

Benefits to the State of Utah

MLF funding is often used as leverage to acquire additional funding from other sources, which allows us to perform even more research in the State. As shown in the map, a significant number of total UWRL projects conducted during the past year that have benefited each of Utah's counties

The following summaries report some of the recent and current benefits produced by MLF funded projects in the UWRL's six program areas, and specific state benefits are detailed in each project summary in subsequent sections of this report.



Drinking Water and Wastewater Treatment

The program is developing engineering approaches for the treatment and production of

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

Environmental Quality Management and Remediation

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

Surface and Groundwater Quality and Quantity

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

Water Conveyance, Distribution and Control

This program utilizes UWRL's unique hydraulics laboratories 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 pipe network designs for water supply, sediment transport, non-contact flow measurement, open channel flow, low-head dam effects, and dam safety risk analysis.

Water Education and Technology Transfer

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

Water Resources Planning and Management

This program area addresses various institutional and legal aspects of water, such as rights transfers, distributed water demand and supply modeling using geographical information systems, and cost allocation and determination of user fees for multiple purpose water resources projects. Additional areas include reservoir operating policies, water conservation, river basin planning, habitat monitoring and restoration, user-driven decision support systems for water planning, and incorporation of remote sensing technology to improve water resources management.

Administration

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
Business Office	$161,585.34	$166,432.90	$171,425.89
Laboratory Infrastructure Support, Travel and Special Request	$66,894.69	$27,000.00	$27,810.00
Publications Office	$69,151.84	$71,226.40	$73,363.19
UWRL Administration	$81,863.87	$84,319.79	$86,849.37
Total	**$379,495.74**	**$348,979.09**	**$359,448.45**

Administration, Advisory Support, and Special Equipment

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

Administration of the MLF Program

The costs of administering the MLF program at the Utah Water Research Laboratory are deliberately held as low as possible, consistent with the needs of evaluating the productivity of the research supported by MLF funds. Collaboration with water managers and policy makers in state and local agencies identifies where applied research can contribute toward the solution of important water resources problems. MLF money spent on administration at the UWRL provides minimal salary support for the UWRL Director and Associate Director and supports the administration of the USGS 104(b) program funding that comes to the state. FY 2014 administrative costs represented approximately 9% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL fluctuate between $ 8 and $ 12 million, and at any point in time there will be nearly 250 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 2014 on these support activities accounted for 2% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2014 for advice and collaborative help on various water problems in the state. In FY 2014, the UWRL provided support to defray travel costs from MLF sources so UWRL faculty could participate in meetings in the state to coordinate UWRL activities with ongoing water problems, to work to identify and seek funding for new applied research in the state, and to provide expert advice relative to current water management issues faced by various state and local agencies. These activities are enumerated in the project reports section of this document.

Special Equipment

Numerous communities in Utah face problems with the management of soils and aquifers that have been contaminated by hazardous materials. The UWRL is active in providing state-of-the-art scientific input to understand these problems. Similarly, the UWRL is engaged in applied research on the management of contaminants of concern for various municipalities that supply potable water to communities in the state, such as is the case for current research on metals and pharmaceuticals for Park City water supplies and wastewater. The UWRL also 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 sometimes made from MLF resources to support these activities and to provide long-term, sustainable capability to continue these efforts in the state. New equipment acquisition and their integration into research are described in specific project reports.

Research Project Summaries

Research Project Summaries

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

Drinking Water and Wastewater Treatment

Environmental Quality Management and Remediation

Surface and Groundwater Quality and Quantity

Water Conveyance, Distribution and Control

Water Education and Technology Transfer

Water Resources Planning and Management

Drinking Water and Wastewater Treatment

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
Biological Phosphorus Removal from Lagoon Wastewater: Pilot-Scale Rotating Algae Biofilm Bioreactor (RABR)	$95,705.76	$98,576.93	$87,300.00
Effectiveness of Utah's On-Site System Design: Depth Considerations and Removal of Emerging Contaminants of Concern	$24,967.56	$56,500.00	$55,000.00
Enhancing Methane Production at Water Reclamation Facilities	$74,830.91	$77,075.84	$0.00
Low Level Hexavalent Chromium (Cr-6) in Drinking Water	$37,766.07	$56,000.00	$0.00
Managing Drinking Water Quality in Park City, Utah	$201,417.55	$207,460.08	$0.00
Producing Bioplastic Materials Using Microbe-Based Processes	$13,722.19	$37,500.00	$0.00
Designated Projects		$227,740.00	$15,400.00
Undesignated research projects in program area		$63,000.00	$10,000.00
Total	**$448,410.04**	**$823,852.85**	**$167,700.00**

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

Principal Investigators:
Ronald C. Sims
Charles Miller
Yousef Soboh (PhD student)
Maureen Kesaano (PhD student)
Terence Smith (MS student)
Chad Nielson (BS student)

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  In addition to removal of phosphorus, Logan City has recently been required to remove both phosphorus and nitrogen from wastewater leaving the Logan Lagoons treatment plant in order to meet water quality criteria established through total maximum daily load (TMDL) studies by the State of Utah, specifically to prevent pollution of Cutler Reservoir. The current lagoon-based system must be upgraded. In order to upgrade the system, a biological-based engineering technology that accomplishes both phosphorus and nitrogen removal to 1 mg/ L or less could save in excess of $40 million compared with the installation and operation of a fully mechanical plant. The new technology, which is based on the uptake of phosphorus and nitrogen by algae grown as a biofilm, is being tested on site in cooperation with Logan City.

- **Benefits to the State:**

  The new biofilm-based engineering technology will allow the creation of new engineering jobs and services in Utah that will boost economic growth and allow other communities using lagoons to upgrade treatment to meet standards at reduced costs (fees) to the communities, as compared with conventional technologies. 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.

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Findings: (1) The Rotating Algae Biofilm Reactor (RABR) that was utilized and described in the 2013 report was redesigned to reduce the amount of energy required to operate the system. This was accomplished by reducing the motor size from 1/ 12 horsepower (hp) to 1/ 58 hp, reducing the turning frequency from 24 hours per day to 12 hours per day, and reducing the friction involved in the rotation of the polygon (Figure 1). (2) In other tests, the RABR successfully removed both nitrogen and phosphorus to levels below 1 mg/ L. (3) Winter operation was successful when the RABR was covered with translucent plastic.

Results: The RABR technology was evaluated using the U.S. Department of Energy assessment protocol whereby the energy required by the system is compared with the energy output of the system, in terms of algae production. The calculation of "net energy ratio" was significantly improved to attain the target value of 1 (energy input = energy output) when design changes were implemented as described in the "Findings" section above. The RABR technology was able to reduce both nitrogen and phosphorus levels to water quality standards (1 mg/ L) in spring, summer, and some of fall seasons. Winter operation was more variable, and will be tested again during the winter season.

A plastic cover was constructed again this year over the enhanced RABR in order to reduce the high levels of toxic sunlight that impact the algae during the summer months, and to provide a greenhouse effect that will increase the temperature during the winter months. The plastic cover reduced light intensity impacting the algae biofilm surface by 30%. The effect of the cover will be determined again in the coming winter to meet the request from the UDEQ for several years of operating and performance data.

Work Plan FY14/FY15

Future research will evaluate nitrogen and phosphorus removal in the winter season, along with mathematical modeling of biofilm growth and performance.

Informational Resources

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

Publications

Kesaano, M. and R. Sims (2014). *Algal Biofilm Based Technology for Wastewater Treatment*. Algal Research. Doi:10.1016/ j.algal.2014.02.003. http:/ / www.sciencedirect.com/ science/ article/ pii/ S221192641400023X.

Figure 1. Logan City Wastewater Reclamation Plant. Single Rotating Algae Biofilm Reactor (RABR) modified with 1/58 hp motor and 12 hours operation (foreground) to reduce energy requirements; RABR system accomplish removal of both nitrogen and phosphorus (background)

Effectiveness of Utah's On-Site System Design: Depth Considerations and Removal of Emerging Contaminants of Concern

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

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

Project Description

- **Need and Purpose:**

  This study investigates the effectiveness of Utah's design procedures for on-site wastewater treatment systems (more commonly known as septic systems):

  Focus Area No. 1: Common practice for on-site wastewater treatment is to locate drain fields at shallow depths in order to maximize aerobic decomposition of organic contaminants, to enhance evapotranspiration in order to reduce transport of contaminants to ground water, and to increase 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 in soil materials that are more permeable than surface layers. The concern is that treatment is not effective at these depths. We are studying how these deep systems perform with regards to treatment of contaminants.

  Focus Area No. 2: Proliferation of new pharmaceuticals and personal care products (PPCP) has resulted in an increased interest in the fate of these emerging contaminants in on-site wastewater treatment systems. This part of the study examined the fate of six selected emerging contaminants (i.e., acetaminophen, caffeine, sulfamethoxazole, fluoxetine, carbamazepine, and progesterone) in a controlled laboratory setting simulating a Utah conventional pipe and gravel on-site drain field and an engineered pipe and gravel drain field, with added absorptive media (peat and charred straw) below the gravel. In addition, laboratory batch studies were conducted to evaluate quantitatively the potential fate (biodegradation and sorption) of the selected contaminants in peat/ soil and charred straw/ soil environments.

Site locations in Cache Valley

- **Benefits to the State:**

  Focus Area No. 1: 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 these investigations are providing information to the health departments on whether they can either continue permitting these types of systems with confidence or should eliminate the use of the systems.

Deep trench system installation, Wellsville, November 2008

  Focus Area No.2: State regulators, including staff at the Utah Division of Water Quality, are becoming more involved in setting requirements for the removal of emerging contaminants of concern from wastewater. Information on ways that on-site systems can be modified to improve removal will be of critical importance.

- **Geographic Areas:**

  Study Area: Cache County.

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

- **Accomplishments:**

  Findings: Focus Area No. 1: 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 utilized deep trenches for treatment of wastewater and four utilized shallow trenches. We have analyzed data collected from the site. We also worked with the owners of the sites to educate them on proper septic system use practices. Focus Area No. 2: Columns were constructed to simulate conventional pipe and gravel on-site wastewater drain fields as well as engineered drain fields containing absorptive materials (peat and charred straw) designed to enhance removal of PPCPs. Septic tank effluents spiked with each contaminant of concern were pumped into the columns, and samples were collected from the bottom of the columns and analyzed for the presence of each of the selected contaminants. Laboratory Batch Studies: The major mechanisms (adsorption, biodegradation, or volatilization/ hydrolysis) for target PPCP reductions in a conventional drain field and in engineered drain fields were investigated by comparing concentrations of the selected PPCPs in PCCP-spiked wastewater reactors compared to PPCP-spiked wastewater reactors with inhibited microbial activity.

  Results: Focus Area No. 1: Leachate samples from the drain fields continue to be analyzed for nitrate nitrogen, phosphorus, coliform bacteria, total suspended solids, and biological oxygen demand to determine treatment effectiveness in both the shallow and deep trench systems. Results continue to indicate that satisfactory treatment of these wastewater contaminants is occurring in both shallow and deep systems. Focus Area No. 2: The column study experiments established that both the conventional and engineered on-site wastewater drain fields have the ability to reduce the concentrations of four of the six target PPCPs. However, the charred straw columns provided the best removals. Laboratory Batch Studies: Results from batch reactor experiments to determine removal mechanisms indicated that volatilization/ hydrolysis was a minimal mechanism for target PPCP concentration reduction. Results also showed that adsorption was the main mechanism for PPCP concentration reduction with the exception of progesterone, where biodegradation played a significant role. Isotherm experiments showed that, overall, charred straw had greater PPCP adsorptive capacities than the peat and soil for most of the contaminants.

Work Plan FY14/FY15

For Focus Area No. 1, we will analyze leachate produced within the eight study drain fields and will continue to determine treatment effectiveness in shallow and deep drain fields. Focus Area No. 2 research has been completed.

Informational Resources

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

Beardall, James (2014). *The Fate of Pharmaceuticals and Personal Care Products in Conventional and Engineered On-Site Wastewater Drain Fields*. M.S. Thesis (Draft), Department of Civil and Environmental Engineering, Utah State University, Logan, UT.

Enhancing Methane Production at Water Reclamation Facilities

Principal Investigators:
Michael J. McFarland
Morris Demitry

Partners/Collaborators:

- ***Local:*** *Lance Wood, Central Weber Sewer Improvement District, Kevin Hall, Central Weber Sewer Improvement District*
- ***State:*** *Dan Griffin, Utah Division of Water Quality; Jeff Barrett, Utah Governor's Office – Renewable Energy Initiative*

Project Description

- **Need and Purpose:**
  Food manufacturers in Utah discharge significant amounts of organic matter including fats, oils, and grease (FOG) into local municipal wastewater collection systems (i.e., sewers). These highly degradable organic wastes result in a large oxygen demands occurring at local wastewater treatment plants, which can cause increased risk of regulatory noncompliance. Moreover, FOG has historically created a severe problem in Utah sewers by restricting flow and resulting in sanitary sewer overflows.

  In order to increase energy production and provide a beneficial reuse of food wastes, several utilities in the United States have been evaluating the co-digestion of food wastes with municipal sewage sludge to enhance methane production. Although the feasibility of increasing methane production through the co-digestion of food wastes with municipal sludge has been demonstrated in laboratory studies, the limited solubility of lipids, as well as long-chain fatty acids, has been cited as a major cause for digester failure.

  The purpose of this research is to establish the technical feasibility of enhancing methane production at the Central Weber Sewer Improvement District Wastewater Treatment Plant (WWTP) using co-digestion with bakery wastes from a large food manufacturer in the state of Utah (CSM Bakeries). Central Weber Sewer Improvement District WWTP currently utilizes their methane gas in co-generation systems to produce electricity that is used to offset their power requirements. Figure 1 depicts the anaerobic digester and co-digestion system at the Central Weber Sewer Improvement District.

- **Benefits to the State:**

  Successful results from this graduate research activity will generate a number of benefits for the state of Utah including the following:
  - Generate new markets for food and other organic wastes
  - Expand the generation and use of renewable energy
  - Reduce organic waste generation through recycling activities
  - Develop new energy production for Utah water reclamation facilities
  - Improve wastewater conveyance system operations

- **Geographic Areas:**

  Study Area: Weber County, Utah

  Areas Benefited: The entire state of Utah

- **Accomplishments:**

  Findings/Results: Preliminary results have shown that co-digestion with bakery wastes and municipal sewage sludge is not only possible but has great potential to allow wastewater treatment plants to lower their need for external fossil fuels. With bakery wastes representing about 5% of the influent flow to the anaerobic digesters, there have been no signs of digester upset while significantly more biogas has been recorded.

Work Plan FY14/FY15

The Utah State University team will work in close collaboration with the technical staff at the Central Weber Sewer Improvement District and the State Department of Water Quality to accomplish this project. The technical focus for the next fiscal year will comprise the following four tasks:

1. Estimate the theoretical production of methane from the co-digestion of bakery wastes from CSM Inc.
2. Continue to increase the organic loading rate to determine the upper limits to co-digestion.
3. Determine if Central Weber Sewer Improvement District can reasonably achieve energy net neutrality using bakery wastes.
4. Develop best management practices for the collection, transport, and management of food wastes by the facility.

Informational Resources

Contact: Dr. Michael J. McFarland, PE, BCEE, Phone: (435) 994-0905, Email: farlandm1@outlook.com.

Figure 1. Anaerobic Digestion System at the Central Weber Sewer Improvement District WWTP (a); Co-Digestion Engine (b)

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

Principal Investigators:
Laurie S. McNeill
Joan E. McLean
Christel Olsen (Graduate student)
Rahel Beyene, (Undergraduate student)
Nate Rogers (Undergraduate student)
Chelsea Stewardson (Undergraduate student)

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  In December 2010, the Environmental Working Group (EWG) issued a public report about hexavalent chromium (Cr-6) occurrence at very low levels in US drinking water sources. In that report, Salt Lake City, UT, was targeted as a system of concern due to a detection of 0.3 parts per billion (ppb) of Cr-6, which was the 11th highest level of the 35 cities tested. SLC easily complies with the current Maximum Contaminant Level (MCL) for Total Cr, which includes both trivalent chromium-3 (Cr-3, a trace nutrient) and hexavalent chromium (Cr-6, a likely human carcinogen). Nevertheless, this report generated a lot of concern within the SLC Department of Public Utilities, other drinking water systems in Utah, and the public they serve. The US Environmental Protection Agency (USEPA) is currently reviewing toxicology data for Cr-6, and may establish a new MCL specifically for Cr-6. A new federal MCL for Cr-6 is likely to be substantially lower than the current MCL for Total Cr, which will have an enormous impact on drinking water systems across the US. The State of California recently established their own MCL for Cr-6 at 10 ppb.

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

- **Benefits to the State:**

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

- **Geographic Areas:**

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

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

- **Accomplishments**:

  Findings/Results: Bench-scale testing was done to investigate mechanisms of chromium removal by "reduction coupled coagulation," where ferrous iron (Fe^{+2}) coagulant is added into conventional ferric iron ($FeCl_3$) coagulants. Results indicate that this method significantly improves Cr-6 removal, which was confirmed by sampling conducted at a full-scale treatment plant in Utah (comparing Figure 1 [conventional coagulation] to Figure 2 [reduction coupled coagulation]).

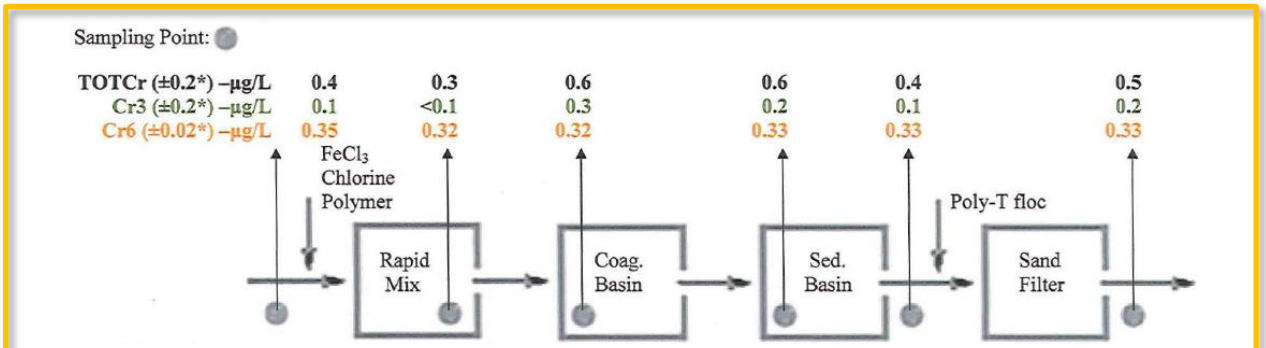


Figure 1: full-scale treatment plant profile using conventional coagulant. Note the Cr6 remains essentially unchanged, with the raw water at 0.35 ug/L and the plant effluent at 0.33 ug/L.

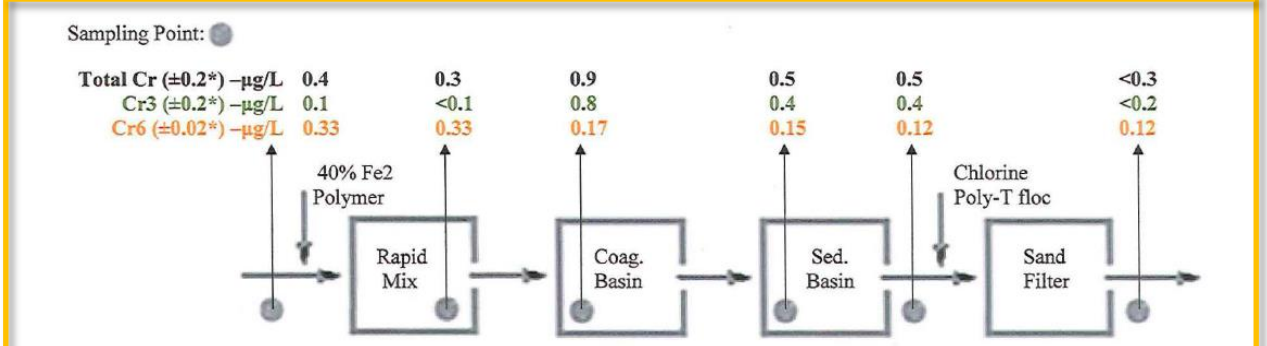


Figure 2: full-scale treatment plant profile using reduction-coupled ferrous coagulant. More than 60% of the Cr6 is removed (raw water value of 0.33 ug/L decreased to 0.12 ug/L in the effluent).

Preliminary results from this MLF project were used to leverage four external research grants to further investigate Cr-6 in drinking water (from the Water Research Foundation, HDR Engineering, Jacobs Engineering, and California Water Services Company). These grants total nearly $500,000, with ~$121,000 in budget for the UWRL.

Work Plan FY14/FY15

Collect additional samples from various water treatment plants across UT to look at sources and treatment of Cr-6.

Informational Resources

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

Publications: Results from this project were presented in one conference poster and will be published in a forthcoming (in press) peer-reviewed journal article.

Managing Drinking Water Quality in Park City, Utah

Principal Investigators:
Laurie S. McNeill
Joan E. McLean
David K. Stevens
William Kent, Tiana Hammer (Graduate students)
Jason Blankenagel, Nate Rogers, Chelsea Stewardson, Rahel Beyene (Undergraduate students)

Partners/Collaborators:

- ***Local****: Park City, UT*
- ***National****: Water Research Foundation*
- ***Business/Industry****: Confluence Engineering*

Project Description

- **Need and Purpose:**

  Park City is one of Utah's most famous cities due to its ski resorts and the Sundance Film Festival. It was named "The Best Town in America" by *Outside* magazine in 2013. However, Park City is also becoming infamous due to its drinking water quality. In 2007 and 2010, Park City experienced adverse water quality events, with discolored water and high levels of arsenic, thallium, manganese, iron, and mercury in their water distribution system. Park City has an incredibly complex water system, with various sources (including groundwater, surface water, and water passing through old mine tunnels), several treatment plants, unique water demand patterns, and a complicated water distribution system with more than 50 pressure zones. The goal of this project is to assess the causes of these adverse water quality events, evaluate monitoring techniques that can be used to predict future events, and recommend strategies to prevent contaminant release. Tasks include the following:

  1. Evaluate historic water quality data as a preliminary assessment of causes of water quality events and assess Park City's current data management practices.
  2. Evaluate techniques to minimize deposition and/ or subsequent release of corrosion scale, sediments, and biofilms in the distribution system. This will include sampling at water sources and in the distribution system, as well as bench-scale experiments.
  3. Develop a strategy for on-line, real-time monitoring of the Park City water system, along with tools to manage and interpret collected data. The ultimate goal is to produce a guidance document to help the water utility respond to changes in their distribution system and avoid adverse water quality events.

- **Benefits to the State:**

  This project will help Park City manage their complex water system to provide high quality water to their citizens and visitors. The understanding gained about chemical and biological processes in the water distribution system, as well as strategies developed for real-time monitoring and assessment of these systems, will be applicable to many other water utilities in Utah and across the US.

- **Geographic Areas:**

  Study Area: Park City (Summit County).

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

- **Accomplishments**:
  Findings/Results: Routine monthly monitoring at 14 different sites within the Park City water distribution system, as well as at eight water sources, was conducted from November 2012

through October 2013. Sites were monitored for field parameters, total and dissolved metals, dissolved major cations and anions, alkalinity, organic carbon, and suspended solids. Data have been integrated into a UWRL-developed database for easy access and analysis by the utility and project team (Figure 1). Two on-line water quality monitoring panels were also installed.

These MLF funds were leveraged into a $495,000 project sponsored by the Water Research Foundation (Assessing and mitigating accumulation and release of inorganics in the Park City distribution system, project lead is Confluence Engineering). For this project, a field trial was conducted in September 2013 to evaluate the effectiveness of three techniques for cleaning deposits out of water pipes (Figure 2). Preliminary results were presented at two conferences.

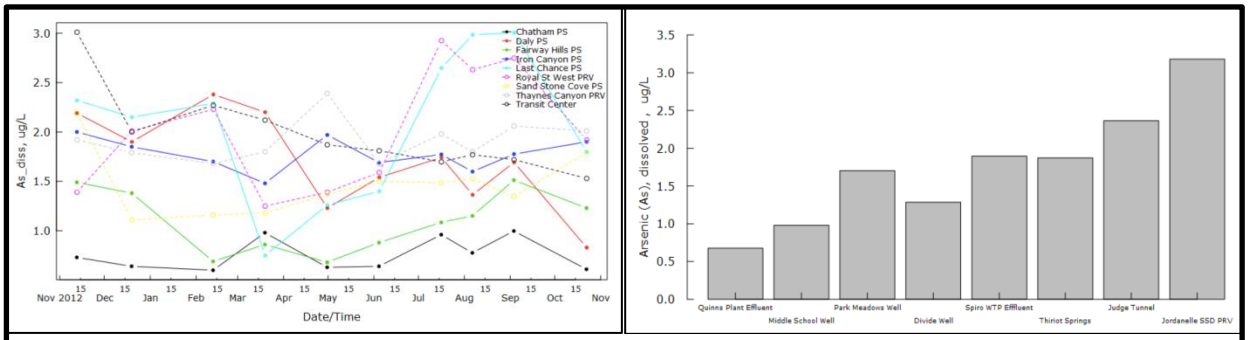


Figure 1: dissolved arsenic at distribution sites (left) and water sources (right)

Figure 2: field trial to flush pipes (left) and resultant sample profile (right)

Work Plan FY14/FY15

1. Compare data from on-line water quality monitoring panels to routine monitoring results.
2. Conduct lab experiments to investigate the role of biofilms and desorption on release of metals from distribution solids.

Informational Resources

Contact: Dr. Laurie S. McNeill, Phone: (435) 797-1522, Email: Laurie.McNeill@usu.edu.
Ms. Joan E. McLean, Phone: (435) 797-3663, Email: Joan.McLean@usu.edu.
Dr. David K. Stevens, Phone: (435) 797-3229, Email: David.Stevens@usu.edu.

Producing Bioplastic Materials Using Microbe-Based Processes

Principal Investigators:
Ronald C. Sims
Charles Miller
Ashik Sathish (Research Engineer)
Asif Rahman (PhD student)
Brian Smith (B.S. student)
Tyler Marlar (B.S. student)

Partners/Collaborators:

- ***Local:*** *Issa Hamud, Logan City*
- ***Business/Industry:*** *WesTech_Inc, SLC*

Project Description

- **Need and Purpose:**

  Bioplastic materials derived from microbes using sustainable and environmentally benign methods are needed to replace non-sustainable petroleum based plastics. New methods to reduce the costs of renewable bioplastic materials are needed to make bioplastics economically competitive with petroleum based plastics. In addition, locally produced bioplastic materials contribute to local economic development, national security, and sustainability. Algae cultivated on municipal wastewater were fed to bacteria that were programmed using synthetic biological engineering principles and tools.

- **Benefits to the State:**

  Microbe-based processes for the production of bioplastic materials that use local organic feed sources will protect water and soil quality, and also generate new jobs, technologies, businesses, and products in Utah. Applications range from one-time use plastics, to commercial packaging, to biomedical designs such as drug delivery systems, tissue engineering, and orthopedics. Bioplastic materials are biodegradable and will reduce the non-degradable plastic materials that accumulate in landfills in Utah communities.

- **Geographic Areas:**

  Study Area: Areas in both urban and rural Utah, and the Logan Wastewater Reclamation facility treating wastes from seven communities in northern Utah.

  Areas Benefited: All areas of the state of Utah, especially rural communities and cities where wastes will be utilized as sources of nutrients for microbes that transform wastes into bioplastic materials.

- **Accomplishments:**

  Findings: Bioplastics were successfully produced when genetically engineered microbes were fed algae, cultivated on wastewater, as a source of carbon and energy. Approximately 4.3 kg of dry algae could be used to produce 1 kg of bioplastic material. The amount of bioplastic material produced was increased with the addition of other food sources.

  Results: The results demonstrate that high value bioplastic materials can be produced using low value waste chemicals. Blending wastewater cultivated algae with other carbon-rich wastes, for example cheese and other food wastes, is expected to increase the production of bioplastic materials.

The resulting process that was developed included algae cultivation, harvesting, and bioplastic products as shown in Figure 1.

Work Plan FY14/FY15

We will optimize the process and utilize algae that are cultivated on agricultural and produced water wastes, blended with feedstocks from other waste materials, to test bioplastic production.

Informational Resources

Contact: Mr. Floyd Griffiths, WesTech-Inc., Salt Lake City, Industry partner.
Dr. Ronald C. Sims, Phone: (435) 797-3156, E-mail: ron.sims@usu.edu.

Publications

Rahman, A., R.J. Anthony, A. Sathish, R.C. Sims, and C.D. Miller (2014). Effects of Wastewater Microalgae harvesting Methods on Polyhydroxybutyrate Production. *Bioresource Technology*. DOI: 10.1016/ j.biortech.2014.01.034.
http:/ / www.sciencedirect.com/ science/ article/ pii/ S0960852414000595.

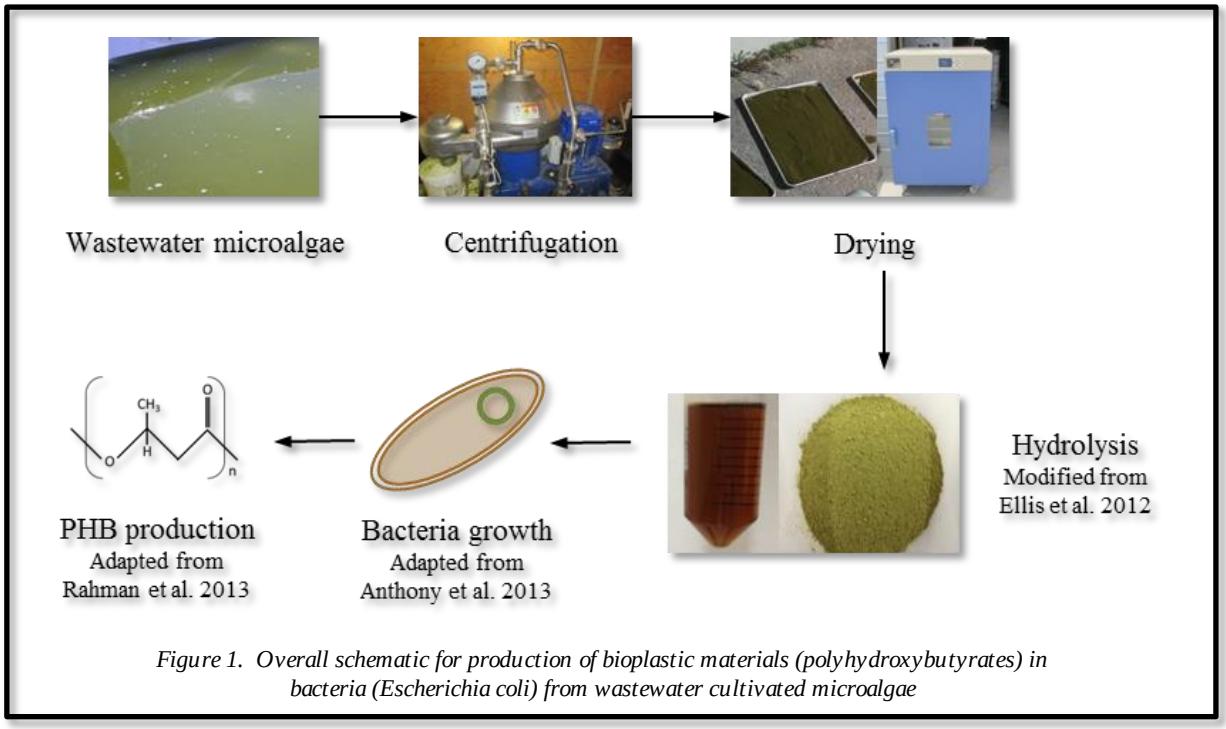


Figure 1. Overall schematic for production of bioplastic materials (polyhydroxybutyrates) in bacteria (Escherichia coli) from wastewater cultivated microalgae

Environmental Quality Management and Remediation

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
Biogeochemistry in TCE Contaminated Aquifers in Northern Utah	$99,935.80	$102,933.87	$33,792.91
Environmental Impact of Expanded Recycling Programs in Salt lake County	$1,000.00	$1,030.00	$1,060.90
Evaluation of Duckweed as a Technology for Management of Nutrients and Pharmaceutical Contaminants in Municipal Wastewater Systems	$32,460.88	$33,434.71	$4,741.70
Impact of Metals and Metal Ions on Soils and Plants	$24,981.19	$58,800.60	$26,522.50
Investigations into Wintertime Indoor vs. Outdoor PM2.5 and Vehicle Starting (Cold vs. Hot) Emissions	$57,142.56	$32,808.65	
Monitoring Organic Contaminants in Air Using Plants as Passive Samplers	$39,807.29	$41,001.51	$42,231.55
Nitrogen Cycling, Oxygen Demand, and the Role of Dissimilatory Nitrate Reduction to Ammonia in Silver Creek below the Water Remediation Facility	$7,521.90	$15,150.00	$0.00
Phytoremediation Evaluation Site for Quantifying the Fate of Trichloroethylene (TCE) Taken Up by Trees	$60,782.42	$62,605.89	$64,484.07
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$13,943.97	$14,362.29	$0.00
Remediation of Chlorinated Sovent Contamination of Groundwater	$76,619.34	$80,272.17	$0.00
Remediation of TCE-Contaminated Soil and Groundwater at Hill Air Force Base (HAFB)	$13,943.96	$44,362.28	$47,471.89
Study of Cache Valley's Vertical Meteorological & Pollutant Profiles and Application to Additional Areas in Utah	$35,694.51	$36,765.35	$37,868.31
Designated Projects		$266,817.91	$57,500.00
Undesignated Projects		$75,000.00	$12,000.00
Total	**$463,833.82**	**$865,345.23**	**$327,673.83**

Biogeochemistry in TCE Contaminated Aquifers in Northern Utah

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Babur Mirza (Post-doctoral Fellow)
Suzy Smith (MS student)
Sarah Kissel (MS student)

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  Trichloroethene (TCE) has been a widely used industrial solvent and is a frequently encountered environmental contaminant. It is also a potential carcinogen. TCE is denser than water and very slow to degrade, especially in oxygenated aquifer environments where labile organic matter concentrations are low. These conditions often exist in contaminated aquifers in Utah. Extensive areas of ground water contamination exist in the industrialized world. TCE contaminates aquifers at Hill Air Force Base (AFB), the Dugway Proving Ground (DPG), and other industrial sites in Northern Utah. Both private and Department of Defense industrial complexes are required to remediate this contamination.

  Biostimulation remediation of TCE adds organic materials to the aquifer. Microbial respiration removes oxygen from the aquifer using this material and creates a reducing biogeochemical environment. Bacteria able to use TCE as a respiratory electron acceptor (dechlororespiration) in this environment may reduce TCE to less chlorinated compounds. The desired, completely dechlorinated product is ethene, a common, non-toxic gas. This research group studied biostimulation of contaminated aquifer material from Hill AFB in microcosms with no observed dechlororespiration. Column (15 x 200 cm) studies conducted over a period of 7.5 years with the same aquifer material showed complete dehalogenation or partial dehalogenation to cis-dichloroethene depending on the kind of organic matter being added. Some investigators have suggested that complete dechlororespiration in biostimulated aquifers is ubiquitous, but the microbial ecology and biogeochemistry for dechlororespiration remains incompletely described, so successful engineering of biostimulation treatment technologies is tenuous.

