MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2015

for

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

by

Mac McKee, Director

Utah Water Research Laboratory
Utah State University
Logan, UT 84322-8200

February 2016

Foreword

The year 2015 marks the 50th anniversary of the dedication of the Utah Water Research Laboratory (UWRL) building on December 6-7, 1965 by Governor George Dewey Clyde along with USU officials and Utah State dignitaries. Today, the UWRL continues its work as one of the oldest and most respected University-based facilities, performing cutting edge research and providing practical solutions to the most pressing water problems facing Utah, and indeed our Nation and the world. While, our goals and mission remain the same, the water resource related problems addressed by UWRL have grown both in scope and complexity. In response, the programs, facilities, and faculty expertise have continued to evolve over the last 50 years in order to assure that the UWRL is able to help meet these challenges. Today, with a cutting-edge research facility and world-class faculty, we look forward to building on the inspiring work of our water engineers and experts, past and present, as we look to the future.

The UWRL receives 2¼% of deposits made to the Mineral Lease (ML) Account, "to be used for activities… having as a purpose the development and exploitation of water resources in the State of Utah." In compliance with House Bill 103 passed during the 1993 Legislature General Session, this report provides a brief description of the UWRL's 241 active research, training and service projects this past fiscal year, along with an accounting of the ML funds for FY 2015, budgeted expenditures for FY 2016, and planned expenditures for 2017.

The UWRL project reports are organized into broad areas of activity that address a spectrum of high-priority water resources needs and issues in the state. Each project includes a statement of the project purpose, the specific benefits to the citizens of Utah, and areas benefited. The UWRL also leverages the results and expands the benefits of these projects through collaboration and partnership with local, state, and federal agencies. This past FY we have worked with most all of Utah's water related agencies and organizations, as well as undertaking some $4 million in project funding from other sources, thus providing additional opportunities for research solutions to State water issues as well as substantial economic benefits.

The "Introduction" to our report provides a general overview of the role and history of the UWRL. This is followed by description of UWRL's activities, organized into research areas, with a summary report for each specific project and its contribution to addressing a high-priority water resources problem or issue in the state. The report for each project includes a statement of the need and purpose, the specific benefits to the citizens of Utah, and areas benefited. Also noted are the local, state, and federal agencies and other organizations participating in the project research and potential applications.

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. As we continue to build on 50 years of accomplishments and look to the future, the UWRL is pleased to submit this year's report the Legislature through the Office of the Legislative Fiscal Analyst, and to the Community and Economic Development Appropriation Subcommittee of the Legislature, which reviews this report as part of its normal budgetary process.

The UWRL welcomes any comments or questions that result from these reviews.