  To understand the successional processes that occurred in the large columns over time, small columns (7.6 cm x 7.6 cm) were assembled with the same aquifer material used previously. The small columns will be sacrificed at specified times to observe biogeochemical and microbial progression leading to complete dechlorination as affected by organic matter addition.

- **Benefits to the State:**

  All counties in Utah would benefit from improved understanding and the 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 County, and Weber County.

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

- **Accomplishments:**

Findings/Results: Aquifer solids were collected from HAFB in December 2013 (Figure 1). The aquifer solids have been packed into small glass columns (7.6 cm diameter and 7.6 cm in height) (Figure 2) and are being fed with TCE containing groundwater from the site. The treatments include whey and lactate, with a no carbon addition control. All columns are bioaugmented with a culture containing known dechlorinating bacteria. One set of columns (in triplicate) will be sacrificed when the monitored effluent from the columns display conditions defining iron reduction. Additional columns are sacrificed when degradation products of TCE are observed. The aquifer solids and the pore water are analyzed for TCE degradation products, water quality, and geochemical properties. The sediments were also be used to identify the active microbial community involved in partial and full reductive dechlorination using bio-molecular methods. Ultimately, the bacterial makeup of the microbial communities in each column will continue to be compared and inferences made about the role of the differences in the development of dehalogenation activity of the communities. We anticipate that the results, in combination with geochemical results, will indicate biogeochemical functions that are necessary for complete dehalogenation.

Work Plan FY14/FY15

Chemical and microbial analysis and data reduction will continue throughout the year as small columns are sacrificed over time. This project is providing support for two MS students. The students will complete their thesis work over the next year.

Informational Resources

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

Figure 1. Collection of aquifer solids from Hill Air Force Base property

Figure 2. Set-up of small column study for testing sequential microbial processing of TCE under different conditions of biostimualtion

Environmental Impact of Expanded Recycling Programs in Salt Lake County

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

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

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

- **Benefits to the State:**

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

- **Geographic Areas:**

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

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

- **Accomplishments**:

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

An increase in food waste composting at the SLVSWMC by diverting only 3% of the food waste component (≈2,803 T/ yr.) yields a net reduction in the facility's carbon footprint by 715 metric T/ yr. and produces an annual energy savings of more than 2,000 million BTUs.

Salt Lake County data indicate that weekly collection of recyclables would increase overall MSW diversion by only 3% at an additional cost of more than $1 million/ yr. Even this small additional diversion rate could result in significant reductions in the carbon footprint (1,353 metric T/ yr.) and energy consumption (19,654 million BTU); however, the region and nation would realize these significant environmental benefits at a very high cost to West Valley City.

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

Results: Findings and recommendations of this project were disseminated to SLVSWM Council, Salt Lake City, Salt Lake County, and West Valley City personnel for their consideration and implementation. Continued discussion with these entities involved the sensitivity of results in terms of waste composition assumptions, recycling and waste generation rates, etc.

Work Plan FY14/FY15

- Continue energy and environmental footprint analyses for Salt Lake County, Salt Lake City, and other communities in the Salt Lake Valley relative to improving the efficiency of their MSW management programs.
- Re-evaluate study results based on waste and recycling stream audits being conducted by Salt Lake City and Salt Lake County during spring and summer 2014 that reflect the expansion of green waste collection and food waste composting throughout the Salt Lake Valley.

Informational Resources:

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

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

Principal Investigators:
R. Ryan Dupont
Leila Ahmadi (Post-Doc)

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 other contaminants such as personal care products and pharmaceuticals (PCPP) in municipal wastewater systems are of increasing concern due to their effect on aquatic ecosystems receiving wastewater treatment plant effluents. Conventional wastewater treatment systems are not effective in the removal of these contaminants, and chemical or advanced biological treatment alternatives that do provide contaminant removal are often prohibitively expensive to implement, particularly for small, rural communities.

  This study is determining the effectiveness of a duckweed-based system (*Lemna turionifera* and *Wolffia borealis*) for the uptake and transformation of nutrients and PCPP contaminants from municipal wastewater, especially in communities like Wellsville City and Logan City that have lagoon wastewater treatment systems currently in place. In addition, work is ongoing to quantify the energy recovery potential of the stabilization of harvested duckweed biomass via anaerobic digestion, and growth of heterotrophic algae on the digester supernatant.

- **Benefits to the State:**

  Protecting surface water quality from nutrient enrichment and PCPPs is a concern in many watersheds in the state. This project is developing an effective, low-cost treatment method to remove nutrients/ PCPPs from wastewater with a net positive energy and environmental footprint.

Figure 1. Duckweed biomass on the Wellsville Lagoons, July, 2014

- **Geographic Areas:**

  Study Area: Cache County, UT.
  Areas Benefited: Utah locations with actual/ potential nutrient and PCPP impacted surface water requiring low-cost, sustainable nutrient management systems for water quality improvements.

- **Accomplishments**:

  Findings: A duckweed-based wastewater treatment system can be feasibly implemented at the Wellsville lagoons based on significant duckweed growth rates, high nutrient concentrations that accumulate in the duckweed biomass, and duckweed PCPP removal rates comparable to more expensive mechanical treatment systems. The effectiveness of such a system is dependent, however, on efficient and cost-effective harvesting and stabilization/ processing of the generated biomass. Mid-scale laboratory anaerobic digesters for harvested biomass stabilization and methane generation have been operating on freshly grown duckweed and field-harvested biomass. We are evaluating methane production capacity, reactor stability, and the fate of PCPPs associated with the harvested biomass within anaerobic digestion systems. We are also exploring

the use of digester effluent to grow heterotrophic algae and the production/ harvesting of potentially valuable biofuel materials.

Results: More than 250,000 lbs. of dried duckweed material could be harvested from the 56-acre Wellsville lagoons annually, amounting to approximately 2,500 lb of phosphorus recovered in the harvested material. In addition, duckweed achieved pharmaceutical compound removal comparable to literature reported values (Acetaminophin 56-99%, Sulfamethxazole 45-86%, Fluoxetine 82-93%, Carbamazepine 0-38%, Progesterone 82-98%) for more expensive and complex physical/ chemical treatment systems. Bi-weekly harvesting of duckweed biomass alone would provide sufficient P removal for Wellsville to meet its permit limits until approximately 2017. This technology is clearly a low cost alternative to much more expensive advanced biological/ chemical treatment processes, and produces a valuable end product in the form of harvested duckweed biomass.

Intermediate scale anaerobic digesters of 5 L volume were initially grown on calcium acetate substrate and were subsequently fed increasingly higher loads of duckweed until the digesters are now being fed a 100% duckweed solids feedstock. Reactor pH and gas composition (≈65% to 70% methane) have stabilized as the digesters moved from pure substrate (calcium acetate) to an entirely duckweed biomass influent stream. These digesters have acclimated to the duckweed feed as shown in Figure 2 in terms of total gas production per g dry duckweed solids added. These anaerobic digesters are yielding ~ 60% of the theoretical conversion of duckweed biomass to methane gas. Current studies are evaluating the effectiveness of utilizing the balance of the undigested duckweed carbon as a substrate for heterotropic algae growth, from which additional biofuel components can be extracted. Production of this algae to average concentrations of > 8.5 g/ L (peak concentrations > 25 g/ L) has been achieved on glucose substrate (Figure 3), and testing of duckweed digester effluent as a substrate for continued heterotropic algae production will commence in early FY15.

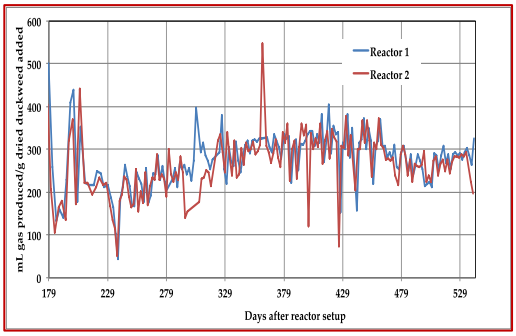


Figure 2. Total gas production from lab scale digester, mL/g dry duckweed added

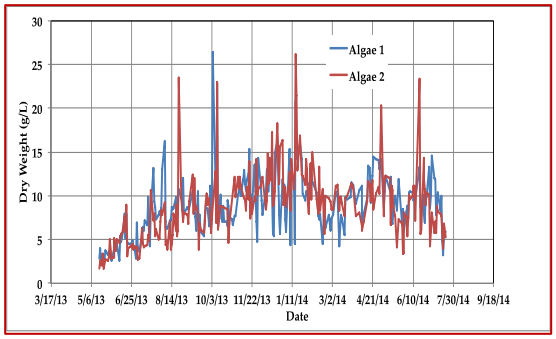


Figure 3. Heterotropic algae reactor solids concentration during the study

Work Plan FY14/FY15

We will evaluate the use of duckweed anaerobic digester effluent to produce heterotrophic algae during FY15. Once demonstrated, we will evaluate the impact of PCPP bioconcentration in the harvested duckweed biomass on sludge stabilization and processing steps (anaerobic digestion, micro-algae production), and the transformation/ fate of PCPP compounds during anaerobic digestion and through the production of heterotropic algae.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.
Website: http://duckweedresearch.blogspot.com/2012/05/duckweed-research-presentations-and.html.

Impact of Metals and Metal Ions on Soils and Plants

Principal Investigators:
Joan E. McLean
Anne Anderson (Biology)
David Britt (Biological Engineering)
Christian Dimkpa (Biology)
John Cupp (Post-Doctoral Fellow)
Joshua Horton (Undergraduate student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Metal oxide nanoparticles (NPs) 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 NPs in various industries and in agriculture may lead to adverse effects on plants and soil microbial ecosystems. This project is investigating the bioavailability and toxicity of metal oxide NPs of copper and zinc on a beneficial soil bacterium and on wheat in order to identify the ways metals affect beneficial soil bacteria survival and impact carbon and nutrient cycling and, ultimately, plant productivity.

- **Benefits to the State:**

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

- **Geographic Areas:**

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

  Areas Benefited: All counties in Utah.

- **Accomplishments:**

  Findings: Copper oxide and zinc oxide NPs released to the environment could create persistent impacts on plant productivity.

  Results: We are conducting laboratory research to study the complex interactions among metal oxide NP/ metal ion geochemistry and biological factors that control the bio-response of wheat plants to nanoparticles (Figure 1). Metal oxide NPs at sublethal concentrations affect the growth of wheat roots (Figure 2). The effect on wheat root growth is mitigated when plants are grown in an alkaline compared with an acidic soil (Figure 2). Soil pH is a major component that controls the solubility of NPs, with NPs being less soluble at higher pH values. However, the soil solution also contains inorganic and organic complexing agents that bind with Cu and Zn ions, holding them in solution and increasing the solubility of the NPs (Figure 3). Journal articles have been published in both *Environmental Pollution* and *Biometals*.

Work Plan FY14/FY15

We will continue to explore the effects of soil properties on NPs, including whether the metal complexes formed are bioavailable to the plant. We will evaluate the specific bio-response at a physiological and molecular level, to distinguish ion affects from NP affects.

Informational Resources

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

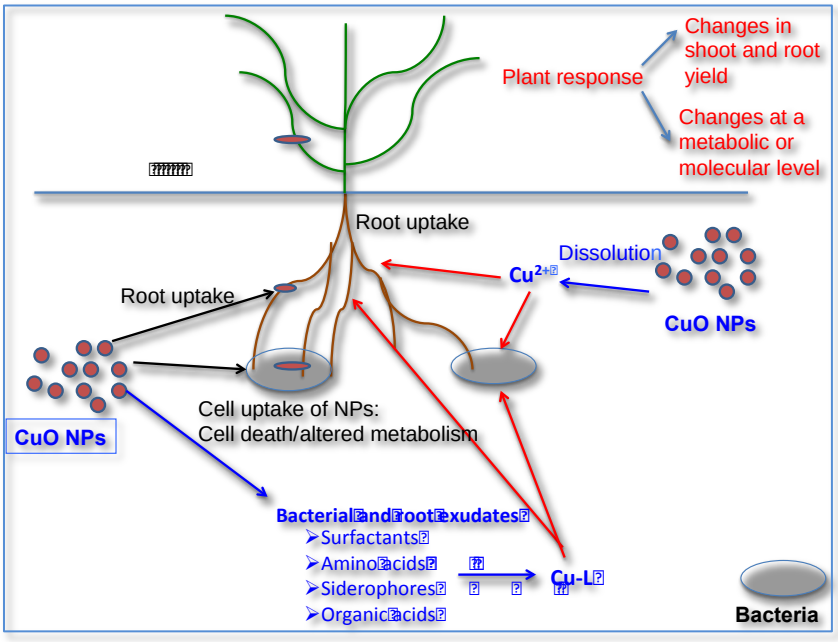


Figure 1. Schematic of the fate of copper oxide NPs in the soil environment with interactions among NPs, geochemistry, bacteria and plants. Blue processes were explored in FY13/14, red will be explored FY14/15.

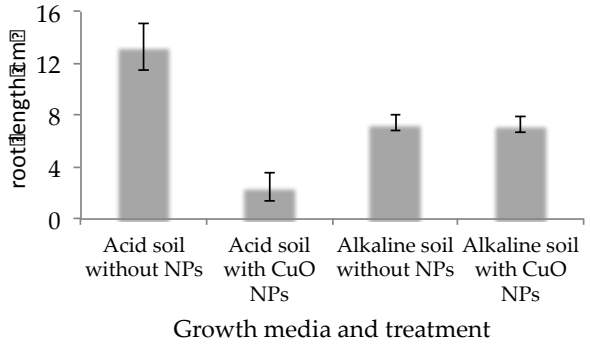


Figure 2. CuO NPs (300 mg Cu/Kg) in acid soil decreased root growth. Root growth in the alkaline soil however was not affected by the addition of CuO NPs.

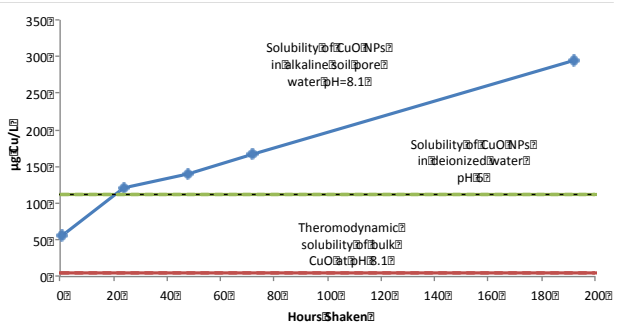


Figure 3. Solubility of CuO NPs over time. CuO on a nano-scale greatly enhance the thermodynamic solubility of the bulk mineral; pH affects solubility, with the solubility decreasing with increasing pH. Due to the presence of inorganic and organic ligands that complex the Cu, holding it in solution and enhancing the solubility, this is not observed here; the NPs being more soluble in the pH 8.1 pore water compared to the deionized water (pH 6). But is the complex bioavailable?

Investigations into Wintertime Indoor vs. Outdoor $PM_{2.5}$ and Vehicle Starting (Cold vs. Hot) Emissions

Principal Investigators:
Dr. Randal S. Martin
Clay Woods (PhD student)
Kori Moore (PhD candidate)

Partners/Collaborators:

- ***Local:*** *Bear River Health Department, as well as several private and commercial facilities*
- ***State:*** *Utah Division of Air Quality (UDAQ) & Air Monitoring (AMC), USURF's Space Dynamic Laboratory, Weber State University's National Center for Automotive Service and Technology (NCAST)*

Project Description

- **Need and Purpose:**

  Preventative and protective strategies addressing the $PM_{2.5}$ issues within the Cache Valley and along the Wasatch Front include recommendations to limit outdoor exposure times (e.g. stay indoors) and questions about the effectiveness of automotive anti-idling programs, as well as the related significance of hot start vs. cold starts. Unfortunately, little hard data are available addressing the efficacy of either of these strategies, particularly as they apply to the wintertime conditions of northern Utah.

- **Benefits to the State:**

  Ultimately, accurately assessing the wintertime O_3 behavior in the Cache Valley will quantify the extent of the potential problem, determine the contributing causes of the elevated pollution, and help to identify the most effective remediation scenarios.

- **Geographic Areas:**

  Study Area: The indoor vs. outdoor study area consisted of various private, commercial, and governmental buildings within the Cache Valley. Additionally, plans were initiated to do some similar testing in the Salt Lake Valley; unfortunately, inversion episodes ended before the Salt Lake studies could begin. The automobile emissions setup and testing have initially taken place at USU's UWRL and also at WSU's NCAST.

  Areas Benefited: The populations of the Cache Valley and the Wasatch Front will see the most direct and immediate benefit of these and future studies. However, the results will also be of use to UDAQ in planning future mitigation strategies and through this work, air quality research partnerships have been established between USU/ UWRL and WSU and U of U.

- **Accomplishments:**

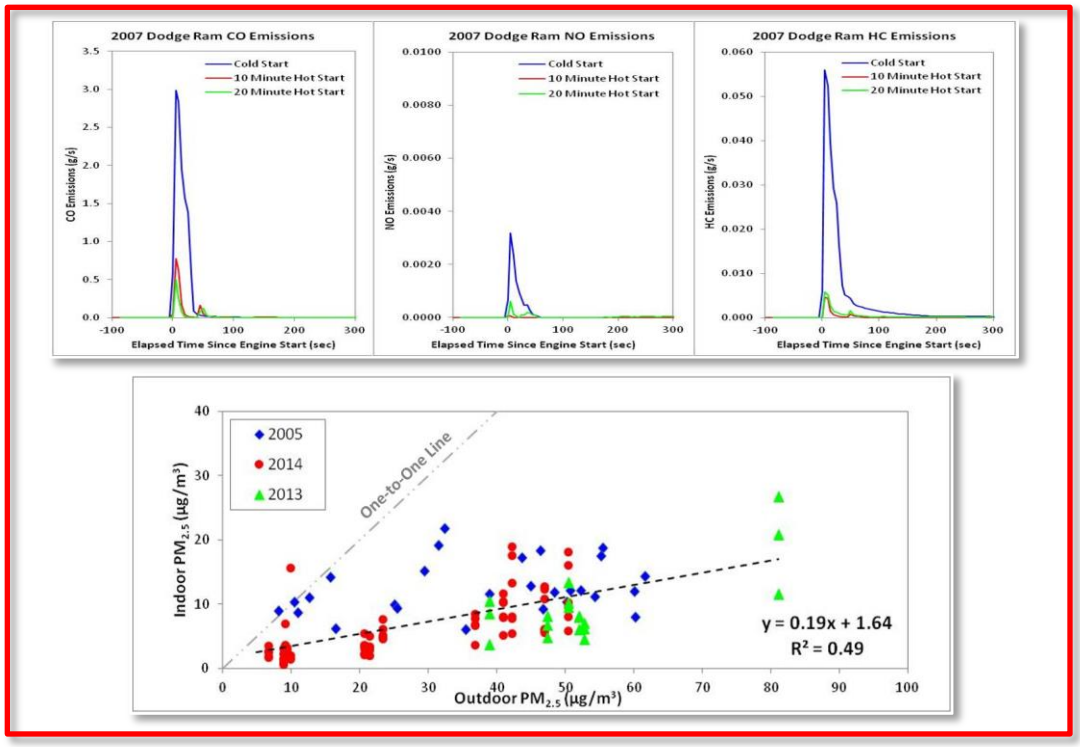
  Findings: Initial automobile studies conducted at UWRL found significant differences between cold and hot starts for a limited set of available vehicles. Additionally, significant differences were found in the idling emissions of the tested vehicles. The first figure below shows the various start emissions of carbon monoxide (CO), nitric oxide (NO), and hydrocarbons (HC).

  A continuation of previous year's investigations, outdoor vs. indoor $PM_{2.5}$ concentrations were measured at several facilities in the Cache Valley, including various school buildings, commercial buildings, private residences, retirement centers, and a hospital. The second figure below show

the indoor v. outdoor $PM_{2.5}$ values at various locations and across various years of study. As can be qualitatively seen, at even the maximum outdoor levels observed, the indoor air never exceed the National Ambient Air Quality Standard (35 µg/ m^3).

Results: One of the major results of the automotive emission phase of the project was the submittal and funding of a much larger project examining the cold start/ hot start/ idling issues typical of Utah's vehicle fleet. These studies were initiated in the fall of 2014 and will continue through the summer of 2015.

The indoor v. outdoor studies have verified that remaining indoors is an effective mechanism for reducing exposure to our photochemically formed $PM_{2.5}$ (primarily ammonium nitrate). Based on our studies, the indoor $PM_{2.5}$ is approximately 20% of the outdoor values. Like the automotive study, this study also led directly to a cooperative proposal with the U of U ($750,000 submitted to EPA, fall 2014).



Work Plan FY14/FY15

The work accomplished in FY13-14 greatly advanced knowledge and capabilities in the project's research fields. Additional work will investigate low-cost PM sensors.

Informational Resources

As previously mentioned, continued and expanded research is being conducted and it is anticipated that project reports and presentations will be available. Additionally, the indoor/ outdoor work was presented at the Fall Conference of the American Association for the Advancement of Aerosol Research (AAAR) and a final manuscript is in preparation.

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
Todd Wetzel

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

Project Description

- **Need and Purpose:**

  Volatile organic compounds (VOCs) enter indoor environments through internal and external sources. Indoor air concentrations of VOCs vary greatly but are generally higher than outdoors. Plants have been promoted as indoor air purifiers for decades, but reports of their effectiveness differ. However, while air-purifying applications may be questionable, the waxy cuticle coating on leaves may provide a simple, cost-effective approach to sampling indoor air for VOCs.

  The objective of this study is to investigate the potential use of plants as indoor air VOC samplers. A static headspace approach was used to examine the relationship between leaf and air concentrations, leaf lipid contents and octanol-air partition coefficients (Koa) for six VOCs and four plant species. The relationship between leaf and air concentrations was further examined in an actual residence after the introduction of several chlorinated VOC emission sources.

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: State of Utah.

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

- **Accomplishments**:

  Findings: The static headspace experiments showed that leaf air concentration factors (LACF) generally increase with increasing chemical Koa value and with increasing solvent extractable plant lipid content. The rapid change in plant VOC concentrations observed in the house experiments indicates that leaf samples provide real time air concentrations rather than the integrated concentrations provided by many commercial passive sampling devices. The parallel relationship between leaf and air VOC concentrations within the residence illustrates the potential for using leaves as indoor air samplers (Figure 1). Analyzing plant leaves to estimate indoor air concentrations will not replace conventional methods such as evacuated canisters and

active or passive sorbent tubes; however, based on experience, residents are often reluctant to allow repeated air samples to be collected because of the invasion of privacy and the disruption to their day-to-day activities. Using plant leaves as indoor air samplers would allow for a more rapid initial sample collection and screening effort. It might also allow the resident to become involved with a longer term monitoring process. Plants and labeled vials could be provided to the residents along with placement and sampling instructions. Leaf samples could be collected over time when it is convenient for the resident and shipped (or delivered by courier) to the analytical laboratory using pre-labeled containers.

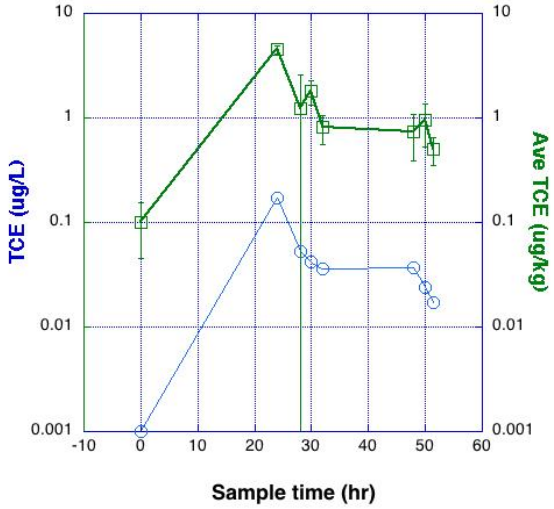


Figure 1. Ficus leaf (average of triplicate leaf samples with error bars showing standard deviation) and air (single measurement) TCE concentrations in source room over time.

Work Plan FY 14/FY15

The project has been completed.

Informational Resources

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

Plant and air sampling within house

Headspace method for leaf-air partitioning

Nitrogen Cycling, Oxygen Demand, and the Role of Dissimilatory Nitrate Reduction to Ammonia in Silver Creek below the Water Remediation Facility

Principal Investigators:
R. Ryan Dupont
Darwin L. Sorensen
Chelsea Stewardson (student)
Thomas Reuben (Post-Doc)

Partners/Collaborators:
State: *Nicholas von Stackelberg, Environmental Scientist, and Erica Gaddis, Section Manager, Water Quality Management Section, Division of Water Quality, Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

  With a March 16, 2011 memo, the US Environmental Protection Agency launched a "Working Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions." One element of the state framework is to ensure the effectiveness of point source permits for municipal and industrial wastewater treatment facilities in reducing the impact of nutrients on effluent receiving waters. The Utah Division of Water Quality (UDWQ) has responded by establishing a nutrient reduction program (http://www.nutrients.utah.gov/). UDWQ is drafting rules for implementing the state's nutrient control strategy. Technology-based limits for total phosphorus will likely be promulgated in late 2014 with limits for nitrogen following soon thereafter. It is anticipated that many of Utah's wastewater treatment facilities will need to demonstrate, by monitoring and modeling that their effluents are of acceptable water quality to receiving waters. One potential negative impact is dissolved oxygen demand for the nitrification process in which ammonia-nitrogen (NH_4^+-N) is oxidized to nitrate-nitrogen (NO_3^--N). Dissolved oxygen modeling in Silver Creek near Park City, Utah, indicated that an oxygen demand existed below the Silver Creek Water Reclamation Facility (SCWRF) discharge that was inconsistent with decomposition of known organic matter loads and nitrification oxygen demand.

  Based on observations of relatively high amounts of peat-like decomposing plant material on the bottom of Silver Creek and some high sediment oxygen demand measurements[1] to provide the necessary reducing power[2], it appears that dissimilatory nitrate reduction to ammonium (DNRA) and re-nitrification of this stream-generated ammonia exists in the sediment and water column of Silver Creek below the SCWRF. These processes almost certainly exist in combination with other nitrogen cycling processes, including denitrification, nitrogen fixation, and nitrogen assimilation. This project is testing each component of the nitrogen cycle under at least two seasonal conditions (including low-flow when the effect of the effluent is anticipated to be at a maximum) using in-stream chambers and water quality measurements to determine their significance related to observed oxygen depletion within Silver Creek and to formulate recommendations to UDWQ regarding modeling and monitoring that may be necessary to accurately describe impacts to Utah streams from nitrogen discharges from our wastewater treatment plants.

[1] Goel, R., M. Hogsett, P. Huang and R. Nasarabi. 2013. SOD and nutrient flux and four locations in Silver Creek, UT. Utah Division of Water Quality, Salt Lake City, UT.
[2] Nizzoli, D., Carraro, E., Valentina, N. and Viaroli, P. 2010. Effect of organic enrichment and thermal regime on denitrification and dissimilatory nitrate reduction to ammonium (DNRA) in hypolimnetic sediments of two lowland lakes. Water Research 44:2715-2724.

- **Benefits to the State:**

  As Utah begins the process of reducing nitrogen loading to streams, deeper insights to the in-stream processing of nitrate from wastewater treatment plants will help set water quality standards and guide the design and operation of wastewater treatment plants in the state.

- **Geographic Areas:**

  Study Area: Park City, Summit County, UT.

  Areas Benefited: All locations in the state with actual or potential nutrient impacted surface water where nitrogen transformation processes and rates are required for development of rational nutrient discharge limits from wastewater treatment plants.

Figure 1. In Situ Benthic Chambers Operating at the Silver Creek Field Site

- **Accomplishments**:

  Findings: Preliminary surface water quality monitoring of the SCWRF discharge and Silver Creek above and below the discharge point has been completed, and six in situ benthic chambers have been designed and constructed (Figure 1). Initial deployment of the chambers will be carried out in late August to early September 2014 and again in late November to early December 2014 to capture wastewater effluent dominated conditions within Silver Creek. These chambers will allow the analysis of denitrification, nitrogen assimilation, anaerobic ammonia oxidation, and DNRA using isotope-pairing techniques.

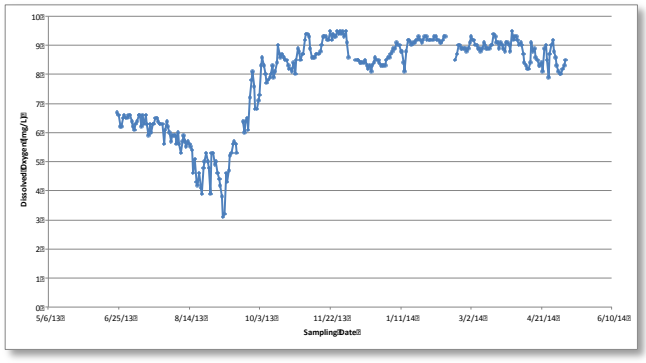


Figure 2. Historic Dissolved Oxygen Concentrations from the USGS Gauging Station on Silver Creek

Results: Background nitrogen sampling in May 2014 confirmed the nearly complete nitrification of the SCWRF discharge with 16.5 to 18.2 mg/ L NO_3^--N and only 0.02 to 0.14 mg/ L NH_4^+-N. Despite this highly oxidized nitrogen in the effluent, oxygen depletion has been historically recorded in the stream from July through October as indicated in Figure 2. A detailed understanding of the fate of nitrogen within the stream ecosystem through the in situ chamber measurements should shed light on the true impact of SCWRF wastewater effluent on Silver Creek.

Work Plan FY14/FY15

Results from the in situ benthic chambers will be collected and analyzed from the two field sampling events scheduled during the Fall/ Winter of 2014, and the significance and rate of various nitrogen transformation reactions in the water, soil, and aquatic plant compartments of Silver Creek will be quantified. Results will be used to update water quality modeling approaches for Utah receiving streams, and will support further nutrient criteria regulations being developed by UDWQ.

Informational Resources

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

Phytoremediation Evaluation Site for Quantifying the Fate of Trichloroethylene (TCE) Taken Up by Trees

Principal Investigators:
William J. Doucette
Oliver Diamond
Joe Stewart

Partners/Collaborators:
- ***Local:*** *Kyle Gorder, Hill AFB, UT*
- *Ivan Ray, Weber Canal Company*

Project Description

- **Need and Purpose:**

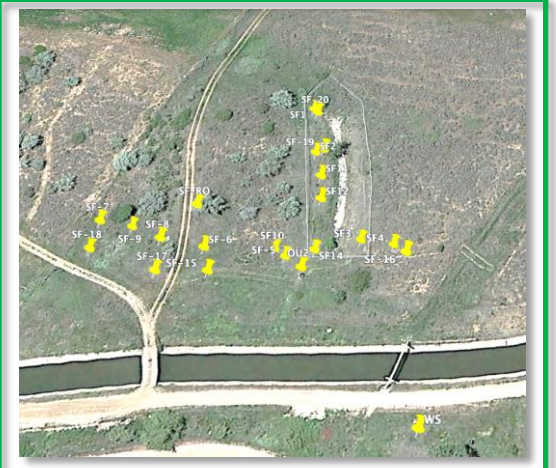
  Chlorinated volatile organic compounds (CVOCs) are among the most common groundwater contaminants in the US and are found at many locations in the State of Utah, including many communities surrounding Hill Air Force Base. Phytoremediation using fast growing trees has been promoted as a low cost, sustainable remediation alternative for the clean-up of shallow groundwater contaminated with CVOCs like trichloroethylene (TCE). Phytovolatilization from leaves and stems is thought to be a significant loss mechanism for TCE and similar CVOCs. Once transferred into the atmosphere the reaction with hydroxyl radicals rapidly degrades the CVOCs. Plants also have the ability metabolize CVOCs into less persistent and toxic compounds.

  One of the main limitations preventing the implementation of phytoremediation at many sites is the lack of acceptance by the regulatory community. This is often due to a limited understanding of the removal mechanisms and the scarcity of quantitative data supporting the removal effectiveness.

  The goal of this study is to establish a small phytoremediation evaluation site just outside Hill Air Force Base Operable Unit 2 (OU2) that can be used to refine measurement and scaling approaches for estimating the total annual mass of TCE and other CVOCs removed from shallow groundwater aquifers by trees through volatilization and metabolism.

- **Benefits to the State:**

  Results from this study will contribute to our basic understanding of phytoremediation and the potential to use trees to monitor and improve groundwater quality. An improved understanding of the phytoremediation removal mechanisms and kinetics will provide regulatory agencies such as Utah DEQ with the necessary information to determine the potential for using phytoremediation as an alternative to more costly remediation approaches.



Aerial view of sampling locations

- **Geographic Areas:**

  Study Area: Weber County.

  Areas Benefited: Phytoremediation could be used statewide, so all counties in the state would potentially benefit.

- **Accomplishments:**

  Findings: Approximately 30 poplar whips were obtained from the Utah State University (USU) research farm and planted in a seep area between the Hill AFB boundary and the Weber Canal within OU2 during May 2013. Because of the relatively late planting and the hot, dry spring, only about half of the initial planting survived. An additional 20 poplar whips were planted during April 2014 to supplement the 2013 planting.

  A limited number of tree core and leaf, trunk, and soil volatilization flux samples were collected and analyzed for TCE and other CVOCs in July, August, and September. Since the newly planted poplar trees were too small to sample during the first year, tree core samples were collected from several mature trees that were located near the newly planted trees.

- **Results:** The limited 2013 analysis showed that TCE and PCE were present in the tree cores and volatilization flux samples, with the concentrations of TCE roughly five to ten times greater than the PCE concentrations. Additional tree core and volatilization flux samples are being collected in 2014 and preliminary results show that the newly planted trees are taking up and volatilizing TCE and PCE. In addition to the tree and volatilization flux samples, leaf samples will be collected and analyzed for metabolites of TCE by GC/ MS after an appropriate extraction and derivitization procedure.

Work Plan FY14/FY15

Continue to collect tree cores, leaves, and leaf, trunk, and soil volatilization flux samples at least once a month between July and October once the trees are established. After sufficient data are collected, a Thiessen approach will be used extrapolate the individual sample or flux measurements to the entire site. This will allow us to predict how long it will take the trees to remediate the site.

Informational Resources

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

Volatilization flux measurement

Poplar pole one month after planting

Volatilization flux measurement

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

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

Partners/Collaborators:

- ***Local:*** *Issa Hamud, Logan City Environmental Department; Michelle DeHaan, Water Quality Program Manager, Park City Municipal Corporation*
- ***State****: Eva Naminski, Division of Drinking Water, Utah Department of Environmental Quality*
- ***Federal:*** *Kyle Gorder, Mark Roginske, Environmental Management Directorate, Hill AFB*

Project Description

- **Need and Purpose:**

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

  This project facilitates development and implementation of routine quantitative molecular biology capabilities within the Utah Water Research Laboratory's Environmental Quality Lab (EQL) to support the development of advanced molecular biology research.