Mac McKee
UWRL Director

Table of Contents

Table of Contents

INTRODUCTION

ADMINISTRATION

PROJECT SUMMARIES

Drinking Water and Wastewater Treatment

Table of Contents

Table of Contents

Table of Contents

Introduction

History of the Utah Water Research Laboratory

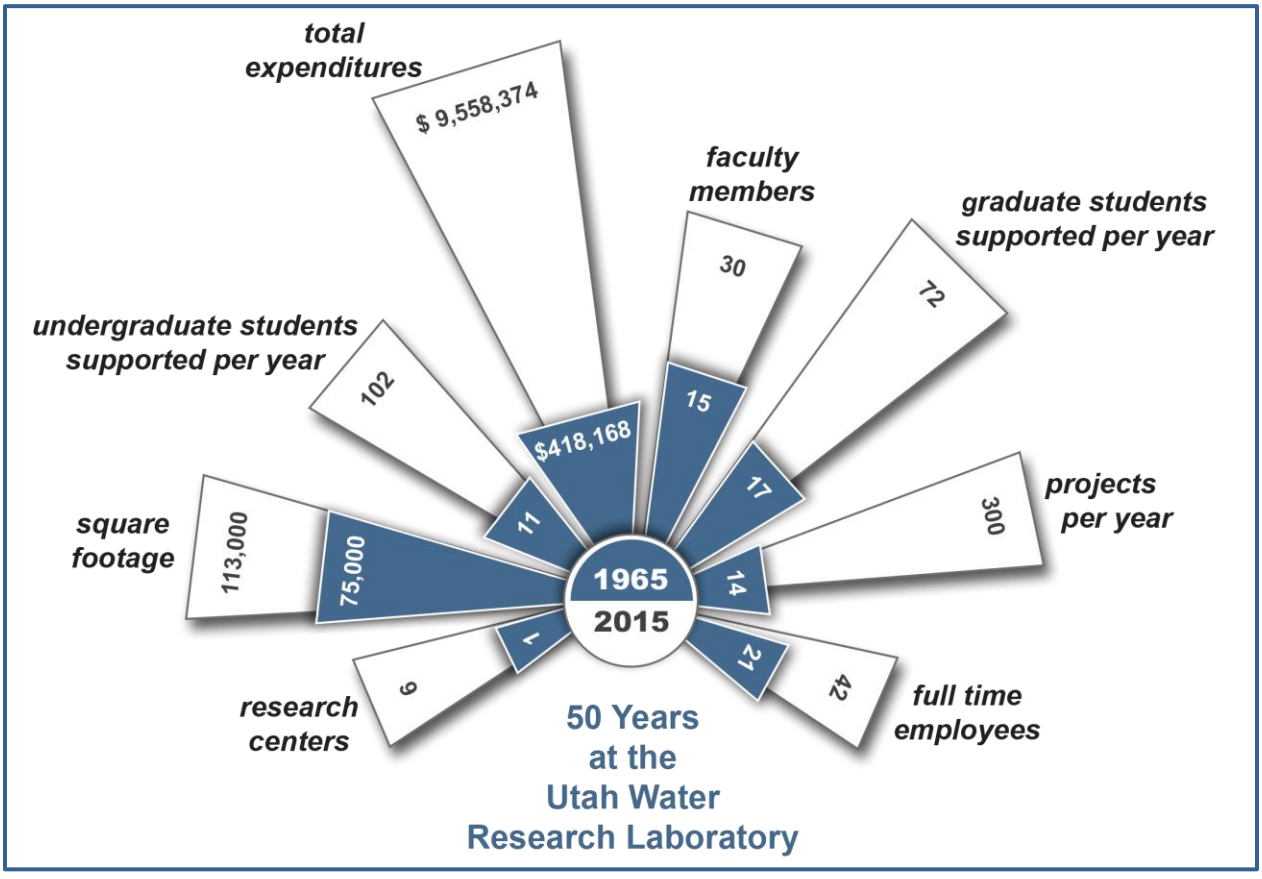
The year 2015 marks the 50th anniversary of the Utah Water Research Laboratory building dedication. The Utah legislature authorized the establishment of the UWRL at Utah State University in 1959 as an important component of the State of Utah's commitment to water resources research, assuring cutting-edge solutions to the State's water problems. In 1963, the ground was broken for construction of the Laboratory building, and in December 1965 Governor George Dewey Clyde, USU Officials, and Utah state dignitaries dedicated the building. Today, the UWRL continues as one of the oldest and most respected University based facilities performing for researching and providing practical solutions to the most pressing problems facing Utah, and indeed our Nation and the world.

Water is often referred to as the lifeblood of Utah. As we look to the future, it is important to recall how important water resources have always been to the prosperity and quality of life of Utah's citizens. This was evident in the vision of our State leaders when USU was established as the State's Land Grant University in 1888. Water and particularly irrigation science and the engineering of water works were of foremost importance as curricular and research components. John A. Widtsoe joined USU's faculty in 1896 and began his research on soils under irrigation. As President of USU in 1907, he convinced the Legislature that water was the key to Utah agriculture and received approval for USU to teach the engineering principles that related to water and irrigation. Students were enrolled, and in 1911, L.M. Winsor received USU's first Irrigation Engineering degree. In 1914, Widtsoe published his treatise "The Principles of Irrigation Practice," the first book to address the scientific and engineering principles involved in design and operation of irrigation systems. The book established USU as the national and world leader in irrigation and agricultural water management. With a growing need for courses, Widtsoe hired Ray B. West in 1912 to direct Agricultural Engineering, and O.W. Israelsen in 1914 to teach and research irrigation and drainage engineering. Israelsen published "Irrigation Principles and Practices" in 1935, which quickly became the worldwide standard textbook for teaching irrigation engineering. One of Israelsen's many students was George Dewey Clyde, who earned his engineering degree in 1921 and his MS from Berkeley and then joined the USU Faculty in 1923. Working in the Engineering Experiment Station, Clyde developed the snow survey as a basis for forecasting the spring runoff, the main source of water for virtually all of Utah's municipal, industrial, and agricultural needs. In 1936, Clyde became Dean of Engineering, serving until 1945 when he accepted a position with the U.S. Soil Conservation Service. As an expert on water, he became director of the Utah Water and Power Board in 1953 and helped to initiate the Flaming Gorge and Glen Canyon dams. In 1957 Clyde was elected the 10th Governor of Utah, serving two terms until 1965, during which time he continued to support research on best practices for using and protecting Utah's precious water resources, including breaking ground for construction of the Utah Water Research Laboratory in 1963.

Over this same period, from the mid-1940s through the early 1970s, Dean Clyde's successors, Gerald Christensen and Dean F. Peterson, continued to build on USU's reputation as the world leader in water engineering as many students from across the nation and around the world came to study on the USU campus. In addition, water engineering and agriculture faculty were serving as specialists on assignments for U.S Foreign Offices in Iran, Egypt, Dominican Republic, Bolivia and throughout Latin America, and ultimately, over the years, extending to almost every country the Middle East, Asia, Africa, Central and South America, and the Caribbean. 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.

As an acknowledged world leader in water engineering, the opening of the new Utah Water Research Laboratory building in 1965 provided the State and USU with world class research capabilities and a facility to support the work of faculty, students, and water professionals from across the state and around the world. The Laboratory's facilities include one of the best hydraulics laboratories in the United States and a unique erosion testing facility with a large rainfall simulator. In 1981, an extensive remodeling project added an environmental quality laboratory wing with facilities and equipment for testing and research. More recently, 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. Today, the UWRL has a total of more than 113,000 square feet of state-of-the-art laboratory, computer, and office space.

The continued growth and productivity of the UWRL, and its state, national and worldwide impact over the last 50 years is clearly seen below:



The table below summarizes the current high-level productivity of the Lab in terms of research, education, outreach and training. The total research funding through the UWRL in FY 2015 of nearly $10 million makes it one of the largest institutes in the nation.

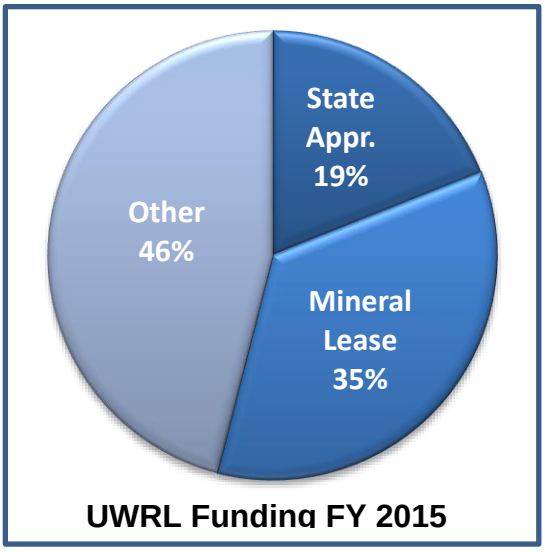
UWRL Financial/Academic Summary (FY 2015)

Number of Active Projects	241
Dollar Value of Active Projects	$9,425,250
Scholarly Publications in Peer-Reviewed Journals	100
Scholarly Presentations at Professional Conferences	202
Outreach Products (FY 15)	
Short Courses and Field Training	19
Degrees Granted	
PhD	12
MS	23
ME	1

In order to leverage the expertise of the UWRL, our 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 many state, national and international engineering and science panels and committees.

Research Program Structure and Organization

Research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and most are also relevant to national and worldwide issues as well. 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 2015, MLF funding of over $3 million accounted for 35% 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 2015 were almost $ 10 million.



UWRL Funding FY 2015

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

- 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

The individual projects 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

Overall, the UWRL research, education, and training activities related to ML funding are very diverse, as is indicated by the project summaries in this report. However, the totality of UWRL's programs, taking into account 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 2015

Graduate Students Supported (FY 15)	52
Undergraduate Students Supported (FY 15)	111

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.

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 ML funds, directly benefit the State of Utah in areas of (1) 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; (2) 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 expensive approaches; (3) investigating groundwater/surface water interactions, quantified as net gains and losses, to determine spatial trends in flow over time in three high mountain streams in northern Utah in support of iUTAH efforts to interpret the biochemical properties in those watersheds and understand the implications of climate change on hydrology within Utah; and (4) identifying key opportunities and challenges faced by irrigation companies as they adapt to changes in land use and urban pressure and helping them understand and adapt to changes associated with the urbanization of an irrigated agricultural landscape. 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 and develop other source water protection strategies, tools, and programs across the State of Utah.

Relevancy and Benefits of the Mineral Lease Fund

As the second driest state in the union, the LIFE BLOOD of Utah's economy and quality of life is WATER. Our average precipitation of only 13 inches of water a year, mostly in the form of winter snowfall, must meet the State's economic, social, and environmental water needs throughout hot, dry summer periods. As has often been emphasized by our state leaders throughout the decades, water is indeed the essential resource needed to sustain Utah's quality of life and economic vitality. The State's investment in its water resources through the ML Fund is critically important to finding the best technologies and methods to protect, manage, and wisely use our precious water for the benefit of all Utah's citizens.