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

- **Benefits to the State:**

  RT-PCR instrumentation provides quantitative capabilities for the low-level detection of specific microorganisms and functional genes in environmental samples. Some projects applying RT-PCR techniques to directly benefit the State of Utah include the following:

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

4. Evaluate the presence and abundance of arsenic reducing bacteria in soil and groundwater surrounding the Logan City Landfill to isolate the landfill's influence on groundwater quality impairment.
5. Analyze the community composition and function associated with biofilms accumulating within the potable water distribution system in Park City.

- **Geographic Areas:**

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

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

- **Accomplishments**:

  Findings: At least seven separate studies are currently underway or have been recently completed utilizing this equipment as a significant part of the analyses to support system performance evaluation or remedial design. These quantitative molecular tools have been useful in tracking the progress of remediation and the growth and maintenance of remediation cultures applied at a chlorinated solvent site at Hill AFB; evaluating the microbial community composition and diversity of groundwater plumes adjacent to Hill AFB; identifying the sources of algal blooms and surface water impacts in Pineview Reservoir; evaluating the presence and abundance of arsenic reducing species in soil and groundwater adjacent to the Logan City Landfill; assessing the composition and diversity of bacterial, archeal, and fungal communities associated with poplar plants in a phytoremediation study at Hill AFB; evaluating 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; and conducting screening level analysis of the microbial community that makes up biofilms that periodically grow and are released into the Park City potable water distribution system.

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

Work Plan FY14/FY15

Ongoing projects: Expanding the range of organisms and functional genes that can be quantified using RT-PCR methods and focused studies improving the recovery of DNA from complex environmental media, and lowering the detection limit of the method.

Recently funded projects: (1) investigating at a very fine scale the rate and extent of reductive dechlorination of TCE in response to different carbon donor amendments, along with the release and transformation of arsenic in response to this biostimulation and (2) identifying arsenic reducing microorganisms isolated from shallow and deep groundwater supplies collected from throughout Cache Valley and northern Utah to support earlier findings of the uniqueness and diversity of arsenic reducing species endemic to this region.

Informational Resources

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

Environmental Quality Management and Remediation

Remediation of Chlorinated Solvent Contamination of Groundwater

Principal Investigators:

Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Babur Mirza (Post-Doctoral Fellow)
Suzy Smith (MS student)

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  All counties in Utah have groundwater contaminated with trichloroethylene (TCE) or perchloroethylene (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 groundwater.

  Biostimulation with or without bioaugmentation has been used at various contaminated sites to promote the reductive dechlorination of TCE. At some sites these remediation strategies are successful, yet at others full dechlorination to non-toxic ethene is not observed. We set-up large columns (6 feet in height) packed with TCE contaminated aquifer solids collected from Hill Air Force Base. The columns were fed with several carbon sources with and without addition of a dechlorinating culture. After seven years of operation only the whey treated columns produced biogeochemical conditions conducive to full dechlorination. An important area of research is why other carbon sources failed to promote the right conditions.

- **Benefits to the State:**

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

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Findings: Complete reductive dechlorination of TCE to innocuous breakdown products was observed in the column sample treated with whey. We observed a shift in the microbial communities in response to the application of different carbon amendments, which influenced geochemical conditions. Reduced conditions in combination with the appropriate soil microbial communities resulted in complete reductive dechlorination. These finding are useful in the reclamation of field sites that have been heavily contaminated with the TCE.

  Results: *Dehalococcoides* (*Dhc*) have been described in the literature as the only bacteria that are capable of converting TCE to non-toxic ethene. The overall influence the *Dehalococcoides*

(Dhc)/ Rdase genes abundance and soil geochemical characteristics on the different stages of TCE degradation was analyzed through Redundancy Analysis (RDA). RDA based on the soil geochemical characteristics suggested a tight clustering of the samples by biostimulation treatments and TCE reduction stages (Figure 1). Samples from the columns where the complete TCE reduction was carried out (whey treated) showed the strong reducing soil conditions as indicated by the association of Fe(II), presence of sulfur as sulfide, and high methane production. *vcrA* gene abundance was strongly associated with the columns under complete TCE reducing conditions.

Work Plan FY14/FY15

This project is complete.

Informational Resources

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

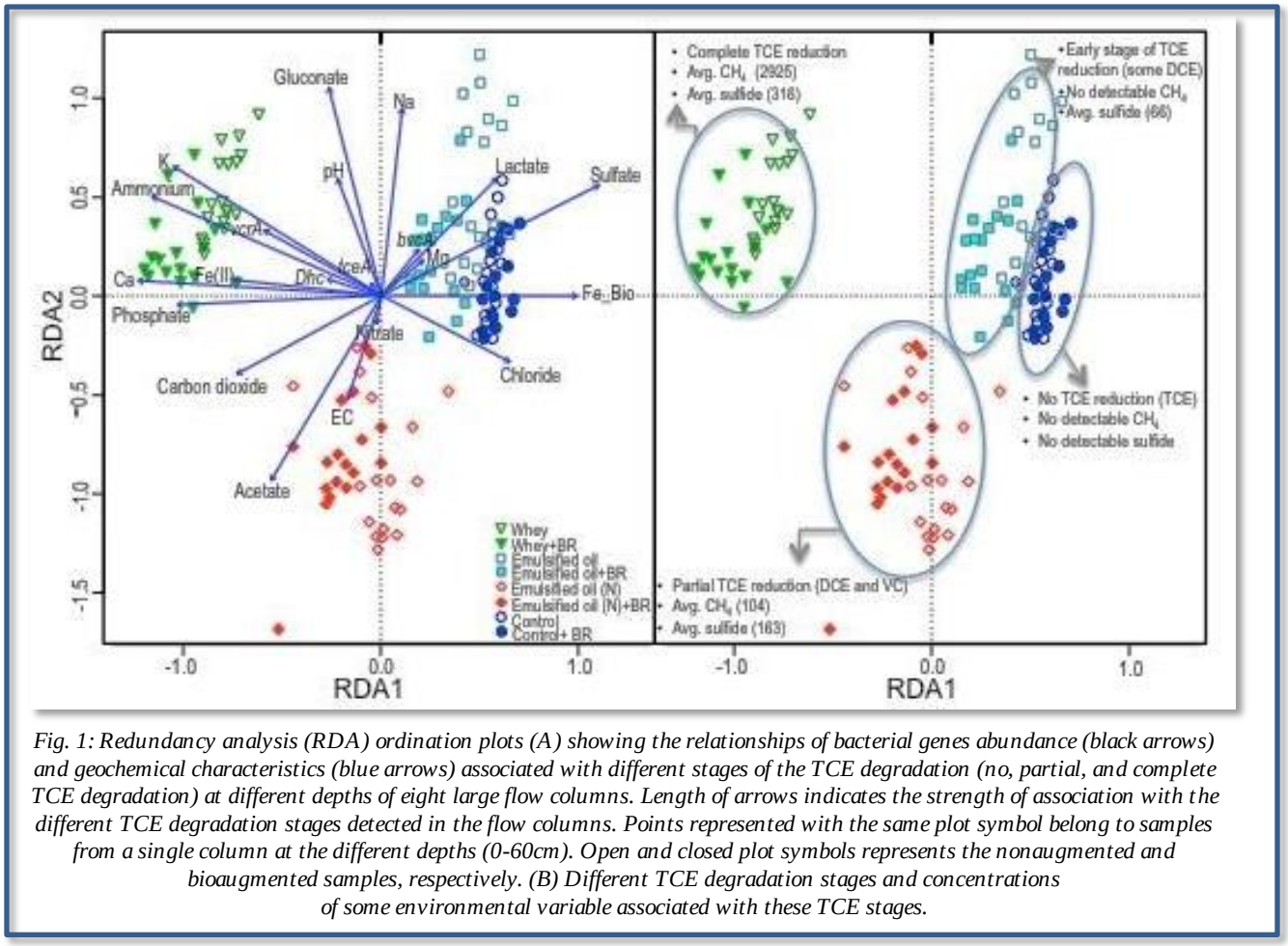


Fig. 1: Redundancy analysis (RDA) ordination plots (A) showing the relationships of bacterial genes abundance (black arrows) and geochemical characteristics (blue arrows) associated with different stages of the TCE degradation (no, partial, and complete TCE degradation) at different depths of eight large flow columns. Length of arrows indicates the strength of association with the different TCE degradation stages detected in the flow columns. Points represented with the same plot symbol belong to samples from a single column at the different depths (0-60cm). Open and closed plot symbols represents the nonaugmented and bioaugmented samples, respectively. (B) Different TCE degradation stages and concentrations of some environmental variable associated with these TCE stages.

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

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Darwin L. Sorensen
Babur Mirza
Wayne Breon

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

Project Description

- **Need and Purpose:**

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

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

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: Hill AFB in Weber County.

  Areas Benefited: All locations in the state with TCE impacted groundwater sources as they improve the predictability and reliability of bioaugmentation for contaminated site remediation.

- **Accomplishments**:

  Findings: The spatial distribution of substrate and the microbial community have a significant impact on TCE transformation in OU5 soil. Unlike the small microcosm studies, complete to partial dechlorination of TCE is observed in the flow-through columns with carbon donor addition without bioaugmentation, depending upon the applied carbon substrate, but

dechlorination reactions were delayed by 1 to 3 years without the addition of a dechlorinating culture. The column study confirmed whey as the optimal carbon source in terms of both the rate and extent of TCE transformation. In addition, whey produced the greatest diversity of microbial metabolic pathways of all donors evaluated, supporting and maintaining a microbial community with full functional gene capability for reductive dechlorination of TCE over the cumulative 2,700 days of the study.

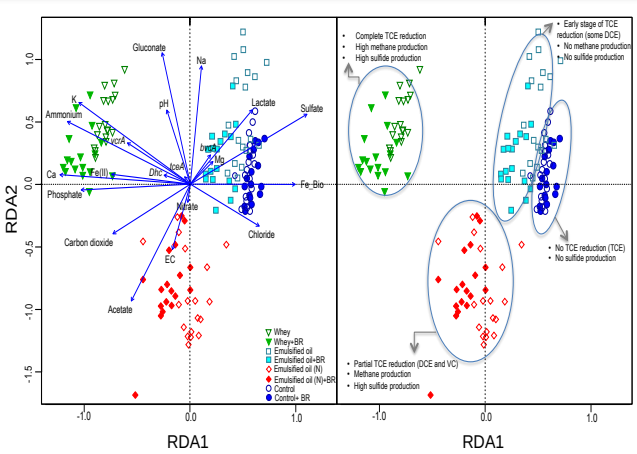
Results: Concentrations of 16S rRNA genes of *Dehalococcoides (Dhc)*, functional genes *tceA*, *vcrA*, and *bvcA* and quantities of *tceA* and *vcrA* transcripts were determined in the top 9 cm layer of each column using Quantitative PCR. QPCR analyses showed essentially equal concentrations of nearly all targets including *Dhc* (log 9.3/ g), *tceA* (log 7.3/ g), and *vcrA* (log 7.5/ g) in both the augmented and non-augmented columns. The transcript numbers for *tceA* and *vcrA* genes was also similar in both augmented and non-augmented columns. However, the *bvcA* gene was only detected in the bioaugmented column. Pyrosequencing found *Dhc* with a frequency of 4.3×10^{-4} among 51,550 sequences from non-augmented column samples and 6.7×10^{-4} among 64,346 sequences from augmented samples; an enrichment factor of 1.6. Bioaugmentation accelerated TCE dehalogenation and enriched the population density of known dehalogenating bacteria for years following treatment. Principle component analysis (see figure below) of water quality, molecular biological measurements, and the resulting extent of reductive dechlorination have identified several variables (ammonium, *vcrA*, Fe(II), *tceA*, *Dhc*) as useful for predicting the extent of TCE transformation in response to a range of carbon donor additions.

Work Plan FY14/FY15

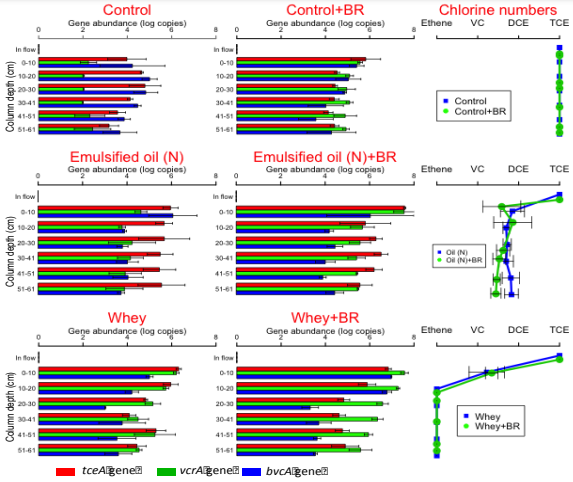
This large flow-through column study is complete, and results from these experiments were used to design small column experiments to assess the time course of the development of reductive dechlorination processes in response to simple and complex carbon donor addition. Detailed biological and physical/ chemical measurements will be collected over time during the early stages of reductive dechlorination following bioaugmentation in these small columns to verify findings of this long-term study.

Informational Resources

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



Principle component analysis of biological and geochemical indicators of various reductive dechlorination conditions



Functional gene abundance along the column length for various carbon donors and subsequent extent of TCE dechlorination

Study of Cache Valley's Vertical Meteorological & Pollutant Profiles and Application to Additional Areas in Utah

Principal Investigators:
Dr. Randal S. Martin
Mr. Clay Woods (PhD student)

Partners/Collaborators:

- ***Local:*** *Utah State University, Utah Climate Center, College of Science, Dept. of Plants, Soils, & Climate (Dr. Lawrence Hipps, Dr. Rong Li)*
- ***State:*** *Utah Division of Air Quality (UDAQ), Air Monitoring Center (AMC)*
- ***Federal:*** *National Oceanic and Atmospheric Administration (NOAA), Earth Research Systems Laboratory (Dr. Russ Schnell)*

Project Description:

- **Need and Purpose:**

  Cache Valley, as well as most of Utah's Wasatch front, is currently non-attainment for $PM_{2.5}$ (particulate matter less than 2 ½ µm in diameter). Additionally, research over the last several years has identified wintertime ozone—typically a summertime phenomenon—as a serious issue in Utah's oil & gas production region of the Uintah Basin. A key to solving these issues is the ability to effectively monitor and understand to the behavior of the vertical structure of both meteorological parameters and the relevant pollutant species. In the case of wintertime $PM_{2.5}$, past research has shown that the availability of oxidants, primarily ozone (O_3), is key to the $PM_{2.5}$ formation chemistry. This project is developing and testing light vertical meteorological and O_3 systems and examining their vertical structure using a package adaptable to different vertical platforms (e.g. tethered balloons and unmanned aerial vehicles (UAVs)). The unexpected phenomenon of unacceptable levels of wintertime O_3 in the Uintah Basin and the need to understand both temporal and spatial O_3 formation, transport, and transformation behaviors has provided an opportunity to apply techniques developed under this project and do comparison studies with external investigators. Also, understanding the influence of the Great Salt Lake (GSL) on O_3 behavior along the Wasatch Front has recently become a topic of growing interest.

- **Benefits to the State:**

  Research into the development of effective methodologies for understanding the vertical behavior of locally generated and regionally transported pollutants will be of key importance when developing remediation strategies, and may be applicable to other air quality issues, as well. Additional air quality benefits may be achieved as differing instrumentation is adapted to the test platform (see subsequent discussions below).

- **Geographic Areas:**

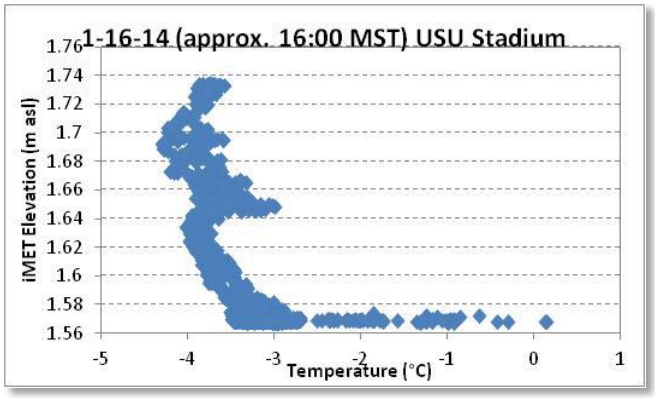
  Study Areas: During this most recent period, flight profiles were conducted within the Cache Valley. However, the flight plans and preparations made to characterize the area east and north of the GSL in fall/ summer 2014, were halted by FAA flight restrictions.

  Areas Benefited: Work over the past couple of years primarily took place in the Uintah Basin, in conjunction with a large study organized by the Utah Division of Air Quality and with many cooperating agencies and universities. The Cache Valley airshed is also a direct beneficiary, as much of this work went into the federally-approved air quality management plan. As mentioned above, future data will also directly benefit the Wasatch Front.

- **Accomplishments:**

Findings: Our 2B Technologies Model 202 Ozone Monitor continues to be modified (data acquisition abilities, UAV system integration, spatial logistics, etc.). This past year the O_3 and meteorological packages were further modified to fit within the payload bay of an autonomous unmanned aerial vehicle (UAV) platform. The UAV airframes are part of the Utah Water Research Laboratory's (UWRL) AggieAir UAV program and as these UAV systems are modified so too must be the pollutants systems. Additionally, a second real-time sensor (O_3/ met.) package was borrowed from NOAA's Earth Research Systems Laboratory.

Results: The photograph below shows the launching of the NOAA balloon-supported package at USU's Caine Dairy in the southern part of the Cache Valley. The data graph on the right shows the clear ability to identify the height of the inversion layer (at the point labeled 1.66 on the y-axis). The data from these flights were processed and, in cooperation with investigators from USU's Department of Plant, Soils, and Climate, are being used to optimize current large scale meteorological models to better predict small scale meteorological phenomenon (e.g. cold [pool inversions). Additionally, the development work described herein has led directly to a cooperative study with the University of Utah on the GSL's O_3 influence, funded by Utah's Division of Air Quality. Initial plans called for UAV flights around the GSL during the early fall of 2014; however, delays in acquiring FAA approval has pushed the flights to summer 2015.



Work Plan FY14/FY15

Work on developing protocols for economically and accurately measuring vertical ozone and meteorological profiles will continue into FY14-15. We also continue to pursue other funding opportunities to aid in the continued evolution of the system to the UAV-based instrument. It is further anticipated that the UAV will be deployed in 2014/ 2015 for studies within the Cache Valley and along the Wasatch Front and may include other small packages, potentially including IR cameras for VOC identification or methane sensors. Dr. Martin has been negotiating with Dr. Mark Zondlo of Princeton University to incorporate one of his miniaturized CH_4 monitors into USU's UAV systems.

Informational Resources

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

Surface and Groundwater Quality and Quantity

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
Incorporation of Heat into Solute Models	$146,845.09	$151,250.44	$155,787.96
Influence of Groundwater/Surface Water Interactions in High Gradient Mountain Streams	$23,502.02	$24,207.08	$24,933.29
"Lab-on-a-Chip" – Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$116,971.28	$120,480.42	$124,094.83
Model Development, Modification and Expansion for Assessment of Utah 319 Projects for Controlling Non-point Source Water Pollution	$53,596.25	$168,724.20	$0.00
Optimizing Stormwater BMP Performance through Vegetation Selection and Harvesting Strategies	$127,465.24	$40,000.00	$41,200.00
Release of Arsenic from Aquifer Solids Under Anaerobic Conditions	$99,328.13	$102,307.97	$105,377.21
Salinity Reduction Measures for the Upper Colorado River Basin	$39,504.91	$40,690.06	$0.00
Source Water Protection for Potential Phosphorus Mining Impacts in the Uintah Basin	$17,226.29	$132,660.10	$86,640.00
Technical Support for Bear River System Data Acquisition	$17,226.29	$17,743.08	$18,275.37
Water Allocation and Salinity Issues of the Sevier River Basin	$27,271.54	$28,089.69	$28,932.38
Designated Projects		$450,141.70	$56,700.00
Undesignated Projects		$141,010.00	$10,000.00
Total	**$668,937.04**	**$1,417,304.74**	**$651,941.04**

Incorporation of Heat into Solute Models

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***Local:*** *Corey Cram, Washington County Water Conservancy District*
- ***State:*** *Brad Hunt/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. Further, because conditions within Curtis Creek have changed significantly over the past few years due to beaver colonization, significant efforts have been focused on understanding the influence of beaver dam complexes on groundwater/ surface water interactions and heat and solute transport.

- **Benefits to the State:**

  This area of research provides for a more complete understanding of the impacts of transient storage and surface water-groundwater interactions on streams in Utah and the Intermountain West. It also provides a platform to understand the influences of beaver dams on instream processes. As methods are developed to measure and predict the fate and transport of constituents in streams 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. This effort will also assist the state in understanding the implications of the recently passed State of Utah Beaver Management Plan.

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Findings: Data collection strategies and new model development approaches have provided more accurate heat and solute fate and transport predictions through the main channel, dead zones, and surface-groundwater interface of rivers and streams (referred to as two-zone transport

models). Analytical solutions have been developed to describe these transport processes better than more traditional methods using numerical solutions. New techniques have also been developed to account for spatial variability in system characteristics using information extracted from aerial high-resolution multispectral and thermal infrared imagery gathered by AggieAir.

Results: Analytical solutions of two-zone solute transport, as well as temporal moments, have been developed with the use of Laplace transforms and have been tested against observed solute data within various systems. These solutions allow parameters within the model to be treated as functions of space rather than having to transfer information from reach to reach. Imagery has been found to be critical in estimating parameters and in capturing the longitudinal and lateral spatial variability present within desert and mountain streams in Utah (see Figure 1). Presentations of results have been delivered by faculty and students. Within the last year a MS thesis was completed that focused on the heat transport processes within beaver dams. Three journal articles have been recently published, one is in revision, and five more nearly ready for submission that are part of dissertation and thesis work.

Work Plan FY14/FY15

The two-zone solute and temperature analytical solutions are complete. We are using these solutions with various data sets within rivers in Utah to determine the spatial scale over which channel information is important for solute predictions and when having high spatial resolution information is critical in temperature modeling. We continue to collect data in different study reaches to quantify the influences of beaver dams on heat and solute transport. Currently a 1 and 2-dimensional hydraulic model has been applied to a study reach where 10 beaver dams are present. We are using these predictions to quantify the influences of beaver dams on solute transport, residence times, and fish habitat.

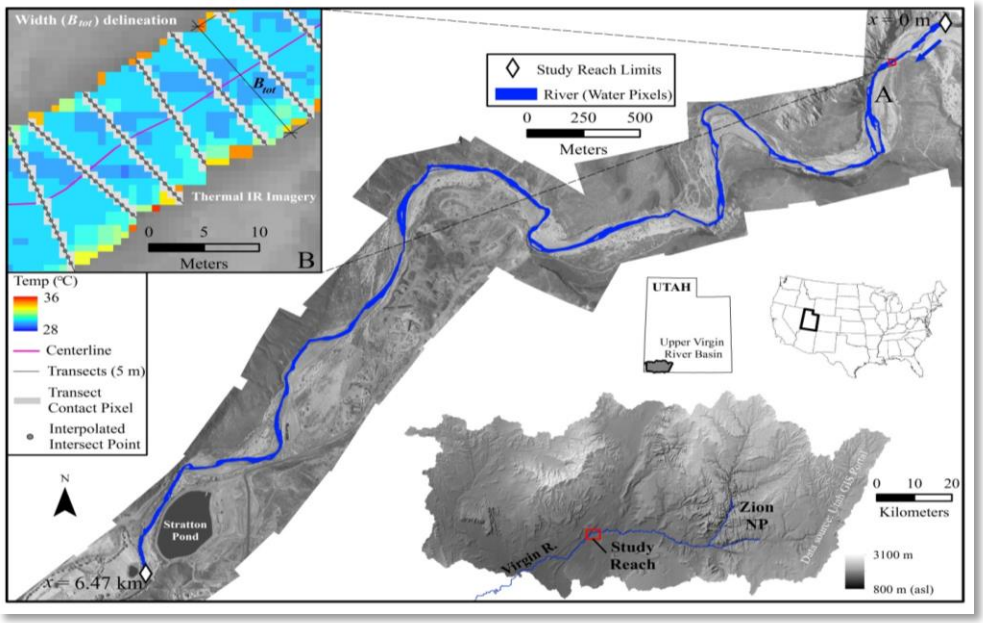


Figure 1. From Schmadel et al. 2014 illustrating the use of aerial imagery to facilitating stream modeling.

Informational Resources

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

Influence of Groundwater/Surface Water Interactions in High Gradient Mountain Streams

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:

- ***Local:*** *Many within the greater iUTAH project*
- ***State:*** *USGS Utah Water Science Center and many others in the greater iUTAH project*
- ***Federal:*** *National Science Foundation, USGS*

Project Description

- **Need and Purpose:**

  Sources, sinks, and residence times of heat and solute mass within stream networks are critical to characterize and quantify because of their role in biogeochemical processes and water quality. One of the biggest challenges associated with understanding and predicting heat and solute movement within a river or stream is attempting to estimate each physical process individually. A key process in many stream systems is the spatially and temporally variable groundwater exchanges, which are particularly important in heat and solute transport. However, groundwater exchanges are not clearly defined and are widely recognized in many situations as being complex and difficult to understand. The interactions between stream flow and subsurface flow can occur in the hyporheic zone, deeper groundwater, parafluvial zone, riparian zone, and alluvial plain. Exchange flow paths and residence times can vary strongly, ranging from centimeters to hundreds of meters and from minutes to years, making locations, quantities, and distributions difficult to anticipate and measure. While some have used model calibration approaches to indirectly estimate groundwater influences on heat and solute transport, a wide range of other data centric methods are commonly used. This project focuses on the most common direct measurements of groundwater exchanges by combining velocity-area methods, rating curve estimates, and tracer dilution gauging to obtain net changes over a reach of interest.

- **Benefits to the State:**

  Recent groundwater exchange studies in Northern Utah have focused efforts on reach scales by using a wide variety of data types [Schmadel et al., 2010; Schmadel et al., 2014], but there is a need for a variable scale investigation of the importance of groundwater gains and losses within additional high gradient streams in the region. As part of a recently awarded Utah EPSCoR Track 1 National Science Foundation project (iUTAH - innovative Urban Transitions and Aridregion Hydro-Sustainability), the ecologic/ climate/ hydrologic system in Utah watersheds will be monitored to better understand biophysical and hydrologic processes. As part of this effort, three different watersheds along the Wasatch Front have been instrumented longitudinally from mountain unimpacted areas to urban areas with flow gaging stations, multi-probe water quality sondes, and weather stations. Additionally, samples are being routinely collected to establish representative biogeochemical conditions throughout each watershed. The groundwater/ surface water gains and loss data collected within this study will complement iUTAH efforts by providing information longitudinally within each system during different seasons.

- **Geographic Areas:**

  Study Area: Logan River, Logan, UT; Red Butte Creek, Salt Lake City, UT; Provo River, Heber and Provo, UT.

Areas Benefited: This research will directly benefit the most populated portions of Utah, but the information gained and methods developed should be applicable to the entire state of Utah.

- **Accomplishments:**

Findings: Data have been gathered at 34–42 sites in the Logan River during June, August, and December of 2014. Similarly, data have been collected in 23 sites in the Provo River and 23 sites in Red Butte Creek in June and August 2014. Example data and preliminary calculations of flow gains and losses are shown in Figure 1.

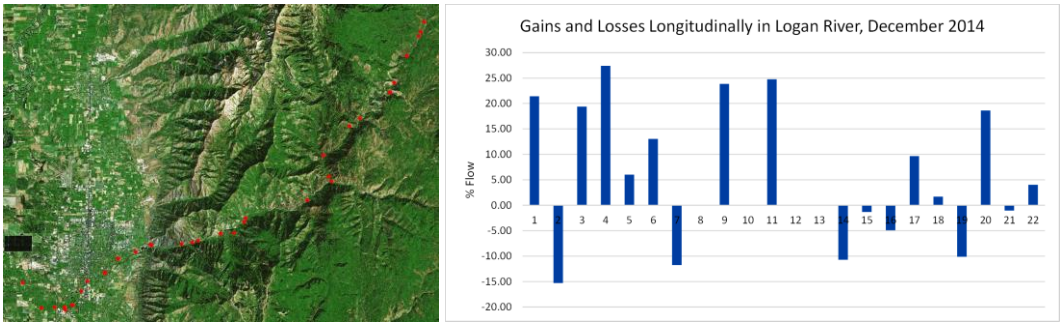


Figure 1. Map showing sample locations within Logan River (left). Gains and losses in flow (%) along the Logan River in December 2014 (right).

Results: This data collection will support: 1) the interpretation of the biochemical data collected longitudinally within the iUTAH study watersheds; and 2) other variable scale water balance modeling efforts within iUTAH that are being conducted to understand the implications of climate change on hydrology within the state of Utah.

Work Plan FY 15-16

We will collect additional data sets and complete analyses of existing and new data sets.

Informational Resources

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

Representative Publications

Schmadel, N.M., B.T. Neilson, and T. Kasahara (2014). Deducing the spatial variability of exchange within a longitudinal channel water balance. *Hydrological Processes*, 28(7):3088-3103, doi:10.1002/ hyp.9854. Posted online 20 May 2013.

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, doi: 10.1016/ j.jhydrol.2010.09.011.

"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) that make 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 developing a portable, reliable, affordable chemical sensor device capable of measuring the concentrations of individual salt ions in the field.

- **Benefits to the State:**

  The ability to detect a majority of salinity ions will help Utah to better manage and control contributions to the Colorado River salinity problem. Benefits of this project include (1) Ion sensor arrays that can measure salt loading in critical Utah rivers, (2) A new portable detector not currently available for measuring the most significant salinity ions contributing to salinity from Utah and other states, and (3) Help for farmers and Utah residents to improve the timing and efficiency of water quality monitoring and to track the salinity sources in the water system.

- **Geographic Areas:**

  Study Area: Logan, Price and San Rafael Rivers, Cache County in Utah.

  Areas Benefited: Salinity concerns are statewide, so all counties in the state could benefit.

- **Accomplishments:**

  Findings: In the past year, we designed and fabricated a miniaturized on-chip sensor device that integrates working, counter, and reference electrodes and conducted the initial performance tests in detecting heavy metal ions (Pb2+, Cd2+) in standard ion solution and the real water samples in the Logan River, UT. These results were compared to the results from the ICP-MS measurement that was also carried out in the analytical lab at the Utah Water Research Laboratory (UWRL). This work has been published in a referred paper. Secondly, we also worked to develop a paper-based microfluidic ion detection technique that is able to integrate colorimetric and electrochemical ion detections in a water sample. These on-chip electrode arrays and paper-based microfluidic detection techniques will be useful for future salinity ion detection once these techniques are fully demonstrated.

  Results:

  1) A **U.S. patent (US8,608,923 B2)** was issued on Dec 17, 2013, inventors include Anhong Zhou, Huifang Dou.
  2) As shown in the figures below, a cost-effective on-chip device (cost $<7 dollars per device) to detect ions in water samples has been designed, fabricated, and initially tested. This on-chip device was able to pattern three electrodes (working electrode where the ions are detected, counter electrode, and reference electrode) on one glass surface. The use of a small vibration

motor increases the sensitivity as well as the detection limit of heavy metal ions. The detection limit is 0.7 ppb for Cd^{2+} and 1.2 ppb for Pb^{2+} without motor vibration, compared to 0.11 ppb and 0.25 ppb when the motor is enabled, respectively.

3) The researchers are working to optimize the fabrication of the integrated sensor array device in the Cleanroom lab at the Physics Department at Utah State University and in the PI's biosensor research laboratory in the Department of Biological Engineering.

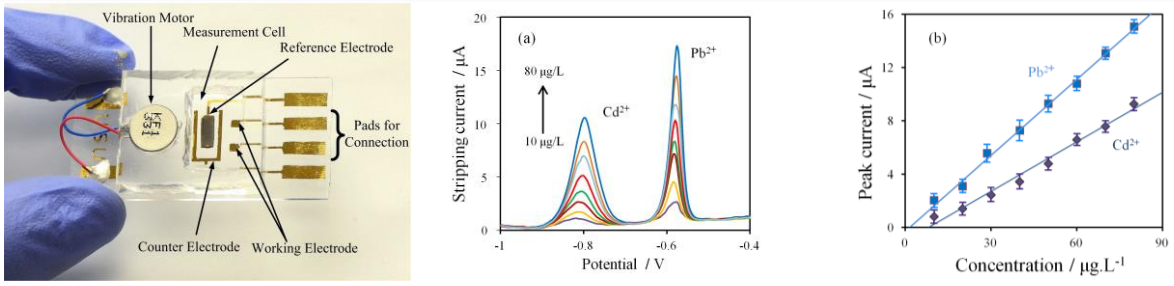


Figure 1. Microfabricated on-chip device that integrates the working electrode (gold), counter electrode (Pt),

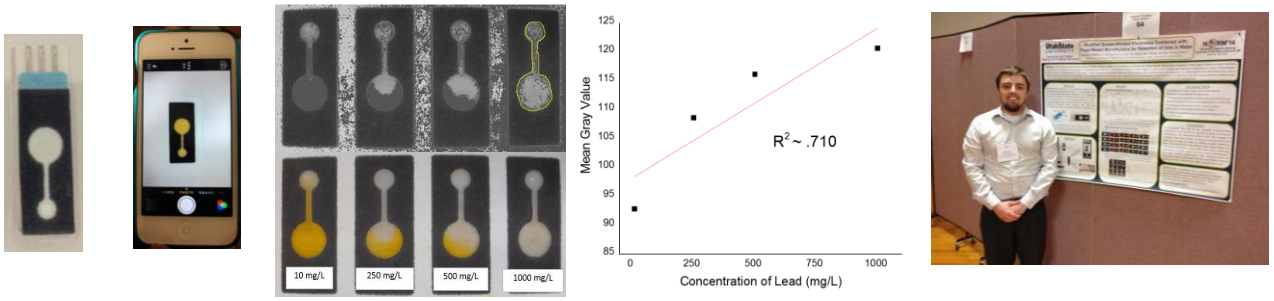


Figure 2. Smartphone based colorimetric detection of heavy metal ion Pb^{2+} in 0~1000 ppm. (Right) MS student Spencer Williams presented his research at the NORM2014 conference in Missoula, MT in summer 2014.

Work Plan FY14/FY15

- Design, fabrication, and test of printed circuit board that can control the measurement of multiple commercial salinity ion probes (Na+, Ca2+, Mg2+, Cl-).
- Optimization of on-chip device for multiple ion detection in water samples.

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.

Publications/Products:

Anhong Zhou, Huifang Dou (Inventors). U.S. patent (US8,608,923 B2).

Williams, S., H. Zhang, W. Zhang, L. Xiao, A. Zhou (2014). Modified screen-printed electrodes combined with paper-based microfluidics for detection of ions in water, NORM 2014, University of Montana, Missoula, MT, June 22-25, 2014.

Zhang, W., H. Zhang, S. Williams, A. Zhou (2014, In press). Microfabricated three-electrode on-chip PDMS device with a vibration motor for stripping voltammetric detection of heavy metal ions, Talanta. http:/ / dx.doi.org/ 10.1016/ j.talanta.2014.08.075.

Model Development, Modification and Expansion for Assessment of Utah 319 Projects for Controlling Non-point Source Water Pollution

Principal Investigators:
David K. Stevens
Nancy Mesner,
Douglas Jackson-Smith,
Phaedra Budy,
Darwin L Sorensen
Lorien Belton
JInsu Choi, Nira Salant (Students)

Partners/Collaborators:

- ***Local:*** *e.g. Bear River Canal Company*
- ***State:*** *Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

  Nonpoint source (NPS) pollution remains a significant public policy concern in the State of Utah. Unlike point-source pollution (e.g., factories or sewage treatment plants), NPS pollution is diffuse, originating from a wide range of small sources dispersed across the landscape. In Utah, the most common agents of NPS pollution are sediments, nutrients, heavy metals, salts, and pathogens (UDEQ 2010).

  The dispersed character of NPS pollution presents challenges in efforts to address pollution problems because many actors are involved and each individual change may not noticeably improve environmental conditions. A major focus of NPS pollution control is the development of public programs to encourage voluntary changes at the landscape scale in individual behaviors thought to contribute to documented water quality problems.

  Most of the agricultural watersheds in Utah have supported non-point source pollution mitigation projects under EPA's 319 program or other federal and state programs. Since 1990, the state NPS program has expended almost $30 million to address water quality problems (UDEQ 2009). Much of this funding has gone to watershed projects that involve cost-sharing, technical assistance, and educational programs that encourage landowners to implement appropriate best management practices (BMPs) to reduce pollution loadings to impaired waterways. This project is assessing the efficacy of these projects.

- **Benefits to the State:**

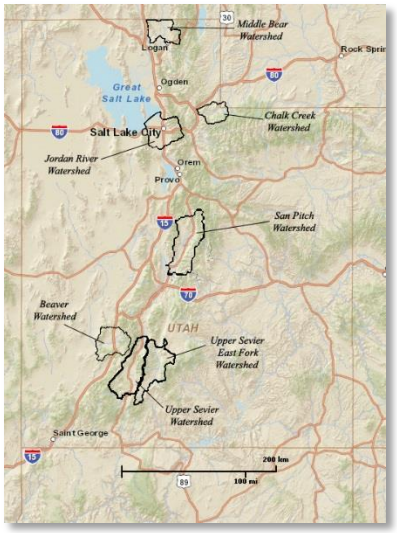
  Some evidence indicates that public efforts to reduce NPS water pollution in Utah have been successful. A comprehensive water quality monitoring program tracks current conditions and water quality trends for all 14,250 miles of rivers and streams, and nearly 3,000 lakes and reservoirs in Utah (UDEQ 2009). State agency assessments suggest that 30% of Utah's waters have impairments that prevent them from meeting their expected uses (UDEQ 2006). This detailed assessment is helping to determine the impact of public 319-funded projects on measured water quality in the state.

- **Geographic Areas:**

  Study Area: Beaver River (Beaver, Piute Counties), Chalk Creek (Summit County), San Pitch River (San Pitch County), Upper Sevier River (including East Fork Sevier River, Garfield County), and Middle Bear River (Cache County). See the map below.

Areas Benefited: Most agricultural watersheds in Utah.

- **Accomplishments:**



Findings: Most respondents had a good basic understanding of the state's NPS program goals and the state's most significant pollutant concerns; however several challenges to efficiency were identified, including concerns that the allocation of 319 funding was too heavily tilted to staff support, rather than actual implementation of projects, poor coordination between the land management programs promoted by different state agencies, poor record keeping on project outcomes and impacts, a convoluted system of contract management, a perception that the program has focused too heavily on agricultural sources, monitoring approaches limited the ability to adequately document program impacts, and a failure of the program to 'tell the 319 story' to Utah citizens and decision makers.

Suggestions for improving program administration and support were submitted to the Utah Department of Environmental Quality. The suggestions included improvements to (1) program administration and implementation, (2) partnership coordination and permit application processes, (3) monitoring and reporting, and (4) communication and outreach.

Results: Overall, the study found that most 319-funded projects are still in place, still functional, and are appreciated by the landowner. Only a small minority of BMPs experienced implementation problems. The qualitative assessment—based on interviews and field assessments—suggested that~60% of BMPs likely or definitely produced positive impacts on water quality, while 15% were in situations that were difficult to clearly evaluate net water quality impacts. About 25% of rural watershed BMPs were considered unlikely to have improved water quality, generally due to placement of the BMPs and/ or designs that mostly accommodated other goals (such as improving irrigation efficiency). Watershed hydrologic models suggested that the full suite of 319-funded BMPs likely improved nutrient loadings and concentrations by very modest amounts (P declined 0.1– 3%, N declined 0.1–0.2%, over a 15-year period of simulations). The small changes in total nutrient loadings were associated with two factors: (1) the relatively small proportion of the watershed that was affected by 319 BMP implementations, and (2) the high background levels of nutrient flows in the affected waterways. Water quality improvements were more significant at the subbasin scale—particularly in the winter and spring when hydrologic conditions generated higher total nutrient loads.

Taken as a whole, assessment of BMP impacts was constrained by poor record keeping, a lack of pre-project data, and the absence of systematic and ongoing monitoring of BMPs and water quality conditions. Improved monitoring efforts and data management for future BMP projects will be necessary to ensure program evaluations can provide more detailed, project-specific information on key parameters for NPS source reduction.

Work Plan FY14/FY15

Completion of student dissertation and publications.

Informational Resources

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

Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Malgorzata Rycewicz-Borecki (PhD student)
Jacob Richardson (MS student)
Thomas Nyanda (Post-Doc)

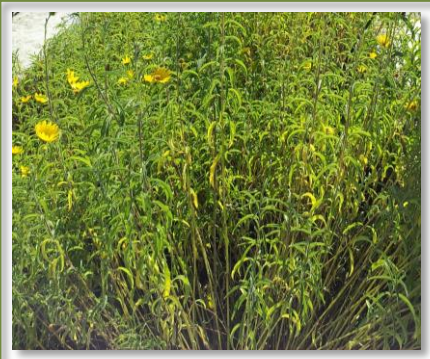
Partners/Collaborators:
- ***Local:*** *Bill Young, Logan City Public Works Department*
  iUTAH Research Coalition. Cache County Storm Water Coalition

Project Description

- **Need and Purpose:**

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

  Logan City and surrounding municipalities are beginning to address storm water quality and quantity issues, and they need locally generated quantitative research to accurately depict vegetative species effectiveness within storm water management facilities. This study measured biomass production and water quality improvement in a controlled laboratory environment and is validating findings at a field demonstration study site. The laboratory scale study provided controlled, replicates of storm water retention basins to measure plant biomass production and total nutrient and metal removal. Water uptake for seven vegetative species was quantified in the laboratory under simulated (frequency and duration) rainfall events. The field demonstration site, an existing subdivision (Green Meadows) storm water detention area in Logan, Utah, is producing quantitative water quality improvement effectiveness data based on plant production / contaminant removal in response to periodic plant harvesting for three species, compared to naturally propagated weed species and non-vegetated control plots.



Vigorous Sunflower Growth at Green Meadows Field Demonstration Site, Spring 2014

- **Benefits to the State:**

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

- **Geographic Areas:**

Study Area: Laboratory study at Utah State University Research Greenhouse, Field demonstration site: Green Meadows Subdivision detention basin, 600 S and 1600 W, Logan, Utah. **Areas Benefited**: All counties in Utah would potentially benefit from quantitative data that can be utilized within storm water management systems.

- **Accomplishments**:

  Findings: Data analysis and reporting for nutrient and metal removal data from the lab greenhouse study are complete. Lab-scale evidence of species differences in nutrient and metal concentrations accumulated in the harvestable, above-ground biomass suggests that the common reed and sedges are optimal plants to improve water quality of stormwater in arid, northern Utah.

  Field-scale performance monitoring occurred at the Green Meadows field demonstration site during summer/ fall FY11, and spring/ summer/ fall FY12 to summer FY14. The masses of both harvested above ground plant material and harvestable nutrients and metals from the treatment areas from mid- and end- season harvesting were documented under actual field climatic conditions. Long-term monitoring from FY11 through FY14 storm events indicates a significant storm water retention and infiltration capacity within the collection system throughout the Green Meadows subdivision. Significant storm water infiltration (10 to 35% of runoff) has been observed prior to entering the on-site storm water treatment area. Site evaluation (FY 13 on) is documenting performance of the as-built storm water collection system. Tracer studies have been completed and groundwater impact monitoring is under investigation to develop design guidelines for the implementation of an "infiltration" collection system at other sites throughout Utah.

  Results: Plant biomass production (sedge, sunflower, cattail, naturally seeded plots), and nutrient and metal mass recovery from the treatment areas, as a function of seasonal harvesting (mid- and end-season versus only end-season), was evaluated and complete for the FY11 through FY13 growing seasons by harvesting above-ground biomass from each of the field test plots. With no surface discharge from the planted areas, maximum nutrient and metal removal is possible in these systems. Harvested biomass increased significantly after plant establishment throughout the field plots for FY12 and FY13 as a function of harvest frequency. The naturally seeded, mixed plant community initially provided significantly higher biomass than other single test species, but by FY13 cattail and sunflower biomass had statistically identical quantities of biomass. Twice a year harvesting did not produce significantly higher biomass yields but did increase the recovery of nitrogen in all species, and phosphorous and zinc in sunflowers. Mid-season harvest has not been shown to negatively impact the production of biomass or recovery of other contaminants of concern in subsequent growing seasons. Outreach activities included on-site tours of the facility by member of the iUTAH Green Infrastructure Research Facility planning committee and participants in an iUTAH summer water quality symposium held in Logan in 2014.

Work Plan FY14/FY15

Contaminant removal performance data will be collected at the field site during summer and fall 2014 and spring 2015. Field plant harvesting and soil sampling from late fall 2014 will be added to the database of nutrient and metal uptake and harvesting performance. A study to investigate the potential to increase metal and nutrient uptake following citric acid addition will be completed during summer and fall 2014. Runoff, storm water storage, and infiltration within the collection system will continue to be monitored, and tracer studies and storm water transport modeling will help to improve storm water collection and treatment system design in the state.

Informational Resources

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

Release of Arsenic from Aquifer Solids under Anaerobic Conditions

Principal Investigators:
Joan E. McLean
Darwin L. Sorensen
Babur Mirza (Post-Doctoral Fellow)
Xianyu Meng (PhD student)
Allie Abu-Ramaileh (MS student))

Partners/Collaborators:
Local: *Issa Hamud, Director of Environmental Department, City of Logan*

Project Description

- **Need and Purpose:**

  Arsenic is one of the most frequently detected individual contaminants in domestic private wells used for household drinking water and public water supplies in the U.S. Of the domestic wells tested that had arsenic in excess of the drinking water limit (10 µg/ L), 10% were located in the basin-fill aquifers of California, Nevada, New Mexico, Arizona, and Utah. Seventeen percent of the well water in Cache County, as reported by the Utah Geological Survey, contained levels of arsenic that exceeded the drinking water limit, with elevated concentrations of arsenic in well water in Salt Lake and Utah counties. Geologic formations throughout Utah contain arsenic; however, 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. This study investigates conditions that lead to arsenic release to groundwater at a sampling location in the Cache Valley Basin.

- **Benefits to the State:**

  All counties in Utah will benefit from an improved understanding of the biogeochemistry governing the behavior of arsenic in subsurface environments undergoing reducing conditions that may lead to groundwater contamination.

- **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 resources throughout the state. Arsenic in groundwater is a worldwide problem.

- **Accomplishments:**

  Findings: Sediment cores (6 m in depth) were collected from a site in the center of the Cache Valley basin-fill aquifer. From detailed geochemical analyses, including the use of high-energy x-ray absorption spectroscopy, we have developed a conceptual model for the sources and sinks of arsenic down the profile and the biogeochemical processes that controls the solubility of arsenic.

  Results: Samples were collected from the soil surface to depth of groundwater. Arsenic association with mineral phases was determined using chemical extraction and molecular-scale analysis using high-energy x-ray absorption spectroscopy.

Conceptual Model (Figure 1): Arsenic is deposited on the soil surface as primary and secondary arsenic minerals derived from volcanic rock in the surrounding mountains (Figures 2–3). These reduced arsenic minerals are oxidized and solubilized under conditions in the near surface soils, releasing arsenic to solution. This arsenic is either transported down the profile or it is retained by iron oxide and carbonate minerals. A unique feature of this geological area is the abundance of carbonate minerals, a characteristic mineral in semi-arid and arid environments. With the rising and lowering water table, the sequestered mineral phase arsenic may be released to the groundwater as the carbonates and iron oxides are dissolved under water-inundated conditions. It is critical to understand and control this zone as it provides arsenic to the groundwater. Under highly reducing conditions, arsenic is again retained by insoluble minerals deep in the profile.

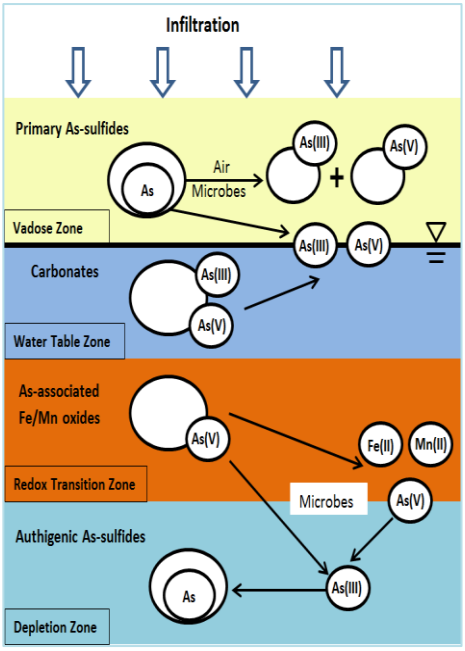


Figure. 1 Conceptual model of the processes controlling arsenic solubility for a sediment core collected from the Cache Valley basin-fill aquifer, from the soil surface to 6 m below ground surface

Work Plan FY14/FY15

We will continue to investigate the biogeochemical factors that lead to the release of arsenic to groundwater from native geologic materials, in particular the role of carbonate minerals. We are developing more sensitive molecular tools to identify the microbial communities mainly responsible for arsenic mobilization in this region.

Informational Resources

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

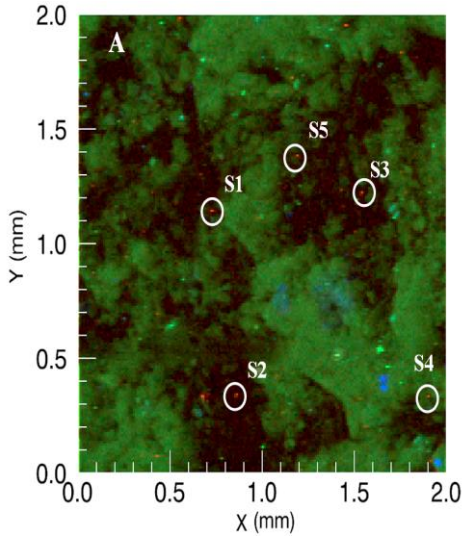


Figure 2. µX-ray fluorescence map of surface soil for arsenics (red), iron (green), and manganese (blue). Circled regions represent the area where µ-XANES spectra were collected. The red dots show the present of arsenic minerals

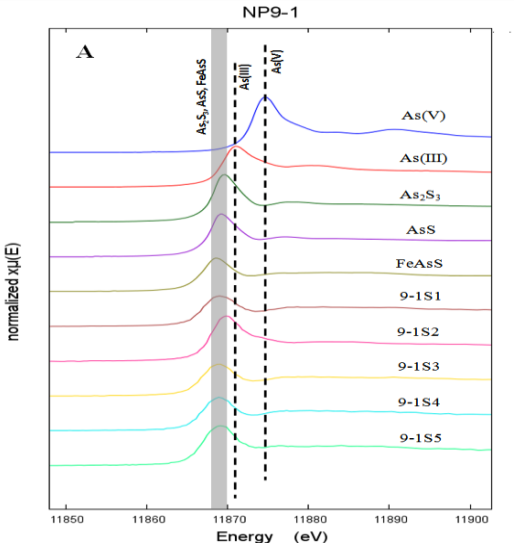


Figure 3. µXANES spectra show that the surface soil contain arsenic sulfide minerals, the potential source of arsenic in Cache Valley Basin sediments

Salinity Reduction Measures for the Upper Colorado River Basin

Principal Investigators:
Jagath J. Kaluarachchi
Jongho Keum, Student

Partners/Collaborators:

- ***Federal:*** *US Geological Survey*

Project Description

- **Need and Purpose:**

  Both natural and anthropogenic sources affect salinity levels in the Upper Colorado River basin, where economic damage due to salinity can be in excess of $300 million per year. Many sources are from individual land uses and practices. Compared to most agricultural pollutants, some of which are known carcinogens, health risks from salinity is considered marginal, with the risk limited to economic losses in agricultural and urban land uses. However, when salinity originates from alluvial (marine) deposits, the pollutants may pose a greater health risk, as with selenium. There is a need to investigate the relationship between the estimated benefits of different levels of reduction in salt loadings and the corresponding economic damage or costs of salinity control. It is also important to distribute the economic impacts as equitably as possible among the different stakeholder groups to minimize conflicts. With recent funding from the US Geological Survey, we investigated the advantages and limitations of an existing modeling framework for predicting salinity in the Upper Colorado River Basin (UCRB). This modeling framework was proposed by the US Geological Survey (USGS) through its SPARROW model. In this work, we investigated optimal salinity reduction measures, considering cost and equity among different land users and strategies. The specific objectives were to evaluate the SPARROW model for predicting the salinity generation from the different watersheds of the upper basin, adequacy of the existing monitoring network, the need to expand the network, and the cost-equity tradeoffs in salinity reduction measures in different watersheds.

- **Benefits to the State:**

  Utah is one of the states benefiting from Colorado River water, so the quality of water used by local stakeholders is important to maximizing the beneficial use of water. Increasing salinity limits the productivity of water in agriculture, and salinity from various land use practices can be costly in terms of salinity reduction for local stakeholders. Therefore, a study dedicated to understanding salinity generation mechanisms, monitoring needs, and salinity reduction allocation tradeoffs is of great value to Utah decision-makers.

- **Geographic Areas:**

  Study Area: The study area consists of the Upper Colorado River Basin.

  Areas Benefited: Mostly irrigated agricultural areas.

- **Accomplishments:**

  Findings: The USGS developed SPARROW91 (Kenney et al., 2007) is a mass balance model for TDS that uses spatial referenced regression with 1991 data. The model is representative and good because it considers both deterministic and statistical properties while accommodating physical properties related to water quality. As a regression model, the number of monitoring locations and the amount of data are important factors determining the accuracy of the model; therefore, the SPARROW model for the UCRB was used in this study without significant revision.

SPARROW mass balance computes the load leaving a reach as the load generated from the reach's incremental watershed and delivered to the reach and the loads from the upstream reaches. In the first analysis we determined how much salt would be generated and how much salt could be reduced by salinity control programs installed in each watershed. In other words, salinity reduction management scenarios required the incremental salt loading of each watershed. This study also investigated alternate methods of improving model calibration to those proposed by Kenney (2007) and extending the analysis period to 2011. The second phase of the study focused on understanding the adequacy of the monitoring network for salinity measurements and proposed an improved method to identify watersheds with redundant or deficit monitoring based on salinity production. Finally, this study investigated cost-equity considerations in salinity management compared to a base scenario of total cost minimization.

Results: Three watersheds in the UCRB generate almost 20% of total salt loadings, as shown in Figure 1. The basin has 218 monitoring stations with specific conductivity (as TDS) data and 59 HUC8 watersheds, or 3.7 stations per watershed. Many of the monitoring stations have relatively low TDS yield, such as HUC 14060004 Strawberry Watershed. In contrast, few monitoring stations have relatively high salt yield, such as HUC 14060009 San Rafael and HUC 140801 Upper San Juan Basin. Results show that the monitoring program should be updated based on the actual salt generating capacity of the watersheds. The number of monitoring stations has steadily decreased in the past two decade, but this methodology can help to identify redundancies or deficits in the network. The cost-equity analysis used three equity measures to develop a total of six scenarios: two corresponded to simple cost minimization or cost allocation based on irrigation land area of each watershed, and four used minimization of equity reference distribution with cost, possible maximum salinity control quantity, percent irrigated land area, and net agricultural income.

Work Plan FY14/FY15

This work is complete.

Informational Resources

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

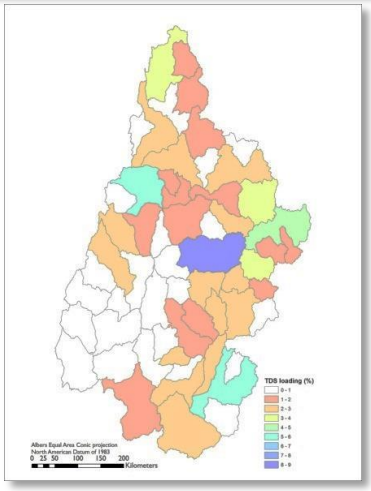


Figure 1. Percentage of the total TDS loading generated within each watershed

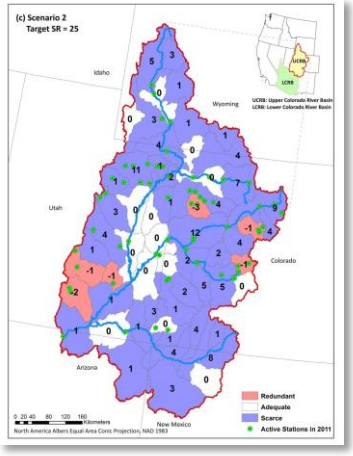


Figure 2. Spatial distributions of proposed monitoring network for the scenario of target SR of 25. The numbers indicate monitoring stations to be added or reduced

Source Water Protection for Potential Phosphorus Mining Impacts in the Uintah Basin

Principal Investigators:
David K. Stevens
Joan E. McLean
Ahmed Bitar (Graduate student)

Partners/Collaborators:
- ***Local:*** *City of Vernal and Uintah County*

Project Description

- **Need and Purpose:**

  Source water protection for drinking water systems remains a significant public policy concern in the State of Utah. A proposed phosphate mine in the Uintah Basin, Utah, near the city of Vernal on Ashley Creek, may threaten the water supply at Ashley Springs for the city with both non-point source runoff that may contaminate the water supply with sediment and inorganic pollutants and potential modifications in flow regimes that could disrupt discharge from those springs. Discussion with city and county officials has highlighted concerns of threats to the water supply. The proposed phosphate mining operation is considered for the ridges surrounding Ashley Creek in Uintah County. Removal of ~20 m of overburden cap rock and the phosphorus-bearing ore will expose buried materials to weathering that will create a significant risk for release of sediment and toxic anions, such as selenium, arsenic, in addition to other anions such as sulfate. All of these materials will threaten the quality of the water supply at Vernal's Ashley Springs and may impact the spring discharge and prompt the city to seek alternative sources. This project begins the process of data collection and assessment to provide the City of Vernal and Uintah County with resources and tools to plan for this possible threat to Ashley Springs.

- **Benefits to the State:**

  The data and information provided by this will provide:
  - An assessment of the current situation and the potential for changes in hydrology and contaminant transport that may threaten drinking water supplies
  - Resources and tools to the City of Vernal and Uintah County to plan for the possibility of this threat to Ashley Springs as a drinking water source.
  - Data and reporting activities that will help city and county decision makers to understand potential threats and act to protect this drinking water source, including: field measurements of physical parameters (e.g. channel configuration) needed to populate the models and collected water quality data near source water protection zones where such data are not available, an observations data model for the database system, a populated database, data summaries, reporting, and public meetings with stakeholders.

- **Geographic Areas:**

  Study Area: All project related work will be performed in Uintah County and at the UWRL.

  Areas Benefited: Watersheds statewide.

- **Accomplishments**: The following elements have been completed:

  Findings/Results:

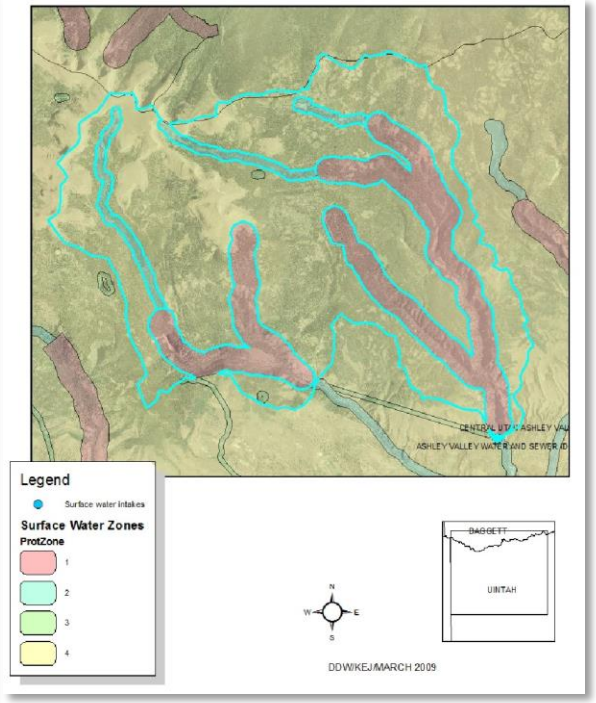
  Assess Data Needs—Existing data have been collected, reviewed, and warehoused in spreadsheets for assessment purposes. An existing database that includes hydrologic and water quality data in Ashley Creek and Dry Fork through 2003 has been updated through 2012, and additional land use, topography, weather and other data have been collected. Once existing data is compiled, we will establish its suitability for source water assessment, and recommend any additional data collection.

  Delineate/ Assess Source Water Protection Zones—A Source Water Protection plan was developed by the Central Utah Water Conservancy District for Ashley Springs based on the land use in effect in 2009. The figure below shows the Zone 1 protection area (the most critical) shaded in red on the map and extending 1/ 2 mile on either side of Dry Fork 15 miles west into Dry Fork and 1/ 2 miles on either side of Ashley Creek 15 miles north, including all tributaries to each stream.

  Assess potential for release of toxic inorganic compounds due to exposure of ore bodies—One important threat to drinking water from mining is exposure of the subsurface rock to oxygen, carbon dioxide, and water. Geological formations in the region have historically released selenium and arsenic when exposed to water and air, threatening viability of the water supply. A preliminary study of the geological of the proposed mining region will inform the City of Vernal of these potential concerns. This will also inform plans for sampling and analysis of subsurface materials and the effects of their exposure to weathering.

Work Plan FY14/FY15

- Complete and deploy model for the effect of P mining on Ashely Spring. Apply SWAT/ APEX rainfall/ runoff/ contaminant transport model to the source protection zone.
- Develop modified source water protection zones for Ashley Springs and assess their suitability in light of potential phosphate mining activities within and adjacent to the Zone 1 protection area.
- Collect and analyze hydrologic, geological, and water quality date, following source protection protocols to add this fifth source and determine what plan changes may be suitable.
- Recommend a source water protection zone
- Complete student thesis based on project results.



View of potential project area for Ashley Gap phosphate mining (CUWCD 2009)

Informational Resources

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

Technical Support for Bear River System Data Acquisition

Principal Investigators:
David K. Stevens
Bethany T. Neilson
Austin Jensen
Hussein Ali Batt (Student)
Mark Winkelaar (Technician)

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

Project Description

- **Need and Purpose:**

  The focus of the project is to provide high-level technical support for development of alternative data acquisition networks for large-scale remote data gathering stations in watersheds, on rivers, and in lakes. We are providing field and analytical support for the Middle Bear River, Little Bear River, the Logan River, and Spring Creek water quality monitoring stations to complete a basin-wide network for assessment of nutrient loads and other water quality measures for Cutler Reservoir and the Cutler Reservoir TMDL implementation. We also provided support for monitoring in Mud Lake (adjacent to Bear Lake) to explore statistical learning theory applications for sediment load estimation.

- **Benefits to the State:**

  Specific benefits of the modeling work ongoing at the UWRL to the State of Utah include:

  1. Improving understanding of the sediment and nutrient dynamics in the Bear River basin.
  2. Providing innovative data acquisition systems for remote areas.
  3. Establishing relationships among regulated water quality variables at key monitoring locations to improve high-frequency load estimation for Cutler Reservoir.
  4. Building data-driven models of sediment-rich water systems to support estimation and management of sediment loads.
  5. Acquiring bathymetric data to assess dynamics of sediment transport in lakes.

- **Geographic Areas:**

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

  Areas Benefited: Watersheds statewide.

- **Accomplishments:**

  Findings: A large and growing database for the rivers in the Bear River Basin has allowed us to develop an unprecedented capability to assess long term relationships at key water quality monitoring points in Cache County for a variety of research and management purposes. These data are publically available and are served through the web-based Bear River Information System developed under previous projects.

  The data collected through this project have been used by a variety of researchers and graduate students at USU and nationwide. Several papers and a book chapter have been published with

data collected using the Bear River monitoring network, and large-scale new projects will use the data from the database system.

Field monitoring carried out during Summer 2011 in Mud Lake to assess the transport of sediment into and out of Bear Lake from the Bear River under this project using Hydrolab measurements to characterize the general water quality has resulted in the successful dissertation defense of the graduate student involved, and two manuscripts have been submitted for publication, with a third nearing completion. The data collected were used in conjunction with a statistical learning model known as relevance vector machines (RVM) to predict the sediment behavior in this shallow, vegetated lake. This provides needed insight for sediment transport in the Bear River Basin, other parts of Utah, and the Intermountain West region. Included in this work were two bathymetric studies of Mud Lake, one in 2009 and a second in 2014, to help determine whether sediment has accumulated in the 5-year interim.

The RVM modeling work completed showed that the RVM model effectively predicted water quality in Mud Lake and helped to identify redundant water quality monitoring stations in the lake. This will be useful for future sediment monitoring network design to minimize monitoring costs without loss of information concerning sediment loads in similar systems.

Results:

- Collected remote data for water quality and hydrologic measurements in Bear River tributaries.
- Created a robust database system for research and public viewing and analysis of flow and water quality data.
- Developed a statistical learning theory model of sediment and other water quality measures in Mud Lake.
- Submitted a journal manuscripts. One has been accepted in Environmental Engineering Science, a second is in review, and a third is nearing completion.
- Completed publications for Mud Lake statistical learning theory model of sediment loading.
- Explored non-parametric statistical analysis of surrogate measures data (e.g., suspended solids or total phosphorus vs. turbidity at several sampling locations) for publication.
- Prepared a proposal for continued funding of a second bathymetric study of Mud Lake – funded by Bear Lake Watch, a local non-profit responsible for lobbying efforts on behalf of Bear Lake and environs and holding a symposium each May. Attended and presented data concerning the results of the two bathymetric studies.
- Supported completion of 2nd Mud Lake Bathymetric data collection in May-June 2014.

Work Plan FY/14FY15

This project will be completed in 2015 with preparation of the bathymetric study report.

Informational Resources

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

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

Water Allocation and Salinity Issues of the Sevier River Basin

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

Partners/Collaborators:

- ***State:*** *Utah Department of Water Resources*

Project Description

- **Need and Purpose:**

  The Sevier River Basin, a closed basin located in south central Utah, covers approximately 10,575 square miles or 12.5% of Utah's land area. This basin provides water for nearly 23% of privately held land and for domestic and industrials uses. The basin is divided administratively into lower and upper basins, with much of the water in the upper basin produced from winter snowfall and spring runoff. The bulk of the spring runoff from the upper basin's high elevations is stored in three major reservoirs: Otter Creek, Piute, and Sevier Bridge. Three smaller reservoirs help regulate flow during the peak growing season. Water for agriculture is typically allocated during early spring, mostly in March. This allocation is based on the available reservoir volumes from the prior year and on anticipated runoff for the coming year, which will not occur until May or June. Since the expected spring runoff is unknown or best estimated using prior data, water availability estimates have considerable uncertainty in any given growing season. Given this uncertainty, allocating water is a challenge for water managers each year.

  Phase 1 will develop a reliable hydrologic model that can predict water availability and expected reservoir volumes using prior year information and measured winter snowfall data. Salinity generated from irrigation return flows during the growing season is also a significant concern in the lower basin. Currently, ground water is used to reduce salinity in the Sevier River. Phase 2 will develop an efficient and low-cost approach to validate FAO's AquaCrop model using remote sensing (RS) estimates instead of crop ground measurements. Regional crop information will be used to predict canopy cover (CC) and above-ground biomass (AGB). This effort will also identify the impacts of salinity on crop yield. Phase 3 will identify the optimal water use between surface water and groundwater for irrigation such that farmers can maximize profits, knowing the forecasted water availability from early spring using snowfall measurements.

- **Benefits to the State:**

  Given the dominance of agriculture in Utah, especially in rural communities, accurate water availability estimates based on winter snowfall measurements and prior year information are crucial to water managers. A successful hydrologic model for the Sevier River Basin, which has managed flows from the multiple reservoirs, we believe the work could be extended to other basins in Utah and the US. Using the forecasted information, this optimization methodology could also provide insight to farm practices such as the best combination of land and crop types to plant for maximum profit, the best allocation/ use of surface water and ground water in a given season, and the risk exposure of farmers to price fluctuation in a given season.

- **Geographic Areas:**

  Study Area: The Sevier Basin, occupying approximately 12.5 percent of the land area of Utah.

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

- **Accomplishments:**

  Findings: Phase I: Because some gauging stations in the main channel of Sevier River do not represent natural flow due to flow alterations and reservoir operations, it is difficult to calibrate a hydrologic model using altered streamflow data directly. Instead, if the natural flow is generated by regionalization methods for ungauged watersheds, the level of alteration and the water use can be computed by comparing generated natural flow with observed data. The proposed approaches are an FDC method using the current precipitation index and lumped and distributed tank models combined with the simplified SNOW 17 model. Daily temperature and precipitation data at SNOTEL stations are used as input. Spatial variation of inputs is estimated from the past 30 years of PRISM data. Thirteen USGS stations not affected by river diversions are selected for calibration and regionalization.

  Phase 2: Developed a radiance use efficiency (RUE) based RS model for estimating aboveground biomass (AGB) with Landsat images and regional crop information. The RS estimates are used to validate AquaCrop's built-in crops and calibrate it under salinity stress. As a result, RS estimates of canopy cover (CC) and AGB were produced from an existing CC model and the proposed AGB model, respectively. These estimates became good replacements of the ground measurements for validation and calibration.

  Results: As a result of phase 1, the proposed FDC method and hydrologic models showed the model performance is acceptable. The three approaches performed well in generating snowmelt runoff. Particularly, even though the FDC method requires less calibration, it shows competitive performance when correlation between streamflow and the current precipitation index is high. Unfortunately it is difficult to generate rainfall driven runoff accurately since this runoff is represented by daily streamflow data that are too small to be distinguished from base flow. In general, the proposed approaches satisfactorily for predicting streamflow from snowmelt, which is the dominant hydrologic process in the Sevier River Basin.

  Phase 2 results showed good agreement between simulations and RS estimates under non-stress conditions for built-in maize from AquaCrop, whereas built-in barley underestimated AGB compared to RS estimates. By comparing the RS estimates in salinity-affected farms to AquaCrop simulations without considering salinity stress, AGB reduction due to salinity stress and corresponding CC reduction were quantified for calibration of AquaCrop under salinity stress.