Research Program Planning and Project Selection

Hence, the goal of the UWRL research programs is to identify and develop projects that will help to 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 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.

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)

In addition, the Utah Center for Water Resources Research (UCWRR) at the UWRL participates as an active member of the National Institutes for Water Resources (NIWR). UWRL faculty members are also active in state sections of professional organizations, and serve 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 and provides opportunities to learn from other research and best practices worldwide. In return, this helps us to identify current and future research needs that will affect our state, and further strengthens the UWRL research identification process to assure the relevancy of our projects to Utah.

Mineral Lease Fund Expenditures

The table below summarizes the actual, budgeted, and planned expenditures of ML Funds allocated to the UWRL for FY 2015 through FY 2017 for research projects in the six major **Program Areas.** UWRL administration and technology transfer expenditures account for approximately 11% of total MLF budgeted and planned expenditures.

Mineral Lease Fund Expenditures			
Research Program Area	**Actual FY2015**	**Budgeted FY2016**	**Planned FY2017**
Drinking Water and Wastewater Treatment	$405,939.98	$710,328.40	$94,714.69
Environmental Quality Management and Remediation	$583,384.48	$814,803.36	$517,880.09
Surface and Groundwater Quality and Quantity	$407,500.48	$859,327.40	$233,970.20
Water Conveyance, Distribution, and Control	$103,524.84	$137,130.58	$30,783.70
Water Education and Technology Transfer	$51,800.46	$56,553.24	$58,024.83
Water Resources Planning and Management	$1,312,097.91	$2,068,935.32	$397,798.51

A detailed breakdown of the expenditures for each project within these **Research Program Areas** can be found in the **Research Project Summaries** section of this report.

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. Every one of Utah's counties have benefited from among the 241 UWRL projects conducted during the past year.

The following paragraphs summarize some of the recent and current benefits produced by MLF funded projects. The specific state benefits of each project are detailed by Program Area in the Project Summaries section 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 wastewater for recycling and reuse of municipal and industrial wastewater, as well as evaluating the effectiveness of various seepage 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.

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.

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.

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 Dept.'s Air Task Force

In addition, UWRL personnel are frequently invited to provide technical and informational presentations 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 both 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. Additional information can be found at:

http://uwrl.usu.edu/partnerships/training/. Undergraduate and graduate students also participate in projects that involve hands-on, real-world activities.

UWRL: Solving Today's Water Problems by Looking to the Future

Our planet is clearly experiencing staggering water problems in the form of increased climatic variability; an expanding population with growing demands for water, food, and energy; and the need to protect valuable environmental resources. The uncertainty about our water availability and quality in the face of these pressures underscores the need for forward thinking research that results in practical solutions. Through its support of UWRL, Utah is investing both in the creation of new knowledge and in the next generation of water engineers and experts that are critical to dealing with these water challenges today and the future. As the UWRL celebrates 50 years of service to Utah, we are proud to acknowledge all the dedicated people, past and present, who have contributed to the Lab's achievements and its world-class reputation for water research and education.

Administration

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

Project Name	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Business Office	$ 168,449.54	$ 173,503.03	$ 178,708.12
Laboratory Infrastructure Support, Travel and Special Request	$ 104,658.84	$ 107,798.61	$ 111,032.56
Publications Office	$ 87,171.72	$ 89,786.87	$ 92,480.48
UWRL Administration	$ 91,249.71	$ 93,987.20	$ 96,806.82
Total	**$ 451,529.81**	**$ 465,075.71**	**$ 479,027.98**