Work Plan FY14/FY15

Work related to Phase 3 is continuing. We will use the information from Phase 1 to forecast water availability in early spring knowing the snowfall measurements in the winter and Phase 2 results to evaluate crop yield for a given water allocation, irrigation schedule, and soil and water salinity. An optimization methodology will be developed to predict the optimal crop/ land use combination to maximize profit and to determine risk exposure due to crop price fluctuations. This analysis will also provide the optimal combination of surface water and ground water to be used to maximize profit, given the cost of ground water pumping and potential reduction of crop yield due to existing salinity.

Informational Resources

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

Water Conveyance, Distribution, and Control

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
Effects of Pipe Wall Offsets on Differential Pressure Meter Accuracy	$3,935.83	$4,053.90	$0.00
Labyrinth Weir Research	$74,729.32	$76,971.20	$0.00
Open Channel and Closed Conduit Field Flow Measurement, Maintenance and Upgrade for the State of Utah	$50,720.38	$52,241.99	$13,484.66
Sediment Management for Small Reservoirs: Logan First Dam Study	$552.83	$1,000.00	$1,030.00
Designated Projects		$20,500.00	$10,000.00
Undesignated Projects		$10,000.00	$5,000.00
Total	**$129,938.36**	**$164,767.09**	**$29,514.66**

Effects of Pipe Wall Offsets on Differential Pressure Meter Accuracy

Principal Investigators:
Steven L. Barfuss
Jesse M. Pope
Jordan C. Jarrett

Partners/Collaborators:

- ***Business:*** *Primary Flow Signal, McCrometer*

Project Description

- **Need and Purpose:**

  Accurate flow measurement is essential for the effective management of any type of fluid system. Many industries, including oil, water, and gas, manage large volumes of fluid every day. A small percentage of error in measurement may cost the system large amounts of money, or resources. Many researchers have studied upstream piping effects on meter accuracy and accordingly have recommended general installation requirements. To minimize the negative effect on metering accuracy, 8-10 straight pipe diameters are commonly required upstream of the meter when valves, elbows, and reducers are installed upstream. If for any reason a meter is incorrectly installed or has a different inside diameter than the pipe that is immediately upstream, the pipe wall offset creates streamline separation, which causes non-ideal flow conditions as water flows through the meter. Subsequently, meter accuracy may be affected. Most flow meters require a steady, near-ideal flow through the meter in order to be accurate; the purpose of this project is to determine the actual effect of pipe wall offsets on flowmeter accuracy.

- **Benefits to the State:**

  The data from this project will improve flow meter accuracy for all water utilities, municipalities, and power plants in the state of Utah. Better-defined pipe installation specifications are available as a result of this research and will continue to be refined.

- **Geographic Areas:**

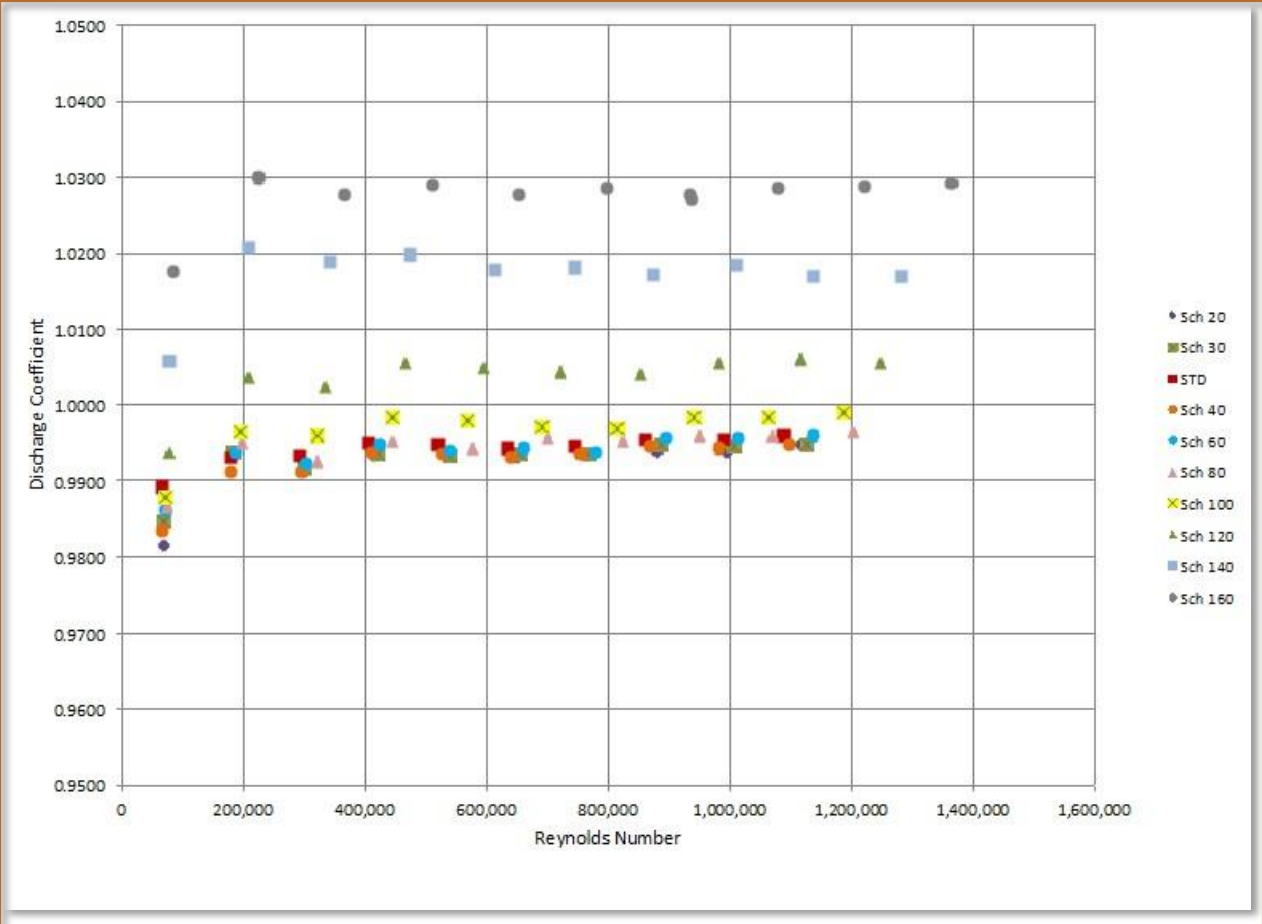
  Study Area: NA.

  Areas Benefited: The results of this study will improve flow measurement accuracy across the globe.

- **Accomplishments**:

  Findings: Seven different flow meters were tested: Ultrasonic, V-Cone, Magnetic, Classic Venturi, Halmi Venturi, Wedge, and X Meter. Each Meter was tested using ten different schedules of pipe installed on the upstream side of the meter. These included schedule 20, 30, standard, 40, 60, 80, 100, 120, 140, and 160, which provide pipe wall offsets varying from -0.25-inch to 1.874-inch. Each of the meters was tested using ten flow rates ranging from 400 gpm to 7000 gpm.

  Results: In most cases the meters are resilient to negative diameter offsets from smaller pipe schedules. However, positive diameter offsets have significant effects in most cases. The sudden expansion in the pipe causes flow measurement error of as much as 8.0% depending on meter type and pipe size.



Example of Results for one of the meters

Work Plan FY14/FY15

- Numerical modeling is currently underway to determine the ability of CFD to simulate this same research and to perform additional configurations that have not been tested in the laboratory.
- A journal paper is being written and will be submitted to the journal of AWWA later this year.

Informational Resources

Contact: Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Jesse M. Pope (435)797 3231, Email: jesse.pope@aggiemail.usu.edu.
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Labyrinth Weir Research

Principal Investigator
Blake P. Tullis

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

Project Description

- **Need and Purpose**:

  With the revisions of probable maximum flood flows and greater emphasis on dam safety, many spillways are found to require rehabilitation or replacement. Labyrinth weirs are often a favorable design option because these 'folded linear weirs' facilitate flood routing and increase base-flow reservoir storage capacity. However, the many geometric design parameters and the distinct hydraulic behaviors of these structures can make it difficult to engineer an optimal weir design. This study included work on the following topics: (a) controlling peak reservoir flood discharges through the use of staged labyrinth weirs, (b) influence of labyrinth weir apex design on hydraulic efficiency, weir flow nappe vibration/ instabilities.

  (a) In many cases, the goal with reservoir flood routing is to maximize the outflow discharge, using highly efficient flow control structures such as labyrinth weirs, to maximize dam safety and minimize upstream flooding. In other cases, the maximum outflow through the spillway should be limited during more frequent lower-magnitude flood events to minimize downstream flooding impacts.

  (b) Labyrinth weir hydraulic inefficiencies have been attributed to the colliding flows at the upstream apex (typically a trapezoidal weir wall geometry in plan view). It is important to make the apex width sufficiently wide to be "constructible" (allow sufficient room for concrete form work) while mitigating the negative effect of overall weir length reduction that comes with wider apexes. Laboratory tests were conducted to evaluate the influence of apex geometry variation on hydraulic efficiency.

  (c) Under certain conditions, the jet of water (nappe) flowing over a weir wall can become unstable and begin to vibrate. Nappe vibration can create significant acoustic energy that may pose structural response risks as well as negative environmental impacts. Laboratory tests were conducted to develop a better understanding of nappe vibration behavior and methods of mitigation.

- **Benefits to the State:**
  The results of this study may provide a spillway upgrade alternative and may prove useful in increasing the sustainability of existing dam with undersized spillways. Labyrinth weirs are a commonly used alternative to a linear weirs for increasing the spillway capacity without increasing the width of the spillway apron. Insufficient data are currently available for the range of labyrinth weir design alternatives. The Utah Division of Water Resources is designing an arced labyrinth weir for Millsite reservoir (UT) based on this research.

- **Geographic Areas:**

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

Areas Benefited: Spillway structures are common to nearly all dams, so the application of the study results could extend globally.

- **Accomplishments:**

  (a) Using previous research results, which established hydraulic discharge relationships for staged labyrinth weirs (staged labyrinth weirs feature weir wall segments with varied crest elevations), the first study evaluated the effects of weir type (linear ogee crest weir, labyrinth weir, staged labyrinth weir) on peak reservoir outflow discharges using a numerical flood routing computer model and a fictitious reservoir. Results showed that, by varying the hydraulic characteristics of the spillway control structure (i.e., weir), the peak reservoir outflow discharge can be manipulated based on how the reservoir flood storage volume is utilized during a flood routing event.

  (b) A second study evaluated a variety of labyrinth weir geometries in the laboratory for hydraulic efficiency. The study found that hydraulic efficiency increases (more discharge) as the apex width decrease (triangular apexes are more efficient than trapezoidal apexes). Apex geometries should be designed based on the minimum constructible width.

  (c) A third study developed two independent test facilities (large-scale and small-scale) and made significant exploratory efforts to help determine causes and methods for mitigation of linear weir vibration, but the research applies to labyrinth weirs, as well. Prototype labyrinth weir nappe vibration has been reported in practice. We used particle image velocimetry (PIV) to evaluate flow conditions at the crest in an effort to identify potential causes of the vibration. We collaborated with Sebastien Erpicum (University of Liege, Belgium) who is also evaluating nappe vibration in his laboratory. This study identified potential causes of nappe vibration and secondary factors that can amplify the effect and evaluated some corrective measures for minimizing the problem.

Work Plan FY14/FY15

In FY15, additional nappe vibration data will be collected using particle image velocimetry techniques and high-speed pressure measurement instrumentation by Mohanad Khodier (post-doc) to investigate the flow behavior along the weir crest, the location most likely responsible for nappe vibration development. We will explore alternative data collection techniques (using low density powder injected behind the nappe to track air current patterns). We will also use computational fluid dynamics to further explore the phenomenon.

Informational Resources

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

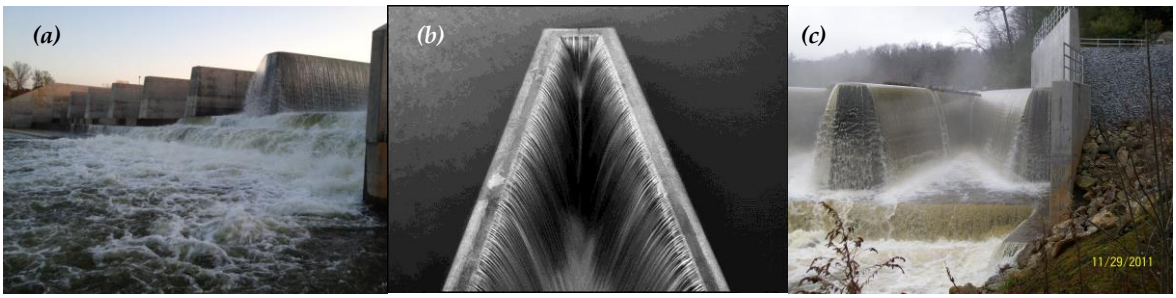


Figure: (a) staged labyrinth weir, (b) labyrinth weir apex geometry, (c) vibrating labyrinth weir nappe

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

Principal Investigators:
Steven L. Barfuss
Jordan C. Jarrett

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

Project Description

- **Need and Purpose:**

  Limited and depleted water resources have become an issue of increased concern, especially in Utah where the arid land requires irrigation to produce ample crops. As a result, water distribution system managers 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 that design manufacturer specifications claim. The purpose of this project has been to determine major contributors to flow measurement errors and to assess the devices that exhibit these errors in an attempt to provide direction for reducing these measurement errors. Another purpose is to provide a resource to irrigation companies for evaluating the accuracy of their flow measurement devices and to provide suggestions on how to improve the accuracy of their devices.

- **Benefits to the State:**

  Improved accuracy of flow measurements throughout the State of Utah will ultimately improve the allocation of water rights. Over time, small errors in flow measurement can add up to very large errors in the allocation of water rights. This project is generating a database of information to determine which flow measurement structures have the greatest need for remediation, repair, or recalibration. The project directly benefits water companies in the State as a result of the in-field calibrations that are performed.

- **Geographic Areas:**

  Study Area: Entire State of Utah.

  Areas Benefited: All irrigated areas of Utah.

- **Accomplishments**:

  Findings: A total of 222 flow measurement device assessments have been performed as of August 1, 2014. These devices include 126 Parshall flumes, 19 ramp flumes, 1 cutthroat flume, 27 weirs, 27 rated sections, 5 sluice gates, 9 ultrasonic meters and 5 magnetic meters. Only 33% of the tested devices measured flow within manufacturer design specifications. The remaining 67% 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, uneven flow where head measurements

are taken, and improper construction of the device. These factors create incorrect measurements that prevent water users from receiving their true water allocations.

Results:

- A list has been generated that details all visited sites and their locations, measurement device types, accuracies, and problems.
- 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.

Work Plan FY14/FY15

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

Informational Resources

Contact: Mr. Steven. L. Barfuss (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Jordan C. Jarrett (435) 797 3231, Email: jordan.jarrett@usu.edu.

Examples of Flow Measurement Devices Tested in Utah

Sediment Management for Small Reservoirs: Logan First Dam Study

Principal Investigators:
Amber S. Jones
Mac McKee

Partners/Collaborators:

- ***Local:*** *Ben Barrett, Stan Kane, and Reid Olsen, Utah State University Facilities*
- ***State:*** *Jeff Ostergaard, Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

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

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

- **Benefits to the State:**

  The state will benefit from the 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 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 and downstream of First Dam.

  Areas Benefited: Small run-of-river reservoirs throughout the State.

- **Accomplishments**:

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

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

- River flow is the main factor in terms of planning for a flushing experiment.
- During a flushing event, close attention must be given to flow data from real-time sites in order to verify that the hydraulic conditions required by the reservoir outlets are being met by the prevailing flow levels into the reservoir.
- For the several days that a flushing/ sluicing event is conducted, available river flow forecasts must be periodically examined to better anticipate future flow conditions and regulate hydraulic operations at the dam.
- Outflows from the hydraulic structures on the dam must be monitored during flushing/ sluicing events to ensure that the required hydraulic conditions are being met and maintained.
- During a flushing/ sluicing event, estimates of the load entering and leaving the reservoir should be made in order to evaluate the performance of the procedures that were followed during the event.
- During lower flow years, the spring runoff conditions may not result in sufficient discharge warrant flushing/ sluicing. The age and conditions of the outlet structure should be considered in determining whether to conduct a slushing/ sluicing event.

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

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

Work Plan FY14/FY15

Researchers at the UWRL will monitor river flow forecasts and advise the operators of First Dam regarding timing in conducting a sluicing event during spring runoff in 2015. 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, Phone: (435) 797-3157, E-mail: mac.mckee@usu.edu.

Water Education and Technology Transfer

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
Education Program for Homeowners and Other Users of Septic Systems in Utah	$24,211.72	$11,378.13	$11,719.47
Enhancement of Septic System Educational Programs in Utah with Advanced Training	$23,096.49	$23,789.38	$25,400.26
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$1,000.00	$1,030.00	$6,960.19
Salt Lake Valley Solid Waste Management Council	$1,000.00	$1,030.00	$1,060.90
State of Utah Drinking Water Board	$4,306.58	$1,030.00	$1,060.90
Statewide Nutrient Criteria Development: Core Advisory Team	$1,000.00	$1,030.00	$1,060.00
Support for State Watershed Modeling and TMDL Plans: Tools to Assist in Nutrient Criteria Development Using QUAL2Kw	$15,074.01	$15,526.23	$1,060.90
Utah Governor's Unmanned Aerial Systems Test Site Advisory Board	$1,000.00		
Utah Water Education Project	$13,341.33	$32,500.00	$0.00
Water Environment Association of Utah (WEAU)	$1,000.00	$1,000.00	$1,000.00
Weber-Morgan Health Department Wastewater Advisory Committee	$1,000.00	$1,030.00	$1,060.00
Designated Projects		$25,420.87	$10,000.00
Undesignated Projects		$7,500.00	$0.00
Total	**$86,030.13**	**$122,264.61**	**$60,382.62**

Education Program for Homeowners and Other Users of Septic Systems in Utah

Principal Investigators:
Judith L. Sims

Partners/Collaborators:

- ***Local:*** *all Utah Local Health Departments*
- ***State:*** *Utah Division of Water quality*

Project Description

- **Need and Purpose:**

  The goal of the project is to develop and deliver an educational approach to improve owner/ user stewardship of on-site wastewater treatment systems. There are many brochures and flyers that list "dos and do nots" for the users of septic systems, but such simple guidelines can be easily forgotten and not incorporated into everyday personal habits. We propose that the effectiveness of educational tools for ensuring that septic systems are adequately operated and maintained would be greatly enhanced if the users better understood their role in the protection of public health and environment (i.e., if they better understood their role as environmental stewards). If septic system users had information focusing on understanding their responsibilities with respect to septic systems, and if they understood the options to fulfill their role as environmental stewards and operators of their "personal wastewater treatment plants," we predict that the effectiveness of homeowner on-site septic systems would be enhanced.

- **Benefits to the State:**

  Expected benefits to Utah watersheds include protection of water supplies from the harmful effects of excessive organic materials, nitrogen, phosphorus, suspended solids, and pathogens that may occur from runoff of wastewater from surfacing failing on-site systems. Subsurface transport of wastewater from overloaded systems may carry contaminants (especially pathogens and nitrogen) to ground water or through watershed base-flow to surface waters. Proper management of septic systems by homeowners or system users should reduce the flow of contaminants to water bodies from failing systems or improperly maintained systems.

- **Geographic Areas:**

  Study Area: Statewide

  Areas Benefited: Presentation of educational workshops will be targeted for areas in Utah with impaired water bodies that may be affected adversely by septic systems or in areas where improperly managed septic systems could potentially impact water bodies or ground water. However, educational materials developed in this project will also be made available to all twelve Utah local health departments for dissemination to homeowners and other septic system users.

- **Accomplishments:**

  Findings: We have investigated approaches to educational programs using social marketing techniques. Social marketing is the use of marketing principles to influence human behavior in order to improve health or benefit society. Social marketing includes: 1) focusing on a key issue; 2) developing a key objective to define the issue; and 3) focusing on reaching the key audience

with messages that work. We also have developed and administered a survey to Utah on-site professionals to help us define topics that are essential for homeowners to know regarding the use (and abuse) and maintenance of their septic systems

Results: Based on our investigations, we have identified the following topics as essential for our educational program:

Ins and Outs of Septic Systems
- What Type of System Do You Have?
- What Do You Need to Know About Your Septic System?
- Do You Know the Location of Your Septic System and Replacement Area?
- Is Your Septic System Working Okay?
- What Maintenance Has Been Done?
- What Maintenance Do You Need to Do?

Day-to-Day Management of Your Septic System
- Don't Use Too Much Water
- Don't Use Your Septic System as a Trash Can
- Protect Your System from Physical Damage
- Dispose of All Wastewater into Your Septic System

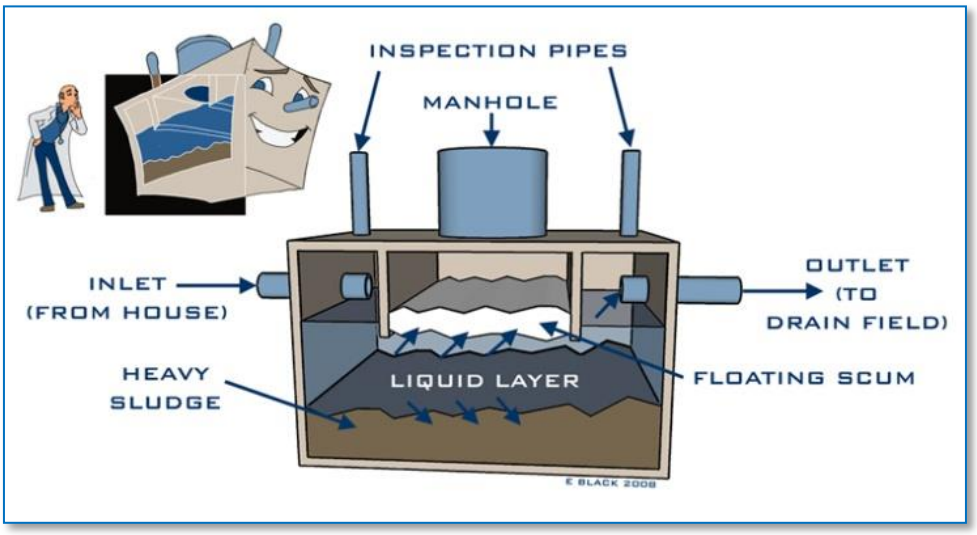
Periodic Maintenance and Repair
- Home and Yard, Including Drain Field
- Septic Tank
- Regulations
- Signs of Septic System Problems

Work Plan FY14/FY15

During FY 14-15, we will finalize the educational program materials, which will include homeowner/ system user handouts and workshop presentations. We will provide homeowner workshops at various locations around the state. We will work with local health department staff who might want to present workshops themselves. We will also provide fact sheets to local health departments for distribution to homeowners and systems users and to real estate groups.

Informational Resources

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



Enhancement of Septic System Educational Programs in Utah with Advanced Training

Principal Investigators:
Judith L. Sims
Richard Jex
Margaret Cashell

Partners/Collaborators:

- ***State:*** *Engineering Section, Division of Water Quality, Utah Department of Environmental Quality*
- ***Local:*** *Utah Health Departments*

Project Description

- **Need and Purpose:**

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

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

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

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

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: The workshops were held in the Tri-County Health Department in Vernal in April 2014 and in Logan in June 2014

- **Areas Benefited:** All of Utah's 29 counties.

- **Accomplishments:**

  Findings: Previously, before the development of these workshops, information was not readily available in Utah regarding advanced site evaluation techniques nor operation & maintenance of alternative, complex on-site wastewater treatment systems that address soil and site limitations.

  Results: Workshops have been developed that address advanced site evaluation techniques and operation & maintenance of alternative systems and that incorporate recent changes to on-site regulations.

Work Plan FY14/FY15

Although the funding for this project has ended, we will continue to deliver the workshops at selected locations around the state.

Informational Resources

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

Website: http://uwrl.usu.edu/onsite_home.

Workshop field and classroom training

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

Principal Investigators:
Laurie S. McNeill

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

Project Description

- **Need and Purpose:**

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

- **Benefits to the State:**

  This committee provides scholarships to students who will contribute to the field of water quality, supply, and treatment in the Intermountain West (Utah and southern Idaho). There are currently four scholarships offered: one undergraduate ($1,000), two graduate ($1,500 each), and one diversity ($1,000). The committee also organizes the "Fresh Ideas Poster Contest" at the Intermountain Section's Annual Conference, with the winner competing at the national AWWA Annual Conference and Exhibition.

- **Geographic Areas:**

  Study Area: Statewide.

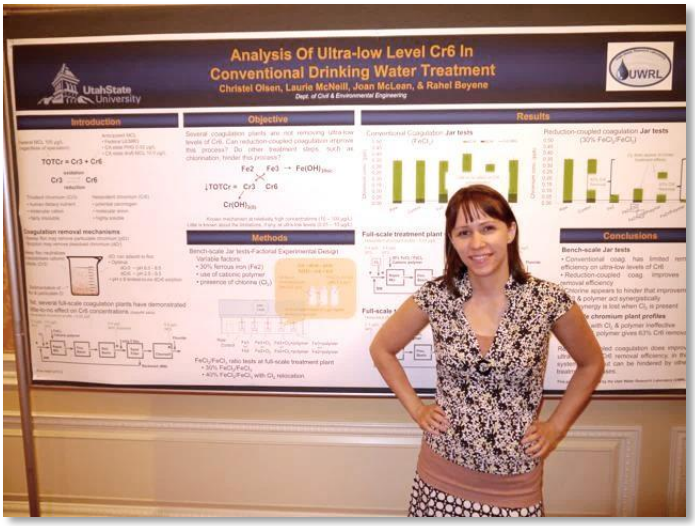
  Areas Benefited: Statewide—students at any college or university in Utah or southern Idaho are eligible.

- **Accomplishments:**

  Findings/Results: Four students (one undergraduate and three graduate) were awarded scholarships totaling $5,000 to study water quality and treatment during the Fall 2013 semester. One student is studying at Utah State University, two at BYU, and one at the University of Utah. A total of 26 applications were received this year. The Fresh Ideas poster contest was also a great success. The winner, a USU graduate student, received funding to present her poster at the national AWWA conference in Boston in June 2014.

Work Plan FY14/FY15

Participation in IMS-AWWA meetings and activities will continue. At least four scholarships will be awarded in Fall Semester 2014, and the Fresh Ideas Poster Contest will take place on September 11-12, 2014.



Christel Olsen, USU Graduate Student and winner of the 2013 Fresh Ideas Poster Contest

Informational Resources

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

Website: http:/ / ims-awwa.site-ym.com/ group/ StudentPO.

Salt Lake Valley Solid Waste Management Council

Principal Investigators:
R. Ryan Dupont

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

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

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

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

- **Benefits to the State:**

  Membership on the SLVSWMF Council provides service to the citizens of Salt Lake City and Salt Lake County, the Utah DEQ, and the regulated community by providing technical overview and expertise in solid waste management to the operating staff of the facility. The PI attends monthly meetings of the SLVSWMF Council, provides comments and input on solid and hazardous waste issues that arise, and has responded to special requests from the Council or facility staff regarding technical issues affecting operation at the facility. Recent examples of special project requests include proposal review and development (FY2013/ FY2014) of a laboratory study investigating the impact of MSW shredding on solid waste compaction, degradability and methane production, and an effort (detailed in a separate report) related to investigating the impact on the SLVSWMF carbon and energy footprint of expanding green waste recycling on a County-wide basis and implementing food waste composting in Salt Lake City.

Figure 1. Windrow composting at the Salt Lake Valley Solid Waste Management Facility

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled SLVSWMF Council meetings throughout FY13-14 and provided review and comment on all Council items relevant to his area of expertise, being heavily involved in analysis and development of recommendations regarding implementation of mandatory green waste recycling, food waste recycling, and increased municipal solid waste recycling throughout Salt Lake City, West Valley City and Salt Lake County, as well as composting system and shredder analyses, gas collection system updates, and cost of services analyses.

Work Plan FY14/FY15

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. Conduct a laboratory scale study evaluating the effect of MSW shredding on the rate and extent of waste decomposition and methane production to support the implementation of large-scale waste shredding at the facility as funding from the SLVSWMF becomes available to support laboratory-scale studies.

Informational Resources

Contact: Dr. R. Ryan Dupont, Phone (435) 797 3227, E-mail: ryan.dupont@usu.edu.
Website: http:/ / www.slvlandfill.slco.org/ .

State of Utah Drinking Water Board

Principal Investigators:
David K. Stevens

Partners/Collaborators:
- ***State:*** *Kenneth Bousfield, Director, Division of Drinking Water*

Project Description

- **Need and Purpose:**

  Under the Utah Drinking Water Act (the Act), responsibility for overseeing drinking water treatment and distribution rests with DEQ and the Utah Drinking Water Board (the Board). The Board has the authority to issue orders implementing the Act and to ensure compliance with the Act's provisions. Jurisdiction of the Board covers public and private community drinking water systems, including the various Federal facilities.

- **Benefits to the State:**

  Membership on the Drinking Water Board provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by providing technical overview and expertise, and oversight of state and federal revolving loan funds, for drinking water management to the Division of Drinking Water in their rulemaking, facility inspections and reviews, policy implementation, and conflict resolution. The PI attends ~monthly meetings of the Drinking Water Board held throughout the State, and provides comments and input on drinking water treatment and distribution issues that arise during the course of the Division's implementation of Federal and State drinking water laws.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled Drinking Water Board meetings and facility tours from July 1, 2013 to June 30, 2014, and provided review and comment on all Board items relevant to his area of expertise. The PI also serves on the Drinking Water Board Finance Committee in previewing projects and making recommendation to the full board concerning action or tabling of proposals.

Work Plan FY14/FY15

Continued involvement in the Board through 2016.

Informational Resources

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

Website: http:/ / www.drinkingwater.utah.gov/ Board/ board.html.

Statewide Nutrient Criteria Development: Core Advisory Team

Principal Investigator:
Darwin L. Sorensen

Partners/Collaborators:
- ***State:*** *Walter Baker, Director, Utah Division of Water Quality*

Project Description

- **Need and Purpose:**

  Utah, along with other states, is in the process of developing water quality criteria for the waters of the state (http:/ / www.nutrients.utah.gov/ index.htm). The policy development inherent with this process must be informed by the best available science because of the environmental, economic, and social impacts that the results will have on the communities and citizens of the state. The team advises the director and staff of the Utah Division of Water Quality. Members of the team include representatives from the Utah Department of Agriculture and Food, the Division of State Parks, the Division of Wildlife Resources, drinking water utilities, the US Environmental Protection Agency, environmental interests, the USDA Natural Resource Conservation Service, the Utah League of Cities and Towns, public owned wastewater treatment plant managers, storm water management, agricultural producers, scientific expertise, and ground water influences.

- **Benefits to the State:**

  Water quality nutrient standards formed by the Division of Water Quality will be applied throughout Utah. Dr. Sorensen is working with the other members of the team and the staff of the division to formulate general and site specific standards. Approaches for cost effective implementation of the standards and cost allocation for technology implementation are also being developed.

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Statewide.

- **Accomplishments:**

  Findings/Results: Various sectors represented on the team have presented their perspectives, and the approaches and standards used by other states are being considered. A technical subcommittee, of which Dr. Sorensen is a part, is focusing on the analysis of existing nutrient water quality data available in the state with the intent of recommending standards for various ecosystems of the state. Source waters, generally within National Forest boundaries, will have anti-degradation standards.

Work Plan FY14/FY15

The team will continue to work into the coming fiscal year. It is anticipated that Dr. Sorensen will continue to serve as member of the team in FY 15.

Informational Resources

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

Support for State Watershed Modeling and TMDL Plans: Tools to Assist in Nutrient Criteria Development Using QUAL2Kw

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:
- ***Local:*** *Jenni Oman, Salt Lake County; Florence Reynolds, Salt Lake City*
- ***State:*** *Nick vonStackelberg, Jeff Ostermiller, 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. Additionally, there are new requirements regarding the development of numeric nutrient criteria. In order to meet these requirements, some sort of watershed and/ or instream water quality model is necessary.

- **Benefits to the State:**

  States are tasked with developing TMDL plans and, more recently, statewide nutrient criteria, but those who must make the decisions often lack the expertise necessary to conduct the modeling studies and the understanding necessary to design the monitoring studies to support the modeling efforts. I have worked to provide guidance to the Utah Division of Water Quality (DWQ) and their consultants in making decisions and prioritizing investments.

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Findings:
  Jordan River TMDL Modeling Review: On the basis of recent work with Utah DWQ, a conference presentation and paper were developed to communicate effective methods of model calibration for use within the TMDL program. The paper was published in the Journal of Water Resources Management and Planning in 2013.

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

  Statewide Wasteload Allocation Study: Efforts have been completed under a contract with Utah DWQ to complete the QUAL2Kw modeling portion of a larger project that is (1) investigating the need for numeric nutrient criteria and (2) providing guidance regarding data collection to develop site specific nutrient criteria. We will continue to work with DWQ to apply the model

findings to development of nutrient criteria. Based on this work, a paper has been accepted in the Journal of Water Resources Management and Planning that provides guidance regarding data collection to support QUAL2Kw modeling.

Numeric Nutrient Criteria Tools: Under a contract with Utah DWQ we developed tools to interface with QUAL2KW to assist in determining phosphorus and nitrogen thresholds that result in instream water quality standard violations. A paper that documents the utility of these tools has been submitted and is now under review in the Journal of Environmental Management.

Results:
Jordan River Temperature Modeling / Statewide Wasteload Allocation/ Numeric Nutrient Criteria Studies: We have completed data collection and the associated instream water quality modeling for nine streams below various wastewater treatment plants throughout the state. The models have been used to assist in determining their utility in developing nutrient criteria. They have also been used in the development of waste load allocations for water reclamation facilities. Many conference presentations, a master's student thesis, and three papers have resulted from these projects.

Work Plan FY14/FY15

Over the next year, I will continue technical support to the State of Utah through the numeric nutrient criteria development.

Informational Resources

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

Representative Publications/Presentations

Jordan River TMDL Model Review

Hobson*, A.J., B.T. Neilson, N. von Stackelberg, M. Shupryt, J. Ostermiller, G. Pelletier, and S.C. Chapra (In review). A tool to identify numeric nutrient criteria with QUAL2Kw. *Journal of Environmental Management*.

Hobson*, A.J., B.T. Neilson, N. von Stackelberg, M. Shupryt, J. Ostermiller, G. Pelletier, and S.C. Chapra (2014). A minimalistic data collection strategy for QUAL2Kw. *Journal of Water Resources Management and Planning*, Accepted.

Hobson, A.J. (2013). "Using QUAL2Kw as a Decision Support Tool: Considerations for Data Collection, Calibration, and Numeric Nutrient Criteria." M.S. Thesis. Utah State University. Logan, UT.

Hobson*, A.J., B.T. Neilson, and N. von Stackelberg (2013). QUAL2Kw as a decision support tool: considerations for data collection, calibration, and numeric nutrient criteria. May, 2013. *Water Environment Association of Utah Annual Conference*, 2013. St. George, UT.