Administration, Advisory Support, and Special Equipment

The Administrative Officers of the UWRL are responsible for managing the facilities and budget of the Lab, and overseeing the diverse projects conducted by faculty and their students. 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 ML 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. ML 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 2015 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 2015 on these support activities accounted for 2% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2015 for advice and collaborative help on various water problems in the state. The UWRL provided support from MLF sources to defray travel costs 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 and 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	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Biofiltration of Utah Municipal Drinking Water	$ 20,202.51	$ 20,808.59	$ -
Biological Phosphorus Removal from Lagoon Wastewater: Pilot-Scale Rotating Algae Biofilm Bioreactor (RABR)	$ 95,659.98	$ -	$ -
Effectiveness of Utah's On-Site System Design: Depth Considerations and Removal of Emerging Contaminants of Concern	$ 22,050.15	$ 22,711.65	$ 23,393.00
Enhancing Methane Production at Water Reclamation Facilities	$ 76,418.84	$ 78,711.41	$ -
Low Level Hexavalent Chromium (Cr-6) in Drinking Water	$ 41,022.28	$ 42,252.95	$ -
Managing Drinking Water Quality in Park City, Utah	$ 67,499.30	$ 69,524.28	$ -
Mitigation of Methane Emissions from septic Systems	$ 20,462.90	$ 21,076.79	$ -
Solar Disinfection of Drinking Water by Point-of-Use Inactivation of Intestinal Pathogens	$ 34,778.46	$ 35,821.80	$ -
Treatment of Wastewater Algae for Bioenergy	$ 25,225.89	$ 25,982.67	$ -
Wastewater Operator Certification Council	$ 2,619.67	$ 2,698.26	$ -
Designated Projects		$ 227,740.00	$ 13,321.69
Undesignated research projects in program area		$ 163,000.00	$ 58,000.00
Total	**$ 405,939.98**	**$ 710,328.40**	**$ 94,714.69**

Biofiltration of Utah Municipal Drinking Water

Principal Investigators:
David K. Stevens
Darwin L. Sorensen

Partners/Collaborators:
- ***State:*** *Eva Nieminski, DDW*
- ***Business/Industry:*** *David Pitcher, Monica Hoyt, Joe Crawford, Mike Rau (CUWCD)*

Project Description

- **Need and Purpose:**

  Biofiltration of drinking water supplies is a promising method to reduce the potential for unwanted disinfection byproducts and to minimize the regrowth of microorganisms in water distribution systems. Because of the site-specific implementation of this technology, the proposed project will study, at pilot scale, the potential for using biofiltration to reduce and modify the organic matter content of drinking water at two Utah water utilities and develop preliminary information pertaining to the design and operation of such utilities.

  The primary objective of the proposed project is the assessment and optimization of biofiltration in selected Utah Drinking Water Treatment plants at pilot scale. The research will seek to answer the following questions: (1) is biofiltration an effective way to reduce organic matter from Utah source waters (2) can biofiltration be used to reduce disinfection by product production potential, and (3) can ATP measurements be correlated with the more definitive measure of biofiltration performance, CBXA, as a surrogate measure of biological activity and organic compound treatment efficiency?

  A series of designed experiments will be carried out at two Utah water treatment plants to examine the questions outlined above. The plants will be chosen in consultation with project partners from the Utah Division of Drinking Water, and the Utah Water Quality Alliance: operators of larger water treatment facilities in Utah. Pilot-scale biofilters will be designed and fabricated for each plant in triplicate, then operation and data collection at the plants will be carried out over the next six months. Influent, intermediate, and effluent water triplicate samples will be collected weekly during this period and assayed for general water chemistry, heterotrophic plate count (HPC), dissolved and total organic carbon, UV254, ATP, nutrients (N and P), and other measures. Regular weekly samples of the biofiltration media will be collected during the study to assess the development of the biological consortia through microbiological analyses.

- **Benefits to the State:**

  Biofiltration is long overdue as a method of water treatment in Utah. This project will help fill the knowledge gap currently make water utilities reluctant to promote its use.

- **Geographic Areas:**

  Study Area: Duchesne, UT.

  Areas Benefited: Statewide.

- **Accomplishments**:

  Findings/Results: Monitoring began in April 2015 with startup of the Duchesne water treatment plant pilot system. Samples are collected by CUWCD and USU personnel for on-site analysis and delivery to the State lab in Salt Lake County. These samples are assayed for a variety of chemical constituents.

  Results: Results are pending completion of monitoring data collection.

Work Plan FY15-FY16

During the period from July 1 to February 29 (end of USGS funding), we will continue data collection and database construction, and begin data analysis. MLF funding will continue to support data analysis. We will also seek additional sources of funding to continue the project for at least an additional year.

Informational Resources

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

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

Principle Investigators:
Ronald C. Sims
Charles Miller
Yousef Soboh (PhD student)
Maureen Kesaano (PhD student)
Jason Peterson (MS student)
Chad Nielson (BS student)

Partners/Collaborators:
Local: *Mr. Issa Hamud, Logan City Environmental Department*
Business/Industry: *WesTech, Inc. Engineering, Salt Lake City, Utah*

Project Description

- **Need and Purpose:**

  Logan City has recently been required to remove both phosphorus and nitrogen from wastewater in order to meet water quality criteria established by the State of Utah. To upgrade the current system, a biological-based technology, the Rotating Algae Biofilm Reactor (RABR), accomplishes both phosphorus and nitrogen removal utilizing the uptake of phosphorus and nitrogen by algae grown as a biofilm. This process treats the wastewater to higher quality and also utilize the biosolids produced to make valuable bioproducts. Collaborators on the project are Utah State University (UWRL), Logan City Environmental Department, and WesTech, Inc. Engineering in Salt Lake City.

- **Benefits to the State:**

  The RABR method for processing harvested algae will improve environmental protection through a wastewater treatment process that produces high-value bioproducts. The method provides a way to avoid landfill disposal of biosolids generated in wastewater treatment by fractionating the algae into several streams that can be used as a feedstock to make valuable bioproducts. The method developed is applicable to other wastewater systems in Utah that depend on lagoons or open ponds for treatment. The new algae processing method will allow the creation of new engineering jobs and services in Utah that will boost economic growth.

- **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 algae can be harvested and processed wet, thus avoiding the high energy cost of drying before processing. (2) The harvested algae can be fractionated into streams that are used to produce several products. One stream serves as feed to a digester to generate biogas to heat and power the treatment plant. A second stream is used to cultivate bacteria for the manufacture of

bioplastic materials that are biodegradable. A third stream has a high protein content and omega fatty acids that can serve as feed for aquaculture and animals.

Results: A method for processing the wet harvested algae was developed, tested, and found to be successful (Publication 1). Algae was successfully digested to make biogas in an Upflow Anaerobic Sludge Blanket Reactor (UASB) (Publication 2). Algae cell water was used to cultivate bacteria to manufacture bioplastic (Publication 3). A fourth stream, the protein stream, was tested for digestibility by dairy cows at the USU Caine Dairy and found to be highly digestible. These results demonstrated the success of the algae processing method for utilizing all fractions of the algae biomass to produce bioproducts of value and to avoid landfilling the biomass following treatment of the wastewater.

Work Plan FY15-FY16

Future research will further evaluate the method and the algae fractions for applications to other wastewater sources in Utah.

Informational Resources

Contact: Mr. Issa Hamud, Director, Logan City Environmental Dept., Phone (435) 716-9752, E-mail: issa.hamud@loganutah.org.
Mr. Rex Plaizier, President and CEO, WesTech, Inc. Engineering, Phone (801) 856-5323, rplaizier@westech-inc.com.

Publications from this project:

Sathish, A., T. Marlar, and R. Sims (2015). A wet microalgae extraction procedure for biofuel and bioproduct production. *Bioresource Technology*, 193:15-24.
Sathish. A., K. Glaittli, R.C. Sims, and C.D. (2014). Miller Algae biomass based media for PHB production by Escherichia coli. *Journal of Polymers and the Environment*, 22:272-277.
Tang, S.Y., K. Neal, J-S Eun, A.J. Young, and R.C. (2015). Sims.Ruminal fermentation characteristics of lactation dairy diets with different forage-to-concentrate ratios without or with lipid extracted algae in continuous culture. *Journal of Dairy Science*, 93:448-449.
Yousef Soboh (2015). Anaerobic co-digestion of algae biomass to produce methane. Dissertation in partial fulfillment for the Ph.D. degree in Biological Engineering, Utah State University, Logan, UT.

Figure 1. Logan City Wastewater Reclamation Plant. Rotating Algae Biofilm Reactor (RABR) for algae treatment of wastewater. Left to Right: students Alan Hodges, Jason Peterson, Dr. Matthew Carr, Director, Algae Biomass Organization, Washington, D.C., and student Chad Nielson

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*

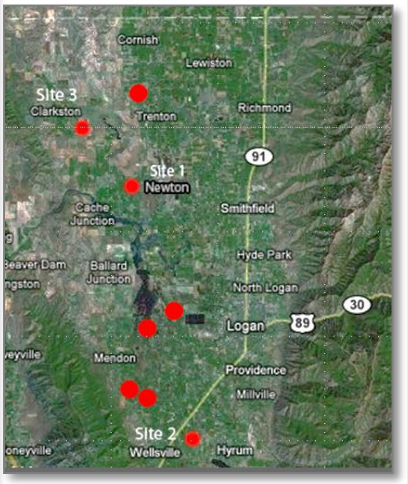
Project Description

- **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 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.

  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.

Deep trench system installation, Wellsville, November 2008

- **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 were 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 indicated 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 FY15/FY16

The project has been completed.

Informational Resources

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

Informational Resources:

Beardall, J. (2015). The Fate of Pharmaceuticals and Personal Care Products in Conventional and Engineered On-Site Wastewater Drain Fields. M.S. Thesis, 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 demand at local wastewater treatment plants, which increases the risk of regulatory noncompliance. Moreover, FOG has historically created a severe problem in Utah sewers by restricting flow and causing sanitary sewer overflows.