Jordan River Temperature Modeling and Statewide Wasteload Allocation/ Nutrient Criteria Study.

von Stackelberg, N.O., B.T. Neilson, H.N. Arens (2010). "Collaborative Calibration of a Water Quality Model of an Urbanized River." November, 2010. ASABE TMDL 2010: Watershed Management to Improve Water Quality Conference. Baltimore, MD.

von Stackelberg, N.O. and B.T. Neilson (2012). A collaborative approach to calibration of a riverine water quality model. *Journal of Water Resources Planning and Management*, doi: 10.1061/ (ASCE)WR.1943-5452.0000332. Accepted. Posted online 17 Nov 2012.

Utah Governor's Unmanned Aerial Systems Test Site Advisory Board

Principal Investigators:
Mac McKee

Partners/Collaborators:

- ***State:*** *Lt. Governor Spencer J. Cox, Jake Garn, Spencer P. Eccles, Ted McAleer, Jeff Edwards, Maj. Gen. M. Pavich, Gen. Ken Gammon, Bill Loos, Robert Spendlove, Gary Harter, Vince Mikolay, Marshall Wright, Sophia Dicaro, Sen. Jerry Stevenson*
- ***Private:*** *Charles Precourt, Susan Opp, Joshua Hintze, Todd Titenson, Jim Sutton*

Project Description

- **Need and Purpose:**

  The Governor's Unmanned Aerial Systems Test Site Advisory Board was created to offer guidance: (1) in the development of a flight test center for unmanned aerial systems (UAS) in the state of Utah and (2) in possible directions for support of the development of a commercial UAS industry in the state.

- **Benefits to the State:**

  The UAS industry in the US is in a fledgling state. It is a new technology that has not previously seen domestic applications, yet forecasts for domestic uses of UASs in agriculture, natural resources management, surveillance, and a host of others call for an $82 billion per year industry by 2025. Utah is well situated to participate in the economic and job growth that UASs will bring, but the state must be prepared to attract the companies that will make this possible. The Advisory Board meets regularly to provide insight into options for how the state of Utah can best respond to the economic opportunities that will present themselves as this technology takes root and begins to grow. For more than eight years, the UWRL has driven the development, testing, and deployment of UASs for use as scientific-grade remote sensing devices in support of research in water, agriculture, and natural resources management problems. Personnel from the UWRL offer extensive scientific, engineering, and management expertise in this newly emerging area that can be of great economic potential for the state.

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Potential economic benefits could be felt state-wide.

- **Accomplishments:**

  Findings/Results: Since its formation, the Advisory Board has met quarterly. The UWRL has played a key role in educating state officials on UAS-related research and development activities that are on-going and on the economic potential of UAS in the area of agriculture and natural resources management. The UWRL has supported the effort to develop a flight test center by co-authorizing a proposal to secure state funds for initial construction and staffing requirements. The proposal was funded.

Work Plan FY14/FY15

The UWRL will continue to provide information and guidance as requested by the Lt. Governor.

Informational Resources

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

Utah Water Education Project

Principal Investigators:
Steven L. Barfuss

Partners/Collaborators:
- ***State:*** *Division of Water Resources*

Project Description

- **Need and Purpose:**

  Utah is one of the fastest growing states in the nation. As the population increases, the demand on water resources will also increase. Because Utah is the second driest state in the country, its limited water supply will always be a top priority.

  In a focused effort to educate the public about the State's water supply, as well as how to conserve its water supply and what is required to provide water to its citizens, a digital photograph computer screensaver has been prepared. This computer screen saver is intended to be widely distributed to school districts, colleges and universities, and government agencies and is available to the general public. The screensaver includes approximately 1000 carefully selected Utah water-related photos, and each photo includes a brief descriptive and educational caption. The captions provide snippets of information and instruction about Utah's water resources and the proper use of the resources without burdening the reader with large amounts of text.

  The purpose of the project is to incrementally educate a diverse public about ways Utah's water is used, specifics regarding water conservation, and information about the State's streams, rivers, and lakes and the animals and people that rely on this resource. The selected photographs are high quality, interesting, and beautiful so that the reader will be naturally encouraged to read the captions. Each photograph includes some aspect of Utah's water resources, water infrastructure, or water use, and photos have been strategically selected so that all 26 counties within the State of Utah are represented in the screensaver.

- **Benefits to the State:**

  Utah is second only to Nevada in gallons of water used per person. Few Utahans would argue against the need to conserve water; however, most people will not change water-use behaviors unless they understand the importance of conservation and the need to be stewards of the resource. The intent of this screen saver project is to encourage viewers of the photos to naturally change personal behaviors in water use through incremental education. The end benefit to the State of Utah, of course, will be a reduction in per capita water use and preservation of the State's water resources.

- **Geographic Areas:**

  Study Area: Entire State of Utah.

  Areas Benefited: Entire State of Utah.

Figure 1. An example of the many photos included in the project.

- **Accomplishments:**

  Findings: The main portion of this project was completed in April 2013 and presented to the Division of Water Resources. A small amount of additional funding was recently provided to the project to maintain and to transition the use of the photos from the UWRL to the Division of Water Resources.

  Results: Upon completion in April 2013, the project had over 900 photos in use, each with its own caption and location. Three hundred pre-1940 historical photos were included in the collection as well. A public website hosted by the Utah Water Research Lab servers has been created and is designed to be the access point for the public. From there, users can download the photos as an installable screensaver for PC & Mac, or view them individually in an online gallery. The product was presented to the Utah Division of Water Resources in April 2013 for collaboration, distribution, and publicity. Efforts to maintain, update, distribute, and publicize the project are ongoing.

Work Plan FY14/FY15

- Work closely with the Division of Water Resources to gather input and collaborate.
- Maintain the photos through updates of the programs and website.

Informational Resources

Contact: Mr. Steven L. Barfuss, Phone: (435) 797-3214, E-mail: steve.barfuss@usu.edu.

Water Environment Association of Utah (WEAU)

Principal Investigators:
Michael J. McFarland

Partners/Collaborators:

- ***Local:*** *North Davis County Sewer District, Central David County Sewer District, Salt Lake Water Reclamation Facility, Kearns Improvement District, Central Valley Water Reclamation, South Valley Water Reclamation Facility, Timpanogos Special Services District, Orem Metropolitan Water District, Snyderville Basin Water Reclamation District*

Project Description

- **Need and Purpose:**

  The goal of the Water Environment Association of Utah (WEAU) is to provide environmental stewardship, financial integrity, safety, and quality service to benefit the environment, residents, businesses, and employees of the State of Utah. WEAU is the State of Utah affiliate or member association (MA) of the Water Environment Federation (WEF). WEAU and WEF are comprised of water quality professionals that include public works staff, treatment plant operators, engineers, scientists, and planners working to preserve and enhance water quality and the global water environment. WEAU is governed by a Board of Directors who serve without remuneration.

- **Benefits to the State:**

  The Water Environment Association of Utah is dedicated to the professional growth of its members and the preservation and enhancement of the water environment in the state of Utah. Specific benefits to the state include:

  1. Opportunities for interaction and professional growth of WEAU members
  2. Greater understanding of the value of water quality and water resources to Utah citizens.
  3. Educational information for State of Utah law makers to form environmental policy
  4. Alliances and information exchange with State of Utah residents
  5. Diverse water quality issues addressed.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled board of director meetings throughout FY13-14 and provided review and comment on all board items relevant to his area of expertise. The PI provided technical training to WEAU members in biosolids land application, energy generation from wastewater residuals and industrial pretreatment. The PI also served as the faculty advisor for the USU student chapter of WEAU as well as for the WEAU student design team.

Work Plan FY14/FY15

Continued involvement in decision-making through attendance at monthly WEAU board meetings as well as WEAU biosolids committee meetings. Continued service as the faculty advisor for the USU student chapter of WEAU as well as for the WEAU student design team.

Informational Resources

Contact: Dr. Michael J. McFarland, PE, BCEE, Phone: (435) 797-3196, E-mail: farlandm1@outlook.com.

Figure 1. Central Valley Wastewater Treatment Plant – Salt Lake City, Utah

Weber-Morgan Health Department Wastewater Advisory Committee

Principal Investigator:
Darwin L. Sorensen

Partners/Collaborators:
- ***Local:*** *Louis K. Cooper, Environmental Health Director*

Project Description

- **Need and Purpose:**

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

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: Weber and Morgan Counties.

  Areas Benefited: Weber and Morgan Counties.

- **Accomplishments:**

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

Work Plan FY14/FY15

It is anticipated that Dr. Sorensen will continue to serve as member of the committee in FY 14-15.

Informational Resources

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

Water Resources Planning and Management

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

Project Name	FY2014 Actual Expenditures	FY2015 Budgeted Expenditures	FY2016 Planned Expenditures
AggieAir Imagery Information Pipeline Improvements	$9,065.26	$72,500.00	
Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties	$33,861.34		
ASR Optimization Protocol and Decision Support	$20,162.24		
Capturing Aerial Imagery on the San Rafael River, Utah, Using an Unmanned Aerial Vehicle (UAV) to Monitor and Assist in Evaluating Restoration Efforts	$11,292.60	$11,631.38	
Crop Water Demand Monitoring and Forecasting	$22,359.66	$23,030.45	
Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management	$283,417.87	$152,500.00	$33,475.00
Flood Potential Due to 100-Year Storm Events for Small Utah Cities	$466.94	$17,000.00	
Gain-Loss Study on the San Rafael River, South Central Utah	$10,553.74		
High Frequency Data and Cyberinfrastructure Tools to Investigate Instream Processes and Integrate High Resolution Modeling in Snowmelt Dominated Watersheds	$47,200.86	$48,616.89	$16,226.51
Improving Hydrologic Model Predictions for the Effects of Land Use and Climate Change	$20,962.93	$21,591.82	
Improving Stream Flow Forecasting	$29,810.42	$30,704.73	
Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates	$26,004.79		
iUTAH – Innovative Urban Transitions and Arid Region Hydro-Sustainability	$47,536.66	$48,962.76	$18,909.18
Low Cost Vertical Take Off and Landing Remote Sensing Systems for Water Engineering	$68,410.07	$98,570.00	$11,757.59
Near-Real-Time Orthorectification and Mosaicking of UAV Images	$10,000.00	$56,750.00	
Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology	$25,098.31		
Quantifying the Flow Field in Baffled Fish Culverts	$9,903.91		
Real-Time Management of Irrigation Systems in the Sevier River Basin	$189,454.64	$242,824.80	$138,000.00
UAV Monitoring and Assessment Applications in Municipal Water and Environmental Management	$2,452.59		
UAV Remote Sensing Service Center	$97,437.40	$102,886.69	
Water Resources Modeling for Utah's Cache Valley	$32,882.81	$33,869.29	
Designated Projects		$582,600.00	$51,537.12
Undesignated Projects		$113,626.50	$0.00
Total	**$998,335.04**	**$1,657,665.31**	**$269,905.40**

AggieAir Imagery Information Pipeline Improvements

Principal Investigators:
Todd Moon
Calvin Coopmans, Post-doctoral Researcher

Partners/Collaborators:

- ***Local**: Utah State University Water Research Laboratory*
- ***State**: Utah Department of Environmental Quality*

Project Description

- **Need and Purpose**

  Since 2006, the AggieAir group at Utah State University has been developing unmanned, aerial remote sensing systems for natural and water resources management. These small aircraft are programmed to fly over research sites, such as farming fields or conservation areas, and collect scientific data (imagery), which can then be used for better crop care, early detection of poor plant health, or conservation of wildlife habitat.

  The process of converting the imagery collected from the aircraft into scientific-grade data includes steps such as orthorectification to place the images on a global map, as well as "stitching," a process that manipulates the images into continuous scientific data. The difficulty of current approaches is that experienced human operators must assemble the imagery and process it into the science data. This can take anywhere from 12 to 48 hours of post-flight work, creating a delays of one to several days in delivery of data to scientists.

  Many important applications for the AggieAir technology (such as day-to-day high-value agriculture) require data in near real time. If AggieAir were to deliver actionable data in a 4-10 hour timeframe, many of these important management applications could be implemented and improved. Hence, the goal of this research is to determine the best way to reduce the image-to-data processing time.

  This study is analyzing the flight and data collection process and the ways these complex operations could be modified or augmented to improve the raw imagery data collected by the aircraft. This will provide a better starting point for transformation into actionable scientific information.

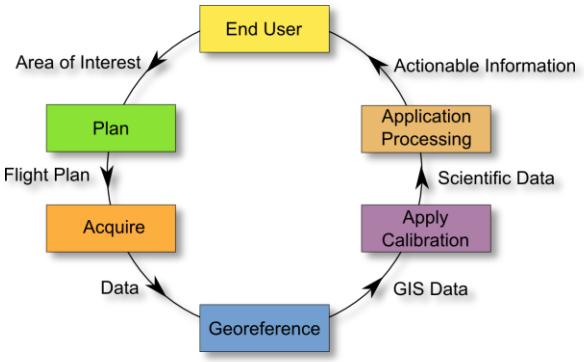


Figure 1: The circle of airborne scientific information gathering

- **Benefits to the State:**

  Utah is part of the high desert Intermountain West, and water is a critical part of agriculture, business, natural habitat, and other natural resource management in the state. The AggieAir group within the UWRL addresses difficult aerial remote sensing problems and applies real world solutions to water management.

  The Federal Aviation Administration quotes the Teal group (an intelligence and aerospace research group), who predicts the unmanned aerial vehicle spending worldwide at $89.1 billion in the next 10 years. In addition to the important agricultural and water-saving benefits, this research helps position Utah to become part of this large, cutting-edge, emerging market.

This research benefits the state of Utah by both promotion of innovative techniques for more optimal resource monitoring and management, as well as keeping these technologies in the state for strengthening industry and promoting job creation.

Figure 2: The airborne payload computer and camera

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Statewide.

- **Accomplishments**

  Findings: Initial findings indicate that the errors introduced during data collection in flight are mainly due to differences between the estimates of the camera position and orientation at a given time, and the true position and orientation. Having better information about the true path the scientific cameras take during a flight mission is the overall solution to the problems.

  Three possible approaches for better tracking of the true camera path during flight have been identified:
  1. Better estimation of the camera position/ orientation from the aircraft navigation sensors
  2. Better estimation of the camera shutter timing correlated with the navigation data.
  3. Greater frame rate from cameras to provide more data about terrain covered by the imagery.

  Results: At this early stage in the project, there are few results to report. However, a new scientific data collection system (payload control computer), a low-cost image tracking camera, as well as a low-cost high-performance global position system (GPS) unit have been purchased. The AggieAir group is in the process of integrating these much higher accuracy components into their airborne systems, which will ultimately benefit this project.

Work Plan FY14/FY15

The work plan for the coming year is as follows:

- Complete the interfacing between the new payload computer and the camera and develop a system that will record full 10+FPS image stream from the camera onto a large flash-based storage device. In addition, integrate the high-accuracy GPS unit to determine its usefulness.
- Analyze data from the aircraft's recorded video and GPS/ inertial data to determine if the camera's high-speed video is of sufficient quality to determine the course of its roll/ pitch and therefore provide deeper insight to the flight path of the airborne mission.
- Determine which, if any, "optical flow" algorithms can be implemented in real-time during typical flights to determine this roll/ pitch data as the mission progresses. These data can then be recorded in lieu of the image data, increasing the mission turnaround time and lowering data post-processing requirements on the ground.

Informational Resources

Contact: Calvin Coopmans, Phone (435) 764 4579, E-mail: cal.coopmans@usu.edu.

Website: http:/ / aggieair.usu.edu/ .

Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties

Principal Investigators:

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Melina Santos Vanderlinder, Liisa Piiparinen,
Amberlee Burrows, Leah Langdon,
Megan Gordon, Taylor Dudunake, Jordan Floyd,
Isaac Robertson (Students)

Partners/Collaborators:

- ***Local:*** *Al Trout, Friends of Bear River Refuge; Joan Degiorgio, The Nature Conservancy; Bryan Dixon, Bear River Land Conservancy; Bob Fotheringham, Cache County*
- ***State:*** *Toby Hooker, Utah Geologic Survey; Pam Kramer, Division of Wildlife Resources*
- ***Federal:*** *Bob Barrett, Sharon Vaughn, Howard Browers, Karl Fleming, U.S. Fish and Wildlife Service*
- ***Business/Commercial:*** *Eve Davies, PacifiCorp*

Project Description

- **Need and Purpose:**

  Wetlands, particularly along the Great Salt Lake, provide critical wildlife habitat, resting grounds for migratory birds, and social and economic services including water purification, storm water retention, and recreation for hunters. Wetlands need water, but in Utah and the western U.S., water is often scarce and not available to flood and maintain wetland habitats and 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 responses by bird populations and native plant species are often uncertain.

  This project extends systems modeling underway at and for the Bear River Migratory Bird Refuge, Utah (the Refuge). Part I is building a wetland systems (optimization) model to identify water and vegetation management actions Refuge mangers can take to improve wetland performance under existing water, vegetation response, budget, staff time, and other constraints. Part II is quantifying the response over time of *Phragmites australis* (hereafter *Phragmites*), a non-native, invasive grass, to changing water levels. Part III is a federally-funded National Science Foundation effort to extend the model and identify the numerous near-optimal water allocation strategies for improving wetland and riparian performance in the lower Bear River Basin.

- **Benefits to the State:**

  The project benefits Utah in several ways. First, the project is helping Utah wetland managers better manage and allocate scarce water, personnel, and budget resources to achieve their wetland objectives. The project is showing how water levels encourage and discourage *Phragmites* spread and how to manage water to reduce *Phragmites* spread. The project is also helping Utah environmental managers allocate scarce water to environmentally important areas across a watershed. These benefits help managers of wetlands and riparian areas promote hunting, birding, and recreation that are vital to the Utah communities that border the Great Salt Lake and the state's rivers. Finally, the project is integrating systems modeling, ecology, and remote sensing and showcases a new Utah-based approach to environmental management.

- **Geographic Areas:**

  Study Area: Bear River Migratory Bird Refuge, north shore of the Great Salt Lake, Box Elder County, Utah; Bear River, Cache, and Box Elder Counties, Utah.

  Areas Benefited: Wetlands and riparian areas throughout the state of Utah.

- **Accomplishments:**

Findings and Results:

- Recommend managing water levels to maintain dry or deep conditions during seed/ seedling stages to reduce the spread of *Phragmites*; also maintaining dry or mudflat conditions during rhizome reproduction (Figure 1).
- Recommend detecting *Phragmites* patches early and eradicating small patches completely rather than partially controlling large patches or delaying until invasive vegetation covers 10% of a wetland unit.
- Presented model results to Refuge managers; they will use recommendations in their future planning and suggested model improvements such as to include more bird species.

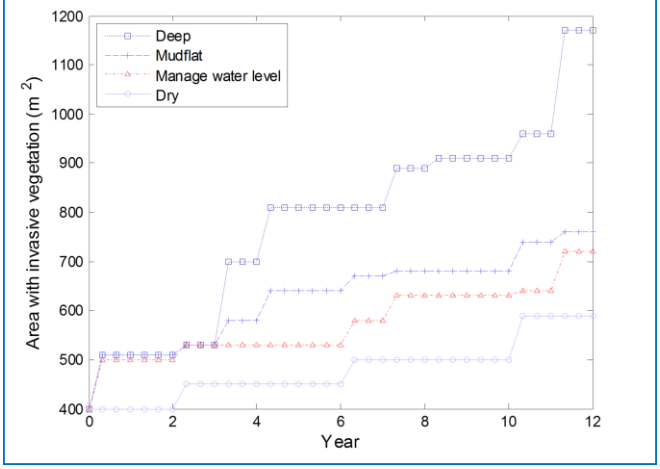

Figure 1. *Simulated invasive vegetation growth over time under different hydrologic conditions. Apply and withhold water at specific times according to plant life stage to reduce* Phragmites *spread (red triangles).*

- Traveled 55 miles of the Bear River above Cutler Reservoir and set up a third water flow and environmental monitoring site in the Morton-Bear River Bottoms area.
- Published article "Use of remote sensing to assess changes in wetland plant communities in response to large-scale disturbance and management: A case study from the Bear River Migratory Bird Refuge, Great Salt Lake, UT" in the peer-reviewed journal *Western North American Naturalist*.
- Resubmitted near-optimal manuscript to peer-reviewed journal *Water Resources Research* and posted codes and scripts at https:/ / github.com/ dzeke/ Blended-Near-Optimal-Tools.
- Presented near-optimal, Refuge, and Bear River environmental work at three conferences: (1) TEDxUSU, Logan, UT: Nov 5, 2013, (2) USU Spring Runoff Conference, Logan, UT: April 1-2, 2014, and (3) International Environmental Modelling and Software Society Conference, San Diego, CA: June 15-19, 2014.

Work Plan FY14/FY15

- Revise and resubmit Refuge systems modeling work for publication in *Water Resources Research*; submit vegetation spread modeling work as a second publication.
- Develop a more user-friendly model interface for Refuge managers.
- Build a systems model for the lower Bear River and apply near-optimal techniques.

Informational Resources

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

Website: http:/ / www.engr.usu.edu/ cee/ faculty/ derosenberg/ projects.htm.
Website: http:/ / bearriverfellows.usu.edu/ .
Website: https:/ / github.com/ dzeke/ Blended-Near-Optimal-Tools.
Website: http:/ / www.iemss.org/ sites/ iemss2014/ papers/ iemss2014_submission_261.pdf.

ASR Optimization Protocol and Decision Support

Principle Investigators:
Richard C. Peralta
Ali Forghani

Partners/Collaborators:

- ***Local:*** Richard Bay, Jordan Valley Water Conservancy District

Project Description

- **Need and Purpose:**

  The Jordan Valley Water Conservancy District (JVWCD) began operating a full-scale Aquifer Storage and Recovery (ASR) system in 2002. Currently, the system has 18 extraction/ injection wells. The JVWCD wishes to optimize management of the ASR system. This includes considering economics and the amount of credit received from the State Engineer for the water that the JVWCD injects (injectate). The State Engineer allows multiple-year carryover credit of injectate, subject to the condition that 10% of the injectate is lost per year of carryover storage after the first 12 months from injection. This loss assumedly represents the escape of groundwater that has flowed laterally, rather than directly toward extracting ASR wells. JVWCD thinks they are physically able to recover more injectate than they receive credit for, and wishes to know more accurately how much injectate they can physically recover. They want to know how best to inject and extract with time. Fully addressing the problem involves more accurately quantifying the amount of injectate that is recovered, and optimizing the timing of injections and extractions, subject to projected temporally varying water availability, water need, and cost. Software to facilitate use of the ASR optimization protocol is also desirable.

- **Benefits to the State:**

  To best integrate use of available water resources, Utah water managers increasingly consider applying aquifer recharge (AR) and aquifer storage and recovery (ASR) techniques. Usually river water is treated and used to recharge (injected into) aquifers in the spring season. Groundwater is extracted (pumped out) later in the year when surface flow is low. ASR should be optimized with respect to cost, reliability, and related issues. Considerations are (1) the amount of injectate the recharging organization can physically recover, and how much credit the State Engineer might give to the recharging organization and (2) the cost (considering energy use and well clogging) and timing of water need and availability. Although optimal ASR strategies are site- and management-specific, the procedure for developing them is transferable to other situations. This project will enhance the ability of the JVWCD to use Provo River water. As the confidence of water managers increases regarding their ability to recover more water and receive credit for it, the procedure will encourage ASR use by other organizations.

- **Geographic Areas:**

  Study Area: The new methodology will be developed and tested for the Jordan River Valley within Salt Lake County.

  Areas Benefited: This project will benefit all water providers that wish to intentionally recharge their aquifers thru wells and later extract the water for use. It will be applicable for sites worldwide. It is especially appropriate where the timing of surface water availability does not coincide with water need.

- **Accomplishments:**

  - Greatly expanded literature review and evaluation concerning (1) international ASR research and field implementation to aid optimization problem design, (2) contaminant transport simulation methods to determine appropriateness for ASR problems, and (3) a new USGS Multi Node Well (MNW2) simulation package to evaluate benefits for ASR.
  - Designed, coded and added to an optimization model two new objective functions for ASR.
  - Optimized multi-period ASR injection and extraction strategies for representative systems using two new optimization objectives (results were consistent with expected responses).
  - Converted CH2MHILL Modflow 96 flow model into a Modflow2005 implementation, to enable using an optimization model best suited for the ASR problem. This involved (1) discovering that USGS software mf96to2k.exe and commercial software cannot do the conversion (layers 2 and 3 are LType = 3; inactive layer 2 cells overlie active layer 3 cells), (2) writing special code to solve the problem for CH2MHill situation, and (3) modifying and recompiling mf96to2k.exe so the capability can be applied to any system.
  - Obtained records and estimates of monthly groundwater and surface water diversions in Salt Lake County from the Utah Water Rights Division of the Utah Department of Water Resources.
  - From historic data, prepared monthly inputs for a Modflow implementation of a Salt Lake Valley aquifers flow model obtained from CH2MHILL (7 layers, 469 rows, 275 columns).
  - Ran the monthly CH2MHILL Modflow 2005 flow model, and a modified MT3DMS transport model for a hypothetical ASR well to evaluate processing effectiveness and efficiency.
  - Improved efficiency of optimization results' analysis efficiency (further work is in progress).

  Findings:

  - Our ASR work differs from reported projects in that (1) few projects investigated recovery efficiency for storage periods of a year or longer and (2) our ASR recovery efficiency doesn't involve a concentration threshold on recovered water. The Total Variation Diminishing (TVD) and Method of Characteristics (MOC) simulation options of MT3DMS both can be considered for ASR simulation.
  - Use of the Modflow USGS Multi Node Well (MNW2) simulation package would improve accuracy in predicting the recovery efficiency of partially penetrating ASR wells.
  - We need to improve efficiency of optimization processing and results analysis.
  - We will consider using only Microsoft Intel compilers for FORTRAN code in the future.

Work Plan FY14/FY15

- Use the prepared monthly CH2MHILL model to perform baseline simulations to demonstrate how the JVWCD groundwater system currently responds to management.
- Add another objective function type to further aid improving ASR recovery efficiency.
- Perform optimizations using three new objective functions within the optimization model.
- Report initial results to Jordan Valley Conservancy District.
- Meet with Jordan Valley Conservancy District.

Informational Resources

Contact: Dr. Richard C. Peralta, (435) 797-2786, E-mail: peralta.rc@gmail.com.

Capturing Aerial Imagery on the San Rafael River, Utah, Using an Unmanned Aerial Vehicle (UAV) to Monitor and Assist in Evaluating Restoration Efforts

Principal Investigators:
Mac McKee
Bethany T. Neilson
Ian Gowing

Partners/Collaborators:

- ***State:*** *Dan Keller – Utah Division of Wildlife; Paul Birdsey – Utah Division of Wildlife*
- ***Federal****: Justin Jimenez – Bureau of Land Management*

Project Description

- **Need and Purpose:**

  The AggieAir Flying Circus, a service center at the Utah Water Research Water Laboratory that provides high resolution multispectral aerial imagery using a UAV, was contracted in 2011 by the Utah Division of Wildlife Resources to fly the lower 50 miles of the San Rafael River to provide high resolution aerial imagery after a high river flow event. As a result of the proposed project, the San Rafael Restoration Committee have again proposed to integrate the high resolution imagery that the AggieAir Flying Circus can provide, along with the analysis of the data contained in the imagery, as an integral component in the San Rafael restoration effort. It is expected that the data and analyses provided by the AggieAir Flying Circus will significantly improve the information content of the entire data collection effort of the San Rafael restoration process, and that significant research questions on the effects of tamarisk control on river morphology will be made easier to answer.

  The project will also yield significant research results on the accuracy and limitations of the use of inexpensive UAV platforms to provide data, such as digital elevation and terrain models, in place of more conventional and much more expensive approaches, such as LiDAR. Additionally, temperature sensors will be positioned within the entire 50 mile study reach to help calibrate thermal imagery captured by Aggie Air to address thermal regime issues within the San Rafael River.

- **Benefits to the State:**

  The San Rafael River is recognized as severely degraded and is listed on the 303D list of degraded waters in the state of Utah. With the implementation of this river restoration scheme, we anticipate restoring the river to a more ecologically acceptable state, providing more comprehensive complex habitat to the native fish, encouraging changes in channel morphology through Tamarisk removal, planting more native riparian species along the river corridor and removing man-made barriers to enhance and encourage fish movement/ passage throughout the entire drainage.

- **Geographic Areas:**

  Study Area: San Rafael River, Emery County, Utah.

  Areas Benefited: Emery County and statewide where river restoration projects are being implemented.

- **Accomplishments**:

  Findings: Temperature sensors (Sensor HOBO water Temp Pro v2 ONSET) were installed within the San Rafael River during May 2014 in anticipation of the proposed flight. These temperature sensors were positioned every 1 river mile, beginning at the confluence with the Green River. Flights were proposed to begin at the end of July/ beginning of August 2014, but due to continued higher than usual flows; the flights have been postponed till July 2015.

  Results: No UAV flights were conducted this year due to higher than usual flows.

Work Plan FY14/FY15

It is anticipated that UAV flights will commence during summer 2015, at which point we will begin monitoring and assisting in river restoration actions currently being implemented both within and along the San Rafael River.

Informational Resources

Contact: Mr. Ian Gowing, (435) 797-3159, E-mail: ian.gowing@usu.edu.

Crop Water Demand Monitoring and Forecasting

Principal Investigators:
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Andres M. Ticlavilca
Mac McKee
Wynn Walker

Partners/Collaborators:

- ***Federal:*** *USGS Earth Resources Observation and Science (EROS) Center; US Bureau of Reclamation, Provo Office*

Project Description

- **Need and Purpose:**

  Current Utah agricultural water management (at farm, irrigation district and state) is restricted to referential, delayed, and often inadequate data that do not represent actual crop water use. This often leads to misguided water related decision-making activities (e.g. irrigation scheduling, water shares). Current research using satellite technology (Landsat) allows for near real-time and historical estimation of actual water use at different levels (field, irrigation district, state). When integrated with automation mechanisms, actual water use made directly available to stakeholders (producers, water managers and policy makers) will help to improve their decision-making activities.

  Project WR-2188 pursues to develop a practical, economical, and easy to understand actionable information platform (called Crop and Water Monitoring and Information System - CWMIS) to provide near real-time and historical records of crop status (water, yield, irrigation management) that can be directly used by policy makers, water managers, and producers in the State of Utah. The CWMIS incorporates recent advances in crop water and status models, continuous NASA's Landsat satellite information for Utah, and web mapping technologies for immediate access to information.

- **Benefits to the State:**

  At field scale information on historical and near real-time crop water consumption can be used by producers to enhance irrigation water use to minimize over-irrigation. At the irrigation district scale, water managers can use total actual crop water use to identify issues in the irrigation system (losses due to scheduling, water irrigation, storage and conveyance, for example). At basin scale, availability of historical records of accurate actual crop water use can support better management of all water uses (e.g. agricultural, urban, ecological, and industrial) and water sources (surface, rainfall, and groundwater).

- **Geographic Areas:**

  Study Area: Central Utah, Millard County.

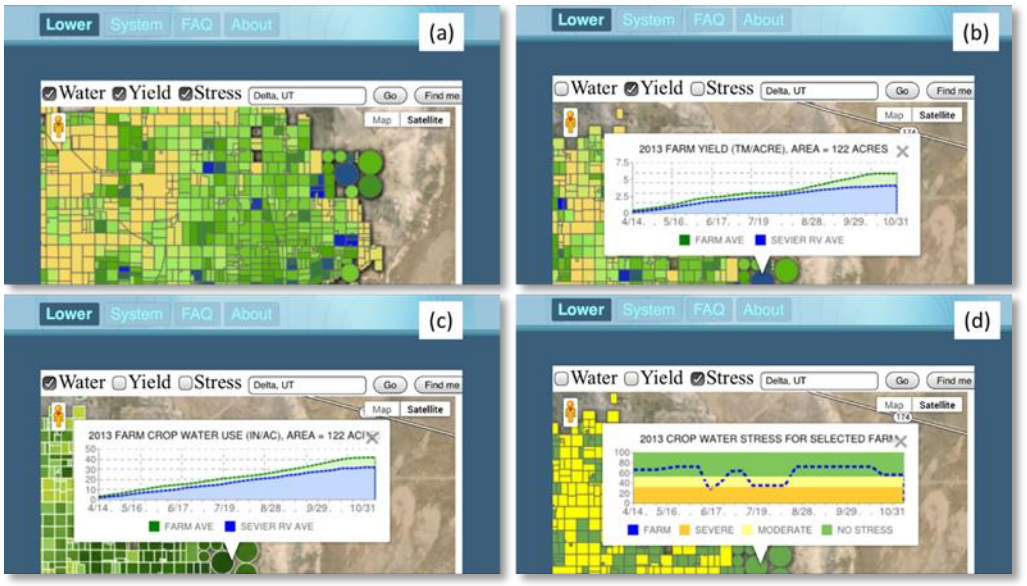
  Areas Benefited: Lower Sevier River Basin, Central Utah, and Millard County.

- **Accomplishments:**

  Findings: CWMIS implementation for Central Utah for the 2013 irrigation season provided updated information on current crop water use to producers on their computers or smartphones. CWMIS display and products can be seen in Fig. 1. CWMIS was introduced to Utah producers,

water managers and officials at the Utah Division of Water Resources, who can now use CWMIS to obtain necessary water-related information for better water management.

Results: The obtained results indicate the possibility of implementing an actionable information platform like CWMIS for the State of Utah that requires minimal operation and maintenance. CWMIS provides information of crop status and water needs every 8 days. Additionally, the internal CWMIS design allows for the production of additional crop- and water-related products of interest for the user (producer, water manager, policy makers) with minimal effort or additional investment.



CWMIS agricultural information at field level for 2013 irrigation season at the Lower Sevier River Basin (a) CWMIS smartphone display, (b) Cumulative Crop Yield in TM/acre, (c) Cumulative Crop Water Use (inches/acre) and (d) Crop Water Stress Severity.

Work Plan FY14/FY15

For FY14/ FY15, meetings will be restarted with the Utah Division of Water Resources to determine possible ways to implement the CWMIS product as part of their and other Utah Agencies' workflow. Initial contacts with Water Conservation District and Tribal Water Authorities in Duchesne will continue to determine sources and secure funding to implement CWMIS to their specific needs. Enhancement of CWMIS will continue to include new products such as crop yield and water demand, and soil water content, among others.

Informational Resources

Contact: Dr. Alfonso Torres-Rua, Phone: (435) 797-3149 E-mail: a.torres@aggiemail.usu.edu.

Crop and Water Monitoring and Information System – Project Website:
https:/ / sites.google.com/ a/ aggiemail.usu.edu/ cwmis_sevierriver/ .

Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management

Principal Investigators:
Austin Jensen
Mac McKee
Cal Coopmans

Partners/Collaborators:
- *None*

Project Description

- **Need and Purpose:**

  Many current sources of remote sensing (e.g. manned aircraft and satellite platforms) are too expensive, have low spatial resolution, or don't update frequently enough to be practical for many applications. A low-cost, small unmanned aerial system (UAS) called AggieAir can fill this need by providing low-cost, multispectral aerial imagery quickly and frequently. In addition, AggieAir is not dependent on a runway for takeoff and landing, which enables it to be launched from almost anywhere. Some examples of applications that could benefit from AggieAir include agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, and fish and wildlife tracking.