  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 new anaerobic digestion system at the Central Weber facility.

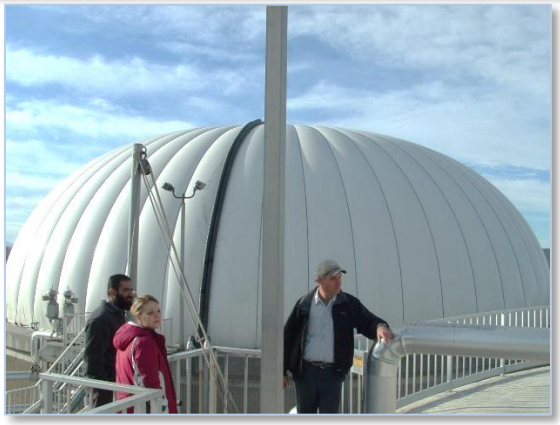


Figure 1. Anaerobic Digester at the Central Weber Water Reclamation Facility

- **Benefits to the State:**

  Successful results from this research activity will generate a number of benefits for the state of Utah including the following:

  - Open up new markets for food and other organic wastes.
  - Expand the generation and use of renewable energy.

- Reduce organic waste quantities through recycling activities.
- Develop new energy production for Utah water reclamation facilities.

- **Geographic Areas:**

  Study Area: Weber County, Utah.

  Areas Benefited: The entire State of Utah.

- **Accomplishments:**

  Findings/Results: Recent 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 reduce their need for external fossil fuels. The following publications present the findings and results from this research effort.

  Demitry, M., J. Zhong, C. Hansen, and M.J. McFarland (2015). Modifying the ADM1 Model to Predict the Operation of an Anaerobic Digester Co-digesting Municipal Sludge with Bakery Waste. Vol. 4(4):38-57.

  Demitry, M. and M.J. McFarland (2015). Defining full-scale Anaerobic Digestion Stability: The Case of Central Weber Sewer Improvement District. *Environment and Pollution,* 4(2):1-13.

Work Plan FY15-FY16

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 in the next phase of this project. The technical work for this fiscal year will focus on the following five tasks:

- Estimate the theoretical production of methane from the co-digestion of bakery wastes from CSM Inc.
- Increase the organic loading rate to determine what the upper limits to co-digestion might be.
- Determine if Central Weber Sewer Improvement District can reasonably achieve energy net neutrality using bakery wastes.
- 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.

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

Principal Investigators:
Laurie McNeill
Joan McLean
Nate Rogers (Graduate student)
Adam Jones (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 (Cr6) 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 Cr6, 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 (Cr3, a trace nutrient) and hexavalent chromium (Cr6, 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 Cr6, and may establish a new MCL specifically for Cr6. A new federal MCL for Cr6 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 Cr6 at 10 ppb.

  In order for drinking water utilities to understand the chromium chemistry within their water and comply with a Cr6 MCL, they must be able to measure Cr6 at those low levels. A second issue is that with these very low levels of Cr6 being of concern, any Cr6 that leaches from water plant infrastructure or is added as a trace contaminant within treatment chemicals may now produce a significant level of contamination, causing utilities to potentially exceed the MCL, even if there is no Cr6 contamination in their source water. Any Cr3 present can also be oxidized to Cr6 by chemical disinfectants present in water distribution systems.

- **Benefits to the State:**

  If USEPA sets an MCL for Cr6, every public water system in Utah must comply. This project has provided a thorough evaluation of preservation and analysis techniques for Cr6, and various UT treatment plants will be sampled to determine the sources of chromium to drinking water and possible treatment techniques for removing Cr6. This will help water utilities understand sources and behavior of Cr6 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 investigated the oxidation of harmless Cr3 into the potentially-carcinogenic Cr6 by two commonly used treatment chemicals: monochloramine (Figure 1) and free chlorine (Figure 2). Results indicate that monochloramine is not strong enough to oxidize Cr3 to Cr6, but free chlorine can create significant amounts of Cr6.