- **Benefits to the State:**

  The data produced by AggieAir have the potential to help save water in Utah by offering farmers a low-cost solution to mapping the soil moisture of their crops to irrigate more efficiently. This data can also help canal operators manage water more effectively. AggieAir can also help wetland managers manage invasive plant species. If these invasive plant species are left unmanaged, they can takeover native plant species, destroy bird habitat, and use excessive amounts of water.

  AggieAir will also indirectly provide new jobs and economic growth to the state of Utah. The long term goal of the AggieAir system is to eventually create a business and sell this technology.

- **Geographic Areas:**

  Study Area: Most of the test flights will take place at our test site near Cache Junction, UT. We have official approval from the FAA to conduct flights here (FAA Form 7711-1 2013-WSA-63).

  Areas Benefited: All counties in the state could benefit.

- **Accomplishments**:

  Findings: In addition to improving the Minion platform by developing a new power and avionics system, a three camera payload (visual, near-infrared, and thermal) has been designed using a new innovative door system and a custom usb hub board. New ground station equipment has also been developed in support of the AggieAir Minion. One of these developments includes a pneumatic launcher to replace the inconsistent and unreliable bungee takeoff system. Another improvement includes an antenna pointer to keep the ground station antennas pointed to the aircraft at all times.

With the addition of thermal cameras to the AggieAir payloads, other developments have been made to help calibrate the thermal imagery, including the ground sampling apparatus shown in Figure 3.

Work Plan FY14/FY15

- Redesign the Minion's wing
- Look at better materials for the Minion fuselage.
- Finish new avionics and power board
- Find and develop software for better cameras.

Informational Resources

Contact: Dr. Austin Jensen, (801) 633-0426, E-mail: austin.jensen@usu.edu.
Website: http:/ / aggieair.usu.edu/ .

Figure 1: The new launcher setup near the AggieAir ground station.

Figure 2: The new three camera payload including thermal

Figure 3: Sampling apparatus used to calibrate the thermal imagery

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

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

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 do not normally have streams can accumulate enough rain water to create a flash flood. Since peak flood runoff information in these mountain ranges does not currently exist, cities are left without this critical potential flood information when considering city planning or flood prevention.

- **Benefits to the State:**

  By determining peak flood runoff in these mountain ranges, a city can better plan around potential flood areas and implement flood prevention methods. Many cities in the State of Utah cannot afford to hire 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 included all basins in the state of Utah that are near or in a city and are considered to have the possibility of significant flood water damage. The following list indicates the number of currently identified study sites in each county: Box Elder (5); Cache County (12); Carbon County (9); Davis County (19); Juab County (2); Millard County (1); Morgan County (11); Salt Lake County (18); Sanpete County (6); Summit County (6); Tooele County (1); Utah County (31); Weber County (10); Wasatch County (2); and Washington County (5).

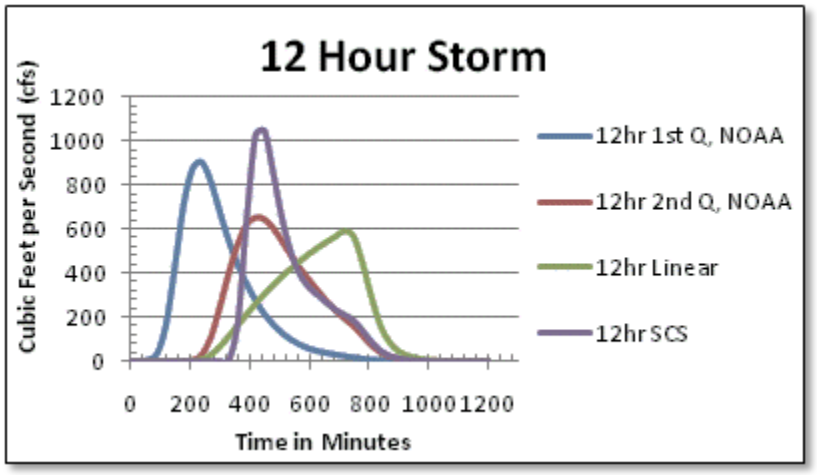
  Areas Benefited: This project will benefit all cities in the state that are experiencing growth and need data relative to planning for potential flood issues.

- **Accomplishments:**

  Of the 138 currently identified study areas, all 138 studies have been completed.

  Findings: The hydrograph figure below is an example of peak runoff flood water from one study out of the 138 identified study sites. This hydrograph represents Hyde Park Canyon for a 12-hour storm. Similar hydrographs have been completed for the other 137 study sites 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 a high probability of flooding in areas of sub basins that do not contain a natural stream; consequently, this condition presents a potential hazard for the citizens and property in the path of the flood waters. This study also recognized that the State of Utah has very limited rainfall curve information, and that some curves differ widely.

Recommendations: Rainfall curve distributions should be made specific to Utah's storms and mountain regions. In many parts of Utah, rainfall gauge data is either lacking or insufficient in period of time or coverage. Since current soil and vegetation data combine valley and mountain areas, soil and vegetation data need to be specific to mountain regions only, which would improve the input data.

Work Plan FY14/FY15

- This project is complete.

Informational Resources

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Mr. Marshall W. Saunders, (435) 797-3152, E-mail: marshallsaunders@aggiemail.usu.edu.

Gain-Loss Study on the San Rafael River, South Central Utah

Principal Investigators:
Mac McKee
Ian Gowing

Partners/Collaborators:

- ***State:*** *Dan Keller and Paul Birdsey – Utah Division of Wildlife Resources*
- *Federal: Justin Jimenez – Bureau of Land Management*

Project Description

- **Need and Purpose:**

  Information relating to seepage gains and losses in rivers is required by water managers in order to understand how and where best to allocate this limited resource. The lower San Rafael River in south central Utah is impacted by fragmentation, dewatering, non-native species, and channelization. Dewatering is sometimes severe and, for example, resulted in a complete lack of flow for two months during summer 2007 (Budy et al. 2009).

  An initial gain-loss study was conduct on behalf of the Emery Water Conservancy District during late 2011 early 2012 (Gowing et al 2012). Data collection and analysis of the San Rafael River during the winter months indicated that net gains and net losses were relatively small in magnitude compared to actual flow rates. However, findings from recent studies (Gowing, I.M. et al. 2013) have illustrated that river flows during the summer months could be critical in providing sufficient river levels for spawning habitat of native fish species and providing continuous river connectivity.

  The purpose of this study is to further investigate the gains and/ or losses that potentially affect the Lower San Rafael River from Highway I-70 to the confluence with the Green River. This will be achieved by re-establishing discharge measurement transects used in the original study along the San Rafael River and collecting flow data once/ twice a month from March through August 2014. Data could be collected bi-monthly during critically low periods of river flow to monitor/ assess net gains/ losses and to investigate river connectivity.

- **Benefits to the State:**

  The San Rafael River is recognized as being severely degraded and is on the 303D list of degraded waters in the state of Utah. With the implementation of this river restoration scheme, we anticipate restoring the river to a more ecologically acceptable state, providing more comprehensive complex habitat to the native fish, encouraging change in channel morphology through removal of Tamarisk, planting more native riparian species along the river corridor, and removing man-made barriers to enhance and encourage fish movement/ passage throughout the entire drainage.

- **Geographic Areas:**

  Study Area: San Rafael River, Emery County, Utah

  Areas Benefited: Emery County and statewide where river restoration projects are being implemented.

- **Accomplishments**:

  Findings: Initial site setup of discharge measurement transects and installation of pressure transducers occurred in April 2014. Bi-monthly data collection has been on-going since May 2014 and continued until the end August 2014.

  Results: Data analysis will commence based on data collected through 2014, and a final report is due March 31, 2015

Work Plan FY14/FY15

Data analysis and interpretation and a final technical report including recommendations are due March 2015.

Informational Resources

Contact: Mr. Ian Gowing, (435) 797-3159, E-mail: ian.gowing@usu.edu.

High Frequency Data and Cyberinfrastructure Tools to Investigate Instream Processes and Integrate High Resolution Modeling in Snowmelt Dominated Watersheds

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Stephanie Reeder
Tony Melcher (Student)

Partners/Collaborators:
***Local**: Logan City, Northwest Field Canal*

Project Description

- **Need and Purpose:**

  This project is advancing the capabilities of water observing infrastructure and cyberinfrastructure for watersheds within Cache Valley, Utah to (1) better understand hydrologic and water quality processes through instrumentation and data collection; (2) investigate phenomena revealed by high frequency, long duration data; and (3) use high frequency data to inform hydrologic and water quality modeling. A better understanding of hydrologic and water quality constituent behavior will interest water managers within snowmelt dominated watersheds of the western United States. The improved data analysis and visualization tools developed will be useful to hydrologists and watershed scientists broadly. In particular, high frequency data collection in Cache Valley watersheds will facilitate an improved understanding of the dynamics of nutrients and dissolved organic matter in snowmelt dominated watersheds, determine estimates of parameters defining stream metabolism for the region, extend capabilities to better estimate water quality constituent loading and timing to a region-wide scale, and test the implementation of hydrologic and water quality models in snowmelt dominated, heavily managed watersheds. We are evaluating current and emerging water observing systems and the role of cyberinfrastructure in supporting day-to-day data collection, management, and sharing to support the next generation of environmental models. We are also examining how the feedback between data collection and modeling can be better supported through cyberinfrastructure.

- **Benefits to the State:**

  The ability to predict hydrologic and water quality responses within arid catchments stressed by changing population, land use, and climate is essential within the state of Utah, but is difficult given high uncertainty in the driving forces and the human-impacted, managed nature of these systems. These monitoring and modeling techniques will provide better information about the timing, magnitude, sources, and flow paths associated with water and constituent fluxes and will be of interest to the Utah Division of Water Quality, utilities providing drinking water from stream and reservoir sources, stormwater managers, and other water managers and users throughout the state. This work will inform monitoring programs within the state regarding critical periods for constituent transport and the necessary sampling frequency to obtain a desired certainty in load determination or other parameters, given watershed characteristics. Finally, the cyberinfrastructure framework and tools developed as part of this project will be essential to researchers across disciplines and water managers within the state who will need enhanced capabilities to work with increasingly complex datasets.

- **Geographic Areas:**

  Study Area: Watersheds in Cache County.

Areas Benefited: River systems state-wide.

- **Accomplishments:**

  Findings: Our work over the past year illustrated that current watershed hydrology models generally lack mechanisms for accurately representing water management (irrigation diversions, irrigation, conveyance systems, etc.). Accounting for these management uses is critical to understanding and predicting hydrology and water quality within these systems. Additionally, representation of snowmelt is limited within most existing models and is inadequate to match the responses being measured using high-frequency in-situ monitoring. Monitoring results show that major water quality constituent loading occurs during very brief periods during the year (e.g., spring snowmelt), underscoring the need for high frequency, continuous data collection.

  Results: We developed a hydrologic and water quality model of the Little Bear River watershed using the Soil Water Assessment Tool (SWAT). SWAT contains some of the best representations of biogeochemical processes associated with human impacted and agricultural landscapes. We worked to incorporate many important process representations into the SWAT model but have also identified significant limitations (such as those described above). We have now partnered with Logan City and the Northwest Field canal to expand our modeling and monitoring work into the urban areas of the Logan River watershed. We are using new data to increase the spatial and temporal resolution of modeling within the Logan City urban water system.

Work Plan FY14/FY15

We will continue to monitor streamflow and water quality at seven sites within the Little Bear River and three sites surrounding Cutler Reservoir, including all associated field work; install new monitoring sites within the Logan River watershed to expand our studies into the Logan City urban water system; continue partnership with Logan City and the Northwest Field Canal to monitor canal flow, canal water quality, and the flow and quality of stormwater outfalls. Use these high frequency data streams to test, calibrate, and increase the resolution of Logan City's existing stormwater model. Work on open-source software tools for managing streaming data from environmental sensing sites.

Informational Resources

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

Figure 1. Continuous data collected at monitoring sites in Cache Valley provide high frequency observations that are challenging the assumptions and process representations in our current suite of hydrologic models.

Improving Hydrologic Model Predictions for the Effects of Land Use and Climate Change

Principal Investigators:
David G. Tarboton
Vinod Mahat (Former student)
Nazmus Sazib (Student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Hydrologic models are needed to predict the availability of water from watersheds within the Western US, including the semi-arid regions of Utah where water is scarce. Hydrologic models are also needed to quantify changes in streamflow due to changes in land cover and land use from agriculture, urbanization, forestation, and climate changes. This project is advancing physically based modeling to improve our ability to simulate streamflow based on information about the detailed processes that occur across watersheds involved in streamflow generation. It includes improvements in the capability to model snowmelt in vegetated areas and to simulate watershed responses to land use changes.

- **Benefits to the State:**

  Water is a critical resource in Utah, and this project will provide a better understanding and an 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 on the impacts of growth on water resources. This work is improving our capability to model snowmelt, which is a major source of water in the state. It is also improving our ability to simulate watershed responses to land cover changes using process based models that represent the land cover in better detail.

- **Geographic Areas:**

  Study Area: The study area is the semi-arid Western U.S., particularly Utah. Detailed snowmelt model evaluation used data from the USU TW Daniels Experimental Forest.

  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) improvement of the Utah Energy Balance Snowmelt model—specifically in the way it represents vegetation and is able to quantify the sensitivity of snowmelt to variability in vegetation density and leaf area index, (2) detailed simulation of watershed responses to climate change to examine how climate change may affect ecologically relevant aspects of the streamflow regime.

  Results: The streamflow that results from snowmelt is affected by vegetation and in particular by the amount of snow that is intercepted versus snow that falls through the canopy to the ground.

Snow that is intercepted is more easily lost to sublimation and does not melt to support streamflow. Improvements to the Utah Energy Balance Snowmelt model representation of interception processes were evaluated using data collected at the Utah State University TW Daniels Experimental Forest. The results, reported in Mahat et al. (2014), demonstrate improvements in the ability to model the role of interception in quantifying snowmelt from forested areas using practically available information.

Work currently underway has moved beyond the focus on improving snowmelt to examining the patterns of streamflow that are important to stream ecology. In an EPA supported project we developed an approach to classify and model streamflow regime variables deemed important for stream ecology using a statistical approach (Dhungel, 2014). However statistical approaches are based on the assumption that past data is indicative of the future, an assumption that is weak when we face changing conditions due to climate and land use change. In this work we are using physically based distributed modeling to examine changes in streamflow regime at sites representative of the streamflow regime classes that were statistically modeled. Preliminary results have identified the degree to which projected precipitation that increased due to climate change may increase high flow events, and the degree to which timing of streamflow may change due to warming and increases in the fraction of rain versus snow in snow fed watersheds. A paper on this work is in preparation and a poster presentation has been prepared for the American Geophysical Union Fall meeting, 2014.

Work Plan FY14/FY15

In the current year we will continue the work on quantifying the sensitivity of streamflow regime to projected climate change using physically based distributed modeling. This will provide information on anticipated streamflow changes to support planning for these changes from both a water resources and ecosystem management perspective.

Informational Resources

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

Publications

Dhungel, S. (2014). *Prediction of Climate Change Effects on Streamflow Regime Important to Stream Ecology*. MS Thesis, Civil and Environmental Engineering, Utah State University, http://digitalcommons.usu.edu/etd/3083/, 124 pp.

Mahat, V. and D.G. Tarboton (2014). Representation of canopy snow interception, unloading and melt in a parsimonious snowmelt model. *Hydrological Processes*, 28(26): 6320-6336, http://dx.doi.org/10.1002/hyp.10116.

Improving Stream Flow Forecasting

Principal Investigators:
Andres Ticlavilca
Mac McKee

Partners/Collaborators:
- *None*

Project Description

- **Need and Purpose:**

  Adaptation to new hydrological conditions of a changing climate and extreme events will require more accurate and timely information for decision-making in order to anticipate these new conditions. Since irrigated agriculture in the state of Utah depends heavily on adequate water supplies and related water rights administration, accurate and timely knowledge of future water supplies is fundamental to effective adaptation to climate variability and change, and fostering resilient, vital rural economies. In this regard, accurate long-term forecasts of future stream flow quantities can be of great potential economic value in Utah, especially to the agricultural sector. Similarly, in a snow-melt-driven region such as Utah, accurate short-term forecasts of expected stream flow conditions can be valuable for planning response to flooding conditions like the ones that occurred during the spring runoff period of 2011. This project developed short- and long-term stream flow forecasting techniques using historic data such as stream flow, snow water equivalent, temperature, soil moisture and Pacific sea surface temperature. The models applied in this project are based on statistical methods and advanced modeling approaches such as machine learning models and wavelet analysis.

- **Benefits to the State:**

  Effectively adapting to climate variability and change in Utah will depend substantially on accurate and timely water supply forecast on timescales ranging from days to decades. Improved water supply forecast can enhance economic value of agricultural decisions for both crop and livestock management because of effects on water rights administration. This in turn will highlight institutional barriers to efficient water management and use, and influence planning of water resources systems in the state of Utah.

- **Geographic Areas:**

  Study Area: Cache County, Sevier River Basin, Uintah Basin.

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

- **Accomplishments:**

  Findings: Short- and long-term stream flow forecasting can be significantly improved with the use of the advance modeling approaches such as those developed by this project. Short-term forecast are daily for a period of up to 7 days into the future. Long-term forecast are monthly for a period of up to 12 months into the future.

Results: Products generated by the project this year include development of a short-term forecasting model for the Logan River in Cache Valley and long-term forecasting models for the Yellowstone River in the Uinta Basin and the Sevier River in the Sevier River Basin with good results. Further applications and testing in other river basins are needed to validate and refine the models. Results have been presented at conferences and two papers have been submitted to peer-reviewed journals.

Work Plan FY14/FY15

- Apply the proposed advanced modeling approaches in more river basins in Utah and compare the results of the forecasting models to those produced by NOAA using more conventional modeling approaches.

- Transfer the model results and applications to potential users.

Informational Resources

Contact: Dr. Andres M. Ticlavilca, Phone (435) 757 0851, E-mail: andres.ticlavilca@usu.edu.

Conference Presentations

Ticlavilca, A.M., I. Maslova, and M. McKee (2014). Computationally Intelligent Models and Wavelet Decomposition Approaches to Improve Streamflow Forecasting in Utah under Climate Uncertainty. Abstract presented at the *2014 UCOWR-NIWR-CUAHSI Conference, Water Systems, Science, and Society under Global Change, Tufts University*, Medford, Massachusetts. http:/ / www.aaes.auburn.edu/ water/ documents/ PreliminaryProgram.pdf.

Ticlavilca, A.M., I. Maslova, and M. McKee (2014). Time-frequency analysis of local climate data, soil moisture and streamflow in Utah using a wavelet cross-correlation approach. *Spring Runoff Conference*, Logan, UT. http:/ / conference.usu.edu/ springrunoff/ system/ Schedule/ sch_Details.cfm?abid=497&ty=grid

Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates

Principal Investigators:
Christopher M.U. Neale
Hatim Geli (Post-doc)
Jonna van Opstal (Graduate student)

Partners/Collaborators:

- ***Local:*** *Bear River Canal Company*
- ***State:*** *Utah Agricultural Experiment Station*
- ***Federal:*** *USDA-NRCS*

Project Description

- **Need and Purpose:**

  The growing demand for fresh water for municipal use in urban areas along the Wasatch front and in Cache Valley has led to water quality and quantity pressures on exiting water resources. The Bear River basin is one of the few systems in the US West that still has unallocated water. Additional dams will likely be built within the system in the future to tap these water resources, even as the system is adjusting to a changing runoff hydrograph due to expected climate change. Solutions for improved management of the water resources in the Bear River basin must involve multiple stakeholders and possibly include policy adjustments to the existing water laws. Improving water management in large surface irrigated areas will be one of the elements important to the solution due to the high consumptive use of these systems and large diversions from the river. This study is providing the information system managers need in order to make future operational management decisions in adapting to changing conditions. The results will be relevant and applicable to other similar systems in Utah.

- **Benefits to the State:**

  Improved water management in irrigated agricultural areas can lead to water savings and, potentially, to improved water quality. Decreases in diversions for irrigation can be stored for future use during drought years and can guarantee minimum flows for the health of river 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.

  Areas Benefited: Irrigated agricultural areas and systems in all 29 Utah counties.

- **Accomplishments:**

  Findings: Spatial evapotranspiration is estimated from a series of satellite imagery acquired over a growing season, and this was used to establish seasonal crop water use in a large irrigated system. These data were then used to establish the water balance and efficiency of the system at different levels. Evapotranspiration estimates were validated with eddy-covariance data from 2012 and 2013 growing seasons. Continuous water depth and electrical conductivity measurements were conducted at 2 points in the Malad River and in an agricultural drainage ditch. These findings help determine the influence of irrigation strategies on outflow water quality. Field evaluations of irrigation events were conducted on 4 different soil types to determine infiltration parameters.

Water quality sensor in an agricultural ditch (left); eddy covariance tower in a wheat field (right)

Results: Evapotranspiration estimates were calculated with the SEBAL model and applied for multi-temporal satellite imagery from Landsat 5 TM, Landsat 8 and MODIS products. Weather station and irrigation diversion data were used to compute the water use and system efficiency in past years. These results indicate the difference in irrigation system management for dry, normal, and wet years. Field irrigation management analyzed using the Ador model simulated the irrigation system infrastructure and on-field irrigation events. The field evaluation data collected on different soil types was analyzed using the SIRMOD model to obtain infiltration parameters, which were put in the Ador model to provide irrigation performance for each head gate area in the irrigation system. Training was given by the developer of the Ador model (Dr. Sergio Lecina) in Spain to understand the use and application of the model. Different scenarios were run with the Ador model to understand the effect of irrigation schedule changes. The results were presented at the board and shareholders meeting of the Bear River Canal Company. Continuous water quality measurements were conducted to understand the potential effect of irrigation schedule changes in an agricultural area and the implications on downstream users.

Work Plan FY14/FY15

Continuous measurements of water depth and salinity were conducted throughout the 2013 irrigation season. These data will be used as input for the Hydrosaline component of the Ador model. Simulations will indicate the effect of different irrigation management strategies and the consequences for downstream water users concerning water quantity and quality.

Informational Resources

Contact: Dr. Christopher Neale, E-mail: christopher.neale@usu.edu.
Ms. Jonna van Opstal, (435) 797-1041, E-mail: j.van_opstal@aggiemail.usu.edu.

Publications:

van Opstal, J.D. and C.M.U. Neale (2014). Irrigation system performance evaluation using remote sensing during wet and drought years. *ASABE International Symposium, Evapotranspiration: Challenges in measurement and modeling from leaf to the landscape scale and beyond*, Raleigh, NC.

van Opstal, J.D. and C.M.U. Neale (2014). Learning from the past, looking at the future: The influence of spring runoff water availability on irrigation performance. *Spring Runoff Conference 2014, Utah State University*, April 2014.

iUTAH – Innovative Urban Transitions and Arid Region Hydro-Sustainability

Principal Investigators:
Jeffery S. Horsburgh
Bethany T. Neilson
David Rosenberg

Partners/Collaborators:

- ***Local**: Logan City*
- ***State:** Utah State EPSCoR Office, University of Utah, Brigham Young University, Weber State University, Utah Education Network*
- ***Federal:** National Science Foundation*

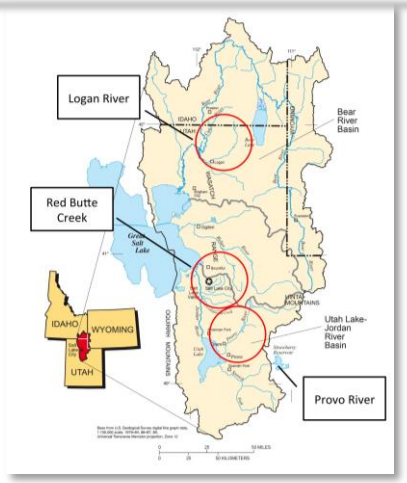
Project Description

- **Need and Purpose:**

  Water is critical to sustainable economic development in Utah and to the sustainability of our urban and natural ecosystems. Freshwater resources are facing immediate and long-term challenges due to population pressure and predicted changes in the amount and timing of precipitation. Utah's population will at least double in the next two decades, with most of this growth occurring along the narrow Wasatch Range Metropolitan Area (WRMA). Growth is expected to generate a significant increase in water demand that will need to be addressed through water transfers, infrastructure investments, and efficiency programs. The overarching goal for the iUTAH project is to enhance Utah's research competitiveness and sustainable water decision-making through strategic investments in the state's physical, human, and cyberscience infrastructure. Transdisciplinary teams of natural and social scientists have been formed to carry out hypothesis-driven research on hydroclimatic sustainability in the WRMA, a coupled human-natural system that is changing as a consequence of climate change and rapid urbanization.

- **Benefits to the State:**

  The innovative and transformational activities in this project include (1) the development of fully integrated hydrologic and social sciences observatories that encompass whole watersheds along an urbanizing land use gradient; (2) strategic activities designed to build a community of scholars across the state of Utah capable of addressing hydro-sustainability as a coupled human-natural system; and (3) integrated education and outreach activities, such as participatory and collaborative modeling efforts, to ensure our research directly addresses societal needs and will translate and communicate our scientific findings to stakeholders, policy makers, and the general public. An improved understanding of this complex system and the development and implementation of innovative solutions require better integration of social, hydroclimate, ecological, and engineering knowledge, and closer links between the academic community and local water management institutions. The theme of the iUTAH EPSCoR project is directly aligned with Utah's Science & Technology plan. It builds on our considerable existing strengths in water and urban and ecological sciences while expanding relevant expertise in the social sciences needed to understand complex, human-dominated systems. iUTAH's infrastructure investments have created a common research platform and facilitate statewide



The iUTAH EPSCoR project is building new observing and data collection capabilities along a gradient of urbanization in three northern Utah watersheds

science collaboration to enhance our ability to compete for major new interdisciplinary funding opportunities.

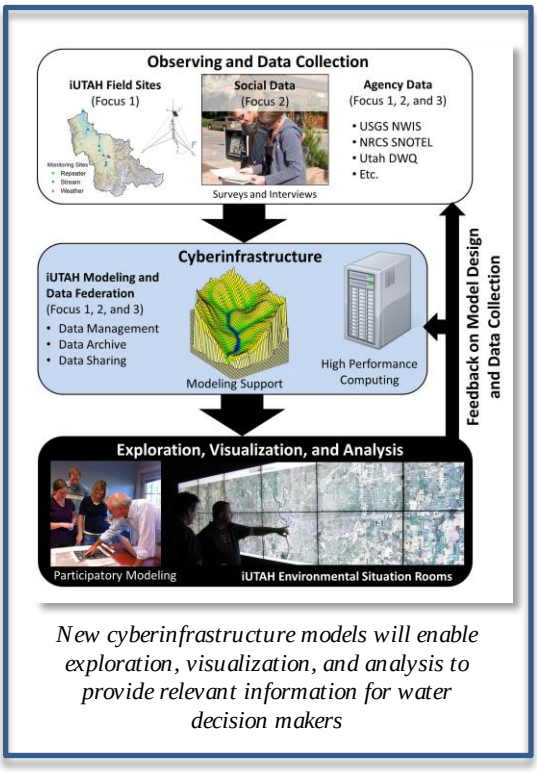
- **Geographic Areas:**

  Study Area: Logan River, Red Butte Creek, Provo River, WRMA, other urbanizing areas statewide.

  Areas Benefited: Logan River, Red Butte Creek, Provo River, WRMA, other urbanizing areas statewide.

- **Accomplishments:**

  Findings: While many hydrologic and water management models currently exist, no single model provides adequate representation of all of the human mediated processes that shape the hydrology of western water systems such as those found in northern Utah, including diversions, transfers, return flows, and water use behaviors. In addition, currently available hydrologic and water quality monitoring data are inadequate to characterize the highly modified hydrology and water quality of systems like the Logan River, Red Butte Creek, and the Provo River. Similarly, our understanding of human water use behavior at both the individual and organizational scale is incomplete, making it difficult for us to generate future water availability scenarios for important Utah water systems.



New cyberinfrastructure models will enable exploration, visualization, and analysis to provide relevant information for water decision makers

Results: In the first two years of this project we have (1) designed and built hydrologic observatories in the Logan River, Red Butte Creek, and the Provo River that further our understanding of the human mediated hydrologic systems within northern Utah along a gradient of urbanization; (2) developed the computer hardware and software cyberinfrastructure required to facilitate data collection within each of these observatories, including innovative new data management and visualization software; (3) participated in the design and development of social science observatories for these same systems, and (4) started working toward integration of these primary data collection activities into coupled interdisciplinary models that better represent the human mediated hydrology of western water systems and provide more information directly relevant to future water availability scenarios and decision making.

Work Plan FY14/FY15

(1) Continue work on the cyberinfrastructure aspects of the iUTAH project, and focus on the software systems required to enable iUTAH scientists and partners to share and collaborate around data and models of the state's hydrologic systems; (2) develop new tools to analyze and visualize social science datasets created by iUTAH partners (3) conduct primary research using the data collected within the watershed observatories (including continuous datasets from stream and terrestrial monitoring sites), and develop the next generation of interdisciplinary coupled models of the human mediated hydrology of the Logan River, Red Butte Creek, and Provo River watersheds.

Informational Resources

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

Low Cost Vertical Take Off and Landing Remote Sensing Systems for Water Engineering

Principal Investigators:
Austin Jensen
Mac McKee
Cal Coopmans (Ph.D. student)

Partners/Collaborators:
- ***Federal:*** *Roger Hansen, USBR*

Project Description

- **Need and Purpose:**

  To better manage water and other natural resources such as wetlands and floodplains, the Utah Water Research Laboratory (UWRL) has been actively developing a small UAV platform known as AggieAir that assists in water resources by capturing high resolution aerial imagery at a lower cost than conventional platforms (e.g. manned aircraft and satellite). AggieAir's fixed wing platform has been used successfully for many applications. However there is also a need for a rotary wing aircraft with the ability to take off and land vertically and to hover. This type of platform could launch and land in constrained areas, make close "point measurements" for applications such as vegetation mapping, and generate more detailed maps of small features such as dams. The goal of this project is to develop a rotary wing aircraft, referred to as the vertical takeoff and landing (VTOL) platform as part of the AggieAir system. This will complement the current fixed wing aircraft for applications in water related scenarios.

- **Benefits to the State:**

  AggieAir's fixed-wing UAVs have proven to be very useful for managing natural resources in the State of Utah. For example, the ability to acquire decision-relevant data on soil moisture and evapotranspiration in a timely fashion and at a low cost gives canal companies and irrigation districts in the state the ability to (1) provide farmers with highly detailed information about soil moisture conditions in individual fields, enabling them to better manage scarce irrigation resources; and (2) manage complex irrigation delivery systems more efficiently, thereby saving water that could be used to increase agricultural output or allocate to other users whose demands are continually growing. The water savings could be as much as 5 or 10 percent of current deliveries.

  AggieAir's VTOL platform will benefit the State of Utah in many similar ways to the fixed wing platform. The VTOL platform will also enable many new emerging applications.

- **Geographic Areas:**

  Study Area: Most of the test flights will take place at our test site near Cache Junction, UT. We have official approval from the FAA to conduct flights here.

  Areas Benefited: All counties in the state could benefit.

- **Accomplishments**:

  Findings: An inexpensive VTOL unmanned aerial vehicle (UAV) has been further developed and is being made robust and capable of carrying and controlling various types of remote sensing equipment to gather aerial imagery. However, while testing for robustness, the autopilot was

found to be insufficient due to a computational limitation in the processor. Therefore, the Paparazzi autopilot is being redesigned around a real-time operating system and with a processor with more computational power. While this new autopilot is still in development, operations with the VTOL have continued using other off-the-shelf VTOL systems.

Work Plan FY14/FY15

- Finish development of the Real-Time Paparazzi system
- Start using the platform for routine data acquisition.
- Develop training and build manuals.

Informational Resources

Contact: Austin Jensen, (801) 633-0426, E-mail: austin.jensen@usu.edu.
Website: http://aggieair.usu.edu/ .

AggieVTOL bookchapter: http://www.igi-global.com/bookstore/titledetails.aspx?TitleId=58292.

Figure 1: Hexarotor in flight

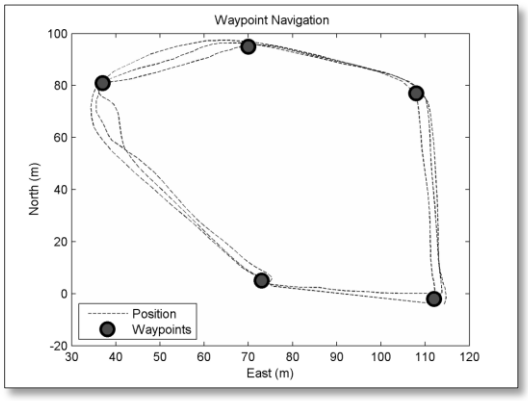


Figure 2: Recorded tracks of an AggieVTOL flight

Figure 3: View from AggieVTOL camera

Near-Real-Time Orthorectification and Mosaicking of UAV Images

Principal Investigators:
Xiaojun Qi
Mohammad Reza Faraji (Student)

Partners/Collaborators:
- *None*

Project Description

- **Need and Purpose:**

  Currently, acquiring an accurate orthorectified mosaic map from the videos captured by an UAV (Unmanned Aerial Vehicle) system is a time-consuming and expensive process, and rarely provides the researchers and farmers in Utah with timely and useful information due to the long delay in the acquisition process. Unfortunately, money and manpower are wasted when the orthorectified mosaic maps cannot be used by researchers and farmers to their full potential. As a result, there is an urgent need to generate accurate orthorectified mosaic map in near real-time or real-time.

- **Benefits to the State:**

  The project applies novel computer vision techniques to generate near real-time or real-time orthorectified mosaic maps using images from a UAV system. This project will mainly benefit the State in the following two ways: 1) Providing Utah farmers with a detailed picture of the variations that exist within a given agriculture field so they can implement management policies to maximize yield while minimizing input. 2) Providing the researchers in Utah with the spatial or temporal view of water quality needed for accurate assessment or management of water bodies.

- **Geographic Areas:**

  Study Area: Utah area at UTM, NAD83, Zone 12.

  Areas Benefited: Precision agriculture (micro-management farming), vegetation mapping, and stream and river applications.

- **Accomplishments**:

  Findings: We experimented with five different matching algorithms to find the best matched region in the base map for each aerial image and found that the MinEigen corner detector based matching method achieves the best performance. We used this best matching method to implement the georeferencing, rectification, and mosaicking process. Using a base map of the area as a reference, we can generate a mosaic map in a reduced resolution for a set of about 160 aerial images in about 30 minutes. This mosaicking time is significantly reduced. Fig. 1 shows the flow chart of the proposed approach.

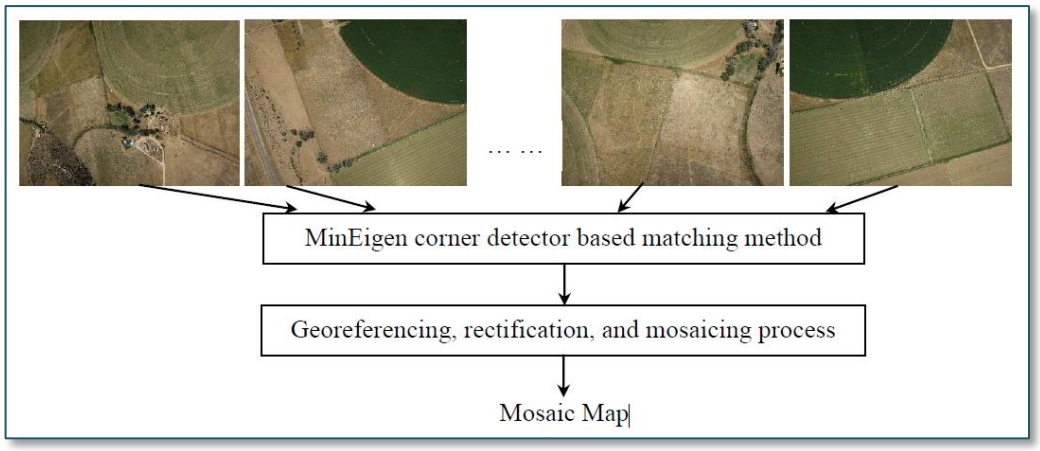


Fig. 1: The flow chart of the proposed approach.

Results:

Fig. 2 shows the encouraging experimental results, whose accuracy is comparable to the accuracy achieved by the other software. We produced this mosaic map in about 30 minutes, which are significantly less than the current running time of the other software to generate the comparable mosaic map.

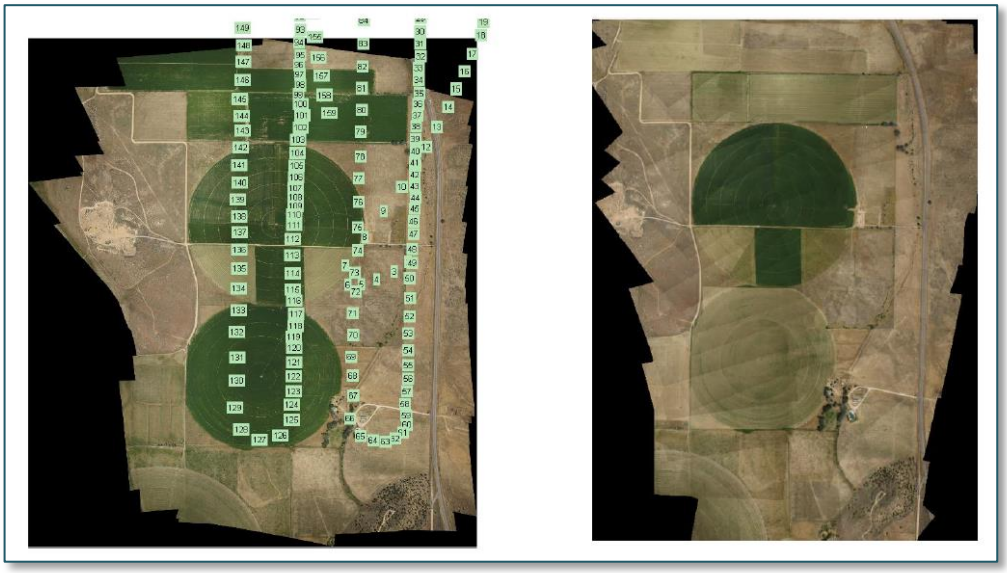


Fig. 2: The base map and the obtained pixel locations for 158 aerial images using GPS information. The mosaic map generated by using the estimated pixel locations, the projective transformation, and the average of pixel values of the overlapping re-orthorectified images.

Work Plan FY14/FY15

Further improve the accuracy of the mosaic map and the running time to generate the mosaic map.

Informational Resources

Contact: Mr. Steven. L. Barfuss, (435) 797 3214, Email: steve.barfuss@usu.edu.
M. Jordan C. Jarrett, (435) 797 3231, Email: jordan.jarrett@usu.edu.
Website: http:/ / aggieair.usu.edu/ imagery.

Pineview Reservoir Operations and Algae/Cyanobacterial Bloom Ecology

Principal Investigators:
Darwin L. Sorensen
Thomas Reuben (Post-Doctoral associate)
Christine Rumsey (Student)

Partners/Collaborators:
- ***Local:*** *Scott Paxman and Brad Nelson, Weber Basin Water Conservancy District*
- ***State:*** *Kari Lundeen, Utah Division of Water Quality*

Project Description

- **Need and Purpose:**

  Nuisance blooms of algae and cyanobacteria occur annually in Pineview Reservoir, Weber County, Utah. Previous water quality studies of the reservoir have identified both phosphorus and nitrogen as the nutrients limiting algae and cyanobacterial growth and have called for management action in the watershed to limit the loads of these nutrients to the reservoir. The socioeconomic costs of these actions are likely to be substantial. The present study, conducted in collaboration with the Weber Basin Water Conservancy District, seeks to provide empirical information for managers so that Pineview Reservoir water quality can be preserved or improved in the most cost-effective way.

- **Benefits to the State:**

  Utah's growing population and water demand will likely lead to the use of Pineview Reservoir as a key water body for the storage and distribution of municipal water to the greater Ogden and possibly the greater Salt Lake City areas in the future. Learning the factors that control phytoplankton productivity in the reservoir and the source and transport of nutrients will allow effective control methods to be selected. The approach and results of the study are likely to be applicable to other water bodies in Utah and the surrounding region.

- **Geographic Areas:**

  Study Area: Ogden Valley including Huntsville Town, Eden, and Liberty in Weber County

- **Areas Benefited:** Ogden Valley, the greater Ogden area, and potentially, similar watersheds and reservoirs in Utah and the Intermountain West.

- **Accomplishments:**

  Results: Pineview Reservoir phytoplankton productivity and water quality was typical of mesotrophic conditions. The reservoir is thermally stratified during summer months and phosphorus accumulates in the bottom (hypolimnion) layer of the reservoir as summer progresses. A significant fraction of this phosphorus is removed from the reservoir as water is withdrawn for irrigation. Annual surface water nutrient loading has been lower than estimated in earlier studies, but loads associated with snow-melt runoff contribute the largest fraction of the total. Short but intense snow-melt events in the late winter and early spring on the valley floor may contribute substantial, "first flush," phosphorus loads. Ground water also contributes less nitrogen and phosphorus than estimated in earlier studies, but certain shoreline sectors near Huntsville contribute more nitrogen and phosphorus than other sectors. Nitrogen cycling and nitrate transport modeling in the Huntsville area suggested that lawns may contribute a

disproportionately high fraction of the nitrate leaching into ground water. Relatively steady concentrations of mobile phosphorus in groundwater at selected sites in and near Huntsville suggest equilibrium between phosphorus on the soil and that in solution. However, laboratory studies indicate that more phosphorus will associate with the soil if phosphorus concentrations increase. Dissolved organic matter does not influence phosphorus sorption.

Work Plan FY14/FY15

The project closed in December 2013.

Informational Resources

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

Publications

Carrigan, L.D. and D.L. Sorensen (2012). *Nonpoint Source Nutrient Export from the Pineview Reservoir Watershed to Streams.* Utah Water Research Laboratory, Utah State University, Logan, UT.

Reuben, T.N. (2013). *Nutrient contribution of the shallow unconfined aquifer to Pineview Reservoir.* PhD Dissertation, Civil and Environmental Engineering, Utah State University, Logan, UT.

Reuben, T.N. and D.L. Sorensen (In Review). Applicability of Kriging for estimating ground water flow and nutrient loads surrounding Pineview Reservoir, Utah, USA. *Transactions of the ASABE.*

Reuben, T.N. and D.L. Sorensen (2014). Estimated nitrate loadings from lawns, irrigated cropland, and on-site wastewater to an aquifer in Ogden Valley, Utah. *Journal of Soil and Water Conservation*, 69(3):243-253.

Worwood, B.K. and D.L. Sorensen (2012). *Pineview Reservoir phosphorus and mineral nitrogen processes.* Utah State University, Utah Water Research Laboratory, Logan, UT.

Reuben, T.N., B.K. Worwood, L.D. Carrigan, and D.L. Sorensen (2011). Pineview Reservoir nutrient loading, unloading, and the role of groundwater in the estimates. *Transactions of the ASABE*, 54(6), 2219-2225.

Figure 1. Light measurement through the ice on Pineview Reservoir

Figure 2. Drilling for water table aquifer cores

Quantifying the Flow Field in Baffled Fish Culverts

Principal Investigators:
Blake P. Tullis

Partners/Collaborators:
- ***Local:*** *Tim Ularich, UDOT-Maintenance*

Project Description

- **Need and Purpose:**

  Many culverts are approaching or are past their original design lives and need to be repaired, rehabilitated, or replaced. Due to the expense and impact of traffic disruption associated with culvert replacement, alternate measures to extend the culvert project life are growing increasingly popular. One such method is slip lining, where a 'sleeve' is installed within an existing culvert barrel and stabilized. Plastic pipe sleeves are very popular for slip lining, but the reduced flow resistance, relative to corrugated pipe, can result in increased flow velocities and reduced flow depths in the culvert, creating a potential fish barrier. Hence, mitigation of the increased velocities should go hand-in-hand with slip-lined projects where fish passage (present or future) is to be considered. There has been very limited experience in providing for fish passage through slip-lined culverts.

  Baffles installed in culvert liners have been recommended as a possible solution for culvert relining when fish passage is a concern, but very limited data are available in the literature regarding baffle performance in circular culverts in relation to fish passage, as well as discharge capacity. Consequently, the evaluation of flow dynamics (turbulence) and the corresponding swimming behavior of fish to that flow environment will be evaluated in this study. As the single largest owner of culverts in the State of Utah, the Utah Department of Transportation (UDOT) has a keen interest in fish passage through rehabilitated culverts. As such, UDOT provided the initial funding for this study and MLF funds have been used to expand the research and contribution. The objective of the currently proposed study is to incorporate a flow dynamics component by determining mean flow velocities and flow depths and, perhaps more importantly, fluid acceleration data for turbulence quantification. Flow dynamics will be compared with fish behavioral results from the UDOT-funded study in an effort to better predict the likelihood of successful fish passage in baffled culvert designs not included in this study (i.e., improve the general applicability of the fish passage data).

  The scope of work for the project is summarized as follows:
  - Develop a technique for evaluating the 3-dimensional flow field in a free-surface flow baffled culvert using a particle image velocimeter. Some complications may include the presence of entrained air bubbles and equipment access to the pipe (light sheet generating laser and imaging camera).
  - Collect high-frequency 3-dimensional velocity data for a range of discharges and culvert slopes using the PIV system and an acoustic doppler velocimeter system for comparison.
  - Process the velocity data to calculate local flow accelerations and representative turbulence parameters.
  - Correlate the turbulence values with the fish behavior, relative to their ability to negotiate the baffled culvert.
  - Use computational fluid dynamics (CFD) to further analyze the flow field and calibrate using the PIV velocity data.
  - Determine hydraulic roughness coefficient data for a baffled culvert using laboratory and CFD data.

- **Benefits to the State:**

  UDOT does not currently have a design standard for baffled slip-lined culverts. The results of this study will be used to aid UDOT in developing a baffled culvert protocol for rehabilitated culverts where fish passage is a concern. The results of the study should have nation-wide application and perhaps even international application.

- **Geographic Areas:**

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

  Areas Benefited: Culvert rehabilitation projects statewide and nationwide where fish passage issues may be of concern.

- **Accomplishments:**

  Findings: The hydrodynamics of flow through baffled culverts was evaluated using computational fluid dynamics (CFD) numerical modeling. The CFD results were compared with the PIV velocity profile previously collected to help calibrate and/ or determine if CFD represents a reliable tool for baffled culvert flow analysis

  Results: The results so far have been published in Mohanad Khodier's PhD dissertation. A peer-reviewed journal paper was published to the Journal of Hydraulic Engineering on fish passage through baffled culverts and two additional papers will be submitted for review during FY15.

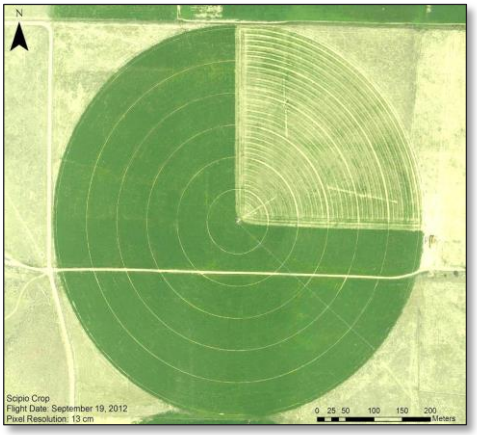
Work Plan FY14/FY15

Additional analysis of the data produced by this study will be conducted with the intent of finding improved hydraulic roughness coefficient predictive relationships that could aid engineers in predicting the discharge capacity of baffled culverts.

Informational Resources

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

A brown trout navigating the baffled culvert during testing



Aerial imagery of the center pivot system in Scipio obtained from UAV flights used to estimate soil moisture, evapotranspiration rates, and plant nitrogen content.

Real-Time Management of Irrigation Systems in the Sevier River Basin

Principal Investigators:
Mac McKee
Wynn Walker
Alfonso Torres-Rua
Andres Ticlavilca

Partners/Collaborators:

- ***Local:*** *Jim Walker, Sevier River Water Users Association (SRWUA)*
- *Ivan Robins, Ex-President Scipio Irrigation Company*

Project Description

- **Need and Purpose:**

  As water demands increase in the western states, concerns for endangered species and water quality will have a greater impact on the allocation of water resources. Emphasis will have to be placed on more efficient water management if existing water rights are to continue to be met. Improvements in efficiency of water management require a low-cost mechanism for obtaining and distributing information about the state of the water supply system. This project is developing and adding significant data analysis functionality to existing Sevier River Water Users Association (SRWUA) water management to support real-time and long-term water management information needs.

- **Benefits to the State:**

  Application of these and related technologies in the Sevier River Basin in the past several years have shown an improvement in the decision-relevant information available to system managers in their efforts to increase the efficiency of basin-wide water management. Similar results could be achieved in virtually every river basin in Utah, especially those with substantial irrigated agriculture. The forecasting techniques developed by this project could potentially provide valuable information for better long-term decisions by farmers and ranchers for investments in crops and livestock, especially in years where drought might be likely. Similarly, the short-term forecasting methods developed by this project can provide system managers with information necessary to more precisely control the operation of large irrigation systems, such as those found in the Sevier Basin, thereby saving water and increasing the overall productivity of the system.

- **Geographic Areas:**

  Study Area: Sevier River Basin, including Sevier and Millard Counties.

  Areas Benefited: Irrigated agriculture is statewide, potentially benefiting all counties in the state.

- **Accomplishments**:

  Findings: Real-time reservoir, canal, and on-farm operations can be improved in the Sevier River Basin by several percent with the use of remote sensing tools and data-driven models such as those developed by this project.

  Results: Products generated by the project this year include the following:

  - Flights of the UWRL autonomous aerial vehicles (UAVs) for fields near Scipio, Utah from previous years have been used to provide high-resolution maps of plant tissue nitrogen and chlorophyll and spatial ET measurements. Models to estimate soil moisture in

irrigated areas using these remote sensing techniques, as well as models to forecast changes in root zone soil moisture, are close to completion and show excellent promise.

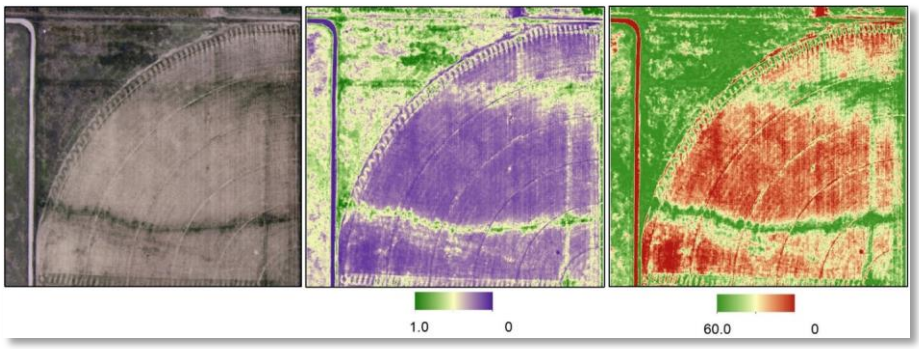
- Assessment of integration of high resolution imagery from flights by the AggieAir™ Flying Circus for fields near Scipio, Utah with satellite platforms (e.g. Landsat) is in progress. The results of this assessment will provide an adequate methodology for spectral and spatial management of information over diverse imagery sources in agriculture.
- Integrated algorithms for the crop and water monitoring and information system (CWMIS) at farm and irrigation system levels in the Lower Sevier River have been completed. These algorithms allows for automated information delivery to farmers, water managers and policy makers within a basin.
- Landsat information is being used to derive a methodology to estimate soil water content for agricultural farms at pixel level. This study is being done at the Lower Sevier River Basin. When combined with spatial evapotranspiration products, they can provide information for better irrigation water management at farm and irrigation system levels.
- Initial conversation with the Utah Division of Water Resources for state-wide implementation of spatial evapotranspiration models for agricultural water management are being held.

Work Plan FY14/FY15

- Continue to work with the US Bureau of Reclamation, Utah Division of Water Resources and the SRWUA to implement all operations models on the SRWUA web site.
- Continue integration of current and completed algorithms within the Sevier River Basin 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 from Landsat.
- Continue assessment of remote sensing and tools for estimating water requirements, evapotranspiration rates, and present and future soil moisture levels in the Scipio and Lower Sevier River areas for better management of center pivot irrigation systems.

Informational Resources

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



True color image of flight in Scipio, UT (left), LAI map (middle), estimated chlorophyll content map (μg.cm-2) (right)

UAV Monitoring and Assessment Applications in Municipal Water and Environmental Management

Principal Investigators:
Austin Jensen
Mac McKee

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

Project Description

- **Need and Purpose:**

  For water and environmental management applications, remote sensing gives managers accurate spatial data to use in making management decisions. Although research has shown that remote sensing can be a very useful tool, many water resources managers do not use it due to high cost, long processing time, and inflexibility. Free GIS state services or applications like Google Earth could be used for aerial imagery instead of purchasing the data; however, the imagery from these sources can be out-of-date, may have poor resolution, and rarely include all spectral information needed to use modern classification software or other advanced analytic techniques. To deal with some of these problems, a new remote sensing platform, called AggieAir, has been developed at Utah State University. AggieAir is a small, autonomous aircraft with multiple on-board cameras to capture aerial imagery during flight. AggieAir is capable of capturing visual (red, green, and blue) imagery, near-infrared (NIR) imagery, and thermal imagery. For this project, we investigated the value to cities such as Logan, Utah, of using AggieAir to help them manage their environment by capturing aerial imagery over areas of interest such as wetland and riparian areas, landfills, and parks and recreation areas such as golf courses.

- **Benefits to the State:**

  This project investigated the use of AggieAir in municipal water and environmental management problems. All areas of the state could benefit by saving more water, money and time while effectively managing the environment.

- **Geographic Areas:**

  Study Area: The Logan River, the Logan Golf Course, and a wetland mitigation site were selected as study areas. Precautions were taken to make sure the UAV does not fly over highly-populated areas.

  Areas Benefited: Logan City and potentially many other cities in Utah.

- **Accomplishments**:

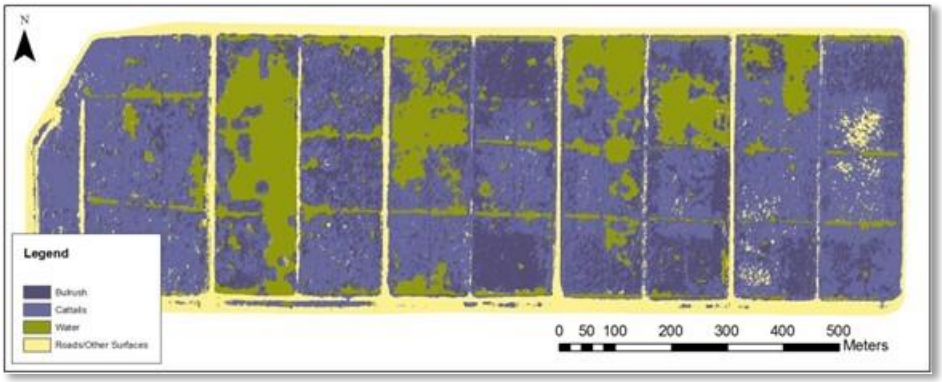
  Results: Imagery was acquired over the Logan River, the Logan Golf Course, the Logan Landfill, and a wetland mitigation area. Multiple sets of images were acquired over the golf course and the wetland. Vegetation Classification was performed on the wetland mitigation area to show city officials how much of the wetland contained harmful invasive plant species. Thermal imagery over the golf course was used to map hotspots on the grass to increase watering efficiency. Finally, the imagery over the Landfill was used to generate a 3D map of the landfill that could be used to monitor usage and project landfill lifetime.

Work Plan FY14/FY15

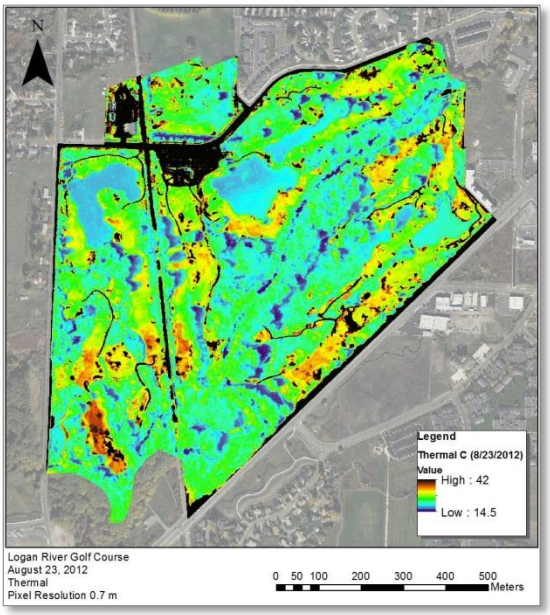
This project is complete.

Informational Resources

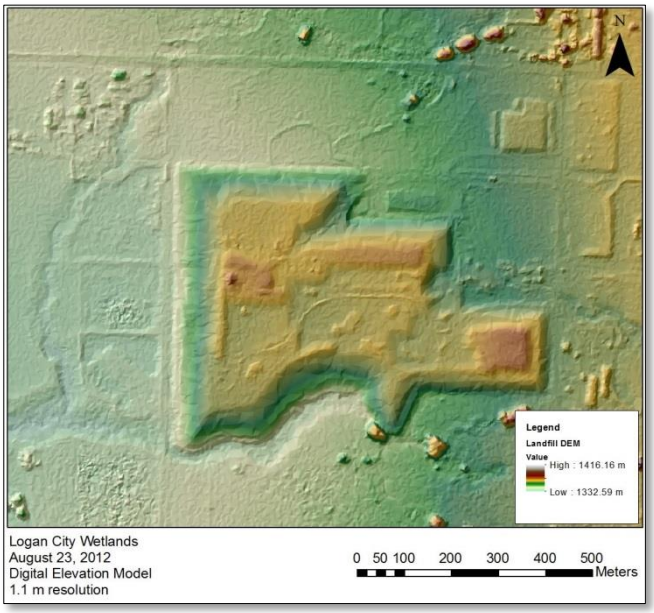
Contact: Austin Jensen, (801) 633-0426, E-mail: austin.jensen@usu.edu.
Website: http://aggieair.usu.edu/ .



Map of classified Logan City Wetlands



Logan Golf Course thermal imagery flown by AggieAir



3D map of Logan City Landfill

UAV Remote Sensing Service Center

Principal Investigators:
Austin Jensen
Mac McKee

Partners/Collaborators:
Various end-users in Utah

Project Description

- **Need and Purpose:**

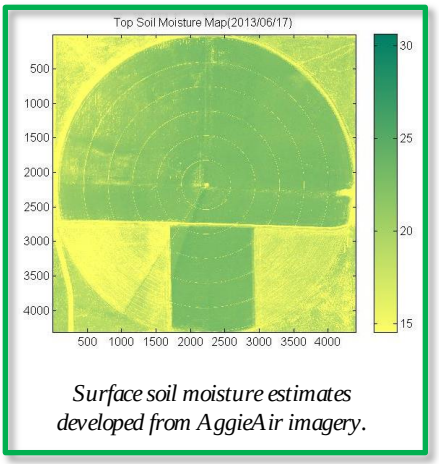
  Many current sources of remote sensing data (e.g. manned aircraft and satellite platforms) are too expensive, have low spatial resolution, or don't update frequently enough to be practical for many applications. A low-cost, small unmanned aerial vehicle (UAV) called AggieAir™ can fill this need by providing inexpensive, multispectral aerial imagery quickly and frequently. In addition, AggieAir's independence from a runway for takeoff and landing enables it to be launched from almost anywhere. AggieAir can benefit applications such as agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, fish and wildlife tracking, and many others.

  Developed over the last several years, AggieAir has become stable and robust. Therefore, using AggieAir on a regular basis to provide aerial images and remote sensing date could benefit many of these applications. The money generated from these applications could help fund continued AggieAir development and research. A service center has been established to handle the operational and maintenance needs so the research can continue to progress undeterred. The service center is also a good source of feedback to help steer AggieAir research and development in the right direction.

- **Benefits to the State:**

  The data provided from the service center has the potential to help Utah save water and manage environmental resources more efficiently. The service center can help save water by offering farmers a low-cost solution for mapping the soil moisture of their crops in order to irrigate more efficiently. Furthermore, this data can also help canal operators and individual irrigators manage water diversions more effectively. The service center can also map roads and highways to monitor the quality of the asphalt and to update the road inventory (e.g. number of lanes, signs, culvert crossings, etc.). Roads can also be surveyed before, during, and after construction by the service center UAVs. Currently this is only done before construction. Wetlands managers can now obtain current data on the distribution of plant species and monitor the success of management practices to control invasive plants. Resources managers who are worried about monitoring and managing water quality can now obtain accurate, high resolution thermal images showing temperature distributions all along a stream or river.

  The service center will indirectly provide new jobs and economic growth to the state of Utah. Long term, the service center will be the first step toward a new business that will be based around the AggieAir UAV platform. The service center will allow us to test the waters, as well as gain experience to learn what would be required to make this happen.



Surface soil moisture estimates developed from AggieAir imagery.

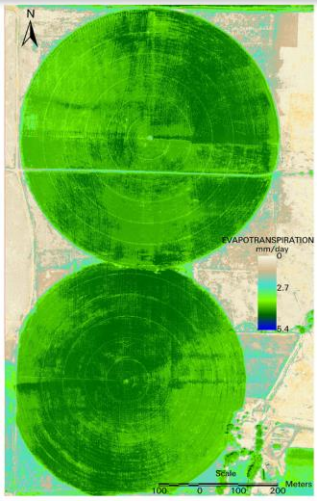
- **Geographic Areas:**

  Study Area: State-wide.

  Areas Benefited: State-wide.

- **Accomplishments:**

Findings/Results: The funds from this project have developed and fully equipped a service center at the Utah Water Research Laboratory called AggieAir Flying Circus (AAFC) (see http:/ / AggieAir.usu.edu). As planned, the AAFC uses AggieAir UAV platforms and sensors on a regular basis to provide aerial images for applications that benefit from remote sensing data. The images below display some of the maps generated by the AAFC and the analysis of the imagery to address water management problems in a variety of applications.



Daily evapotranspiration rates developed from AggieAir

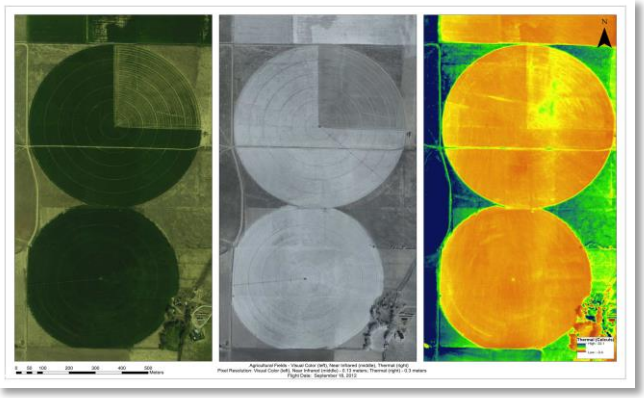
The AggieAir service center completed manuals to train customers who have purchased the UAVs from USU. Aircraft have been sold to organizations that wish to use AggieAir for their own remote sensing purposes, and licensing agreements are in place with private companies in Utah to manufacture AggieAir aircraft and avionics. AggieAir technology sales were made this year to research groups at UC Merced, Texas State University, and Oklahoma State University. Additional field crews have been trained to fly the UAVs and process the imagery they collect.

In the past year, the AggieAir Flying Circus has provided support to research contracts in several states, with a very large number of flights conducted on a wide array of resources management problems in Utah. The AAFC is currently engaged in research projects to improve irrigation and nutrient management for center pivot irrigators in Scipio and to quantify salt that flows into the Green River from the Price River Basin, as well as a large number of other similar projects. The AAFC is also been engaged in projects in water and natural resources management in Cache Valley for the City of Logan and in numerous other applications around the State.

The AAFC obtained two Certificates of Authorization (COA) from the US Federal Aviation Authority (FAA) in the past year that certify the AggieAir platform is airworthy and authorize its use subject to FAA rules. A license was signed between USU and a private company in Utah to manufacture the aircraft, and negotiations are now underway to create a spinoff company that will market AggieAir equipment and services. New payloads are in development that will include a wider array of sensors, and a new airframe is being designed that will provide much better capability in the field.

Work Plan FY14/FY15

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), and complete the development and deployment of new aircraft and payloads.



Daily evapotranspiration rates developed from AggieAir imagery, near Scipio, Utah

Informational Resources

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

Water Resources Modeling for Utah's Cache Valley

Principal Investigators:
David E. Rosenberg
Leah Meeks (student)

Partners/Collaborators:
Local: *Bob Fotheringham, Cache County*
State: *Gertrudys Adkins, Will Atkins, Utah Division of Water Rights; David Cole, Utah Division of Water Resources*
Business/Industry: *Joan Degiorgio, The Nature Conservancy*

Project Description:

- **Need and Purpose:**

  Water resources management is becoming more important as water demands increase and water supplies decrease. As a semi-arid state, Utah has a growing need for improved water management. Various state and federal agencies and others have modeled certain hydrologic and legal aspects for specific geographic regions in Utah. For example, the Utah Division of Water Rights is currently using MODSIM for the Green River and ArcView GIS to generate maps of some of the State's water resources. Cache Valley is a unique area because it has many of the water ailments that are becoming more prominent in Utah and the western United States: drought, flooding, water quality, full water allotment, increasing demand, and transitioning agricultural to urban land uses. Managers require systems modeling tools to integrate the hydrologic, legal, and management aspects of the water system to inform management.

- **Benefits to the State:**

  Because of its unique geographic and demographic location, Cache Valley is on the forefront of many water resources issues that are currently affecting many locations throughout Utah. Network analysis tools can identify promising water system locations to source water for agricultural to urban water transfers, build or remove dams, protect ecosystem services, implement conservation measures, or diversify water supplies. Additional tools can also help automate the tedious process to query thousands, tens-of-thousands, or millions of individual water rights records for a river basin and aggregate them for use in a systems model. Once represented, the model can study the impacts on existing water users of large-scale system changes like agricultural to urban water transfers, climate change, dam removals, and other system management. These tools will help Utah's water resource agencies make better and more informed planning decisions and recommendations.

- **Geographic Areas:**

  Study Areas: Lower Bear River, Cache, and Box Elder Counties, Utah.

  Areas Benefited: Municipal water providers and landowners statewide in all counties.

- **Accomplishments:**

  Findings:

  - Extended the prior Ranking Automation for NetworKs (RANK) tool to include unidirectional flows in a network.

- Within the lower Bear River water system, updated results show that the Cache Irrigation and Urban service areas as well as the South Cache Irrigation and Urban services areas are highly redundant. The Cache and South Cache Irrigation service areas are also very stable. Removing or altering these agricultural service areas would affect other locations very little. These agricultural service areas are promising candidates for agricultural to urban water transfers.

- Water flows to the Weber Basin, Wasatch Front, and Idaho service areas are heavily affected by other locations in the water system. Thus, these sites are promising areas to implement conservation actions and/ or diversify water supplies.

- Most junctions along the mainstem of the Bear River are topologically significant. Removing or altering these sites would affect many other locations in the system. Thus, these junctions are promising locations to protect environmental and ecosystem services.

Results:

- Revised the article on the RANK tool in response to peer reviewer comments from the *ASCE-Journal of Water Resources Planning and Management*.

- Presented the RANK tool at the conference: GIS and Water Resources VIII: Data to Decisions, American Water Resources Association 2014 Spring Specialty Conference, Snowbird, Utah: May 14, 2014.

- Published code for the RANK tool and examples at https:/ / github.com/ lmeeks/ RANK.

Work Plan FY14/FY15

- Develop the workflow to automate the querying of water rights data from the state's database and aggregating of queried data to include in a systems model.

- Study the effects of different methods to aggregate water rights data including at different spatial scales.

- Meet with collaborators to discuss results for the different aggregation approaches.

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.
Code for the RANK Tool: https:/ / github.com/ lmeeks/ RANK.

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Research Faculty, Professional, and Support Staff

Utah Water Research Laboratory and Utah Center for Water Resources Research

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R. Ivonne Harris, MS, Publications Specialist
Austin Jensen, PhD, Research Engineer
Richard Jex, Research Assistant
Amber Jones , MS, Research Engineer
Monahad A. Khodier, PhD, Post-Doctoral Associate
Andrew Lee, Research Engineer
Babur Mirza, PhD, Post-Doctoral Associate
Tamara Peterson, BS, Business Manager
Stephanie Reeder, BS, Programmer/Analyst
Thomas N. Reuben, PhD, Post-Doctoral Associate
Carri Richards, BS, Public Relations Specialist
Zac Sharp, MS, Research Engineer
Joe Stewart, MS, Research Engineer I
Shannon Syrstad, MS, Research Engineer
Chad Taylor, Engineering Technician II
Andres Ticlavilca, PhD, Research Engineer
Alfonso Torres, PhD, Research Engineer
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
NeCole Walton, BS, Accountant
Mindy Whiteley, BS, Staff Assistant/Receptionist
Mark Winkelaar, MS, Research Engineer

Adjunct Appointments and Emeriti Faculty

Lloyd Austin, MS, Adjunct Professor, CEE/UWRL/Utah Department of Natural Resources
Jay M. Bagley, PhD, Professor Emeritus, CEE/UWRL
Duane G. Chadwick, MS, Professor Emeritus, EE/UWRL
Daniel H. Hoggan, PhD, Professor Emeritus, CEE/UWRL
Trevor C. Hughes, PhD, Professor Emeritus, CEE/UWRL
Eugene K. Israelsen, MS, Senior Research Engineer Emeritus, UWRL
Roland W. Jeppson, PhD, Professor, CEE/UWRL
Upmanu Lall, PhD, Adjunct Professor, UWRL/CEE/Columbia University
Eva C. Nieminski, PhD, Adjunct Associate Professor, CEE/UWRL/Utah Department of Environmental Quality
J. Paul Riley, PhD, Professor Emeritus, CEE/UWRL
Norman E. Stauffer, PhD, Adjunct Professor, CEE/Utah Department of Natural Resources
J. Paul Tullis, PhD, Professor Emeritus, USU Foundation, CEE/UWRL