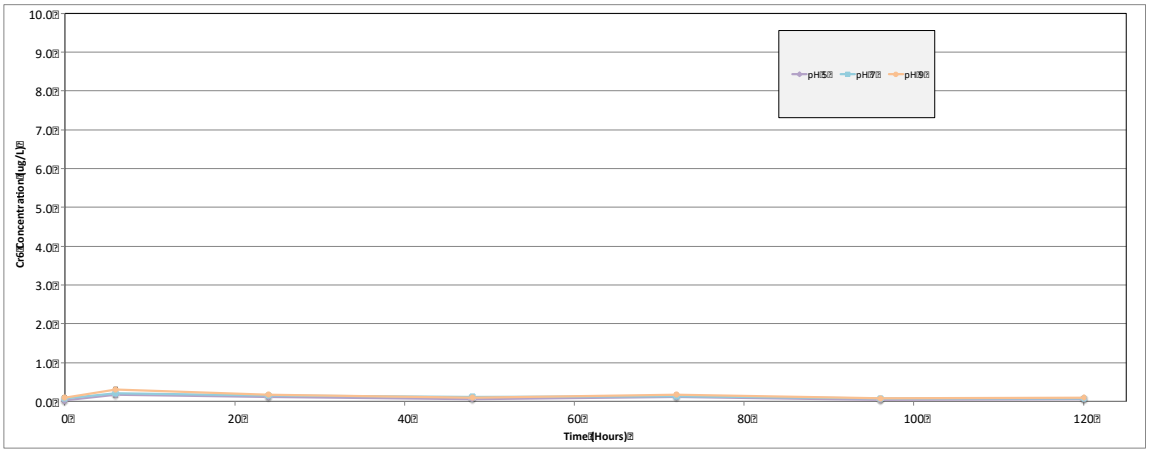


Figure 1. Effect of 4 mg/L monochloramine. Initial conditions: Cr3 = 10 ppb, temperature = 5C. Essentially no oxidation to Cr6 is observed at any pH

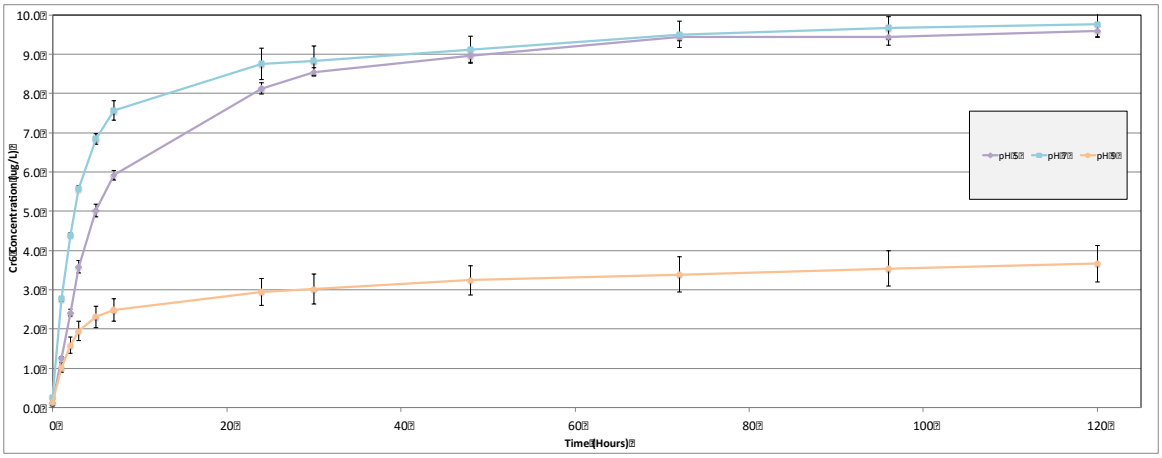


Figure 2. Effect of 4 mg/L free chlorine. Initial conditions: Cr3 = 10 ppb, temperature = 5C. Significant Cr6 is formed, especially at pH 5 and 7. Error bars represent standard deviation of triplicate experiments

Work Plan FY 15-FY16

Collect additional samples from water treatment plants across UT to look at sources and treatment of Cr6, with a focus on systems that use different oxidants (monochloramine vs. free chlorine).

Informational Resources

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

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

Managing Drinking Water Quality in Park City, Utah

Principal Investigators:
Laurie McNeill, Joan McLean, David Stevens
William Kent, Tiana Hammer (graduate 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. Park City's current data management practices will also be assessed.
  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: Data from routine monthly monitoring at 14 different sites within the Park City water distribution system were integrated into a UWRL-developed database for easy access and analysis by the utility and project team (Figure 1). One known cause of variability during the year-long monitoring period was the Judge Tunnel source, which is the principal source serving the Old Town zone (sites OTT, OTA, DLP) and sometimes serves the Thaynes zone (sites MPB, ICP, WKC, THC). Judge Tunnel was taken offline on May 20, 2014 then put back in service in June 18th and finally taken permanently offline (until treatment can be installed) on July 16th. It is the only source with significant suspended arsenic (6.6 to 8.1 ug/L), and its influence on the monitoring sites is clearly shown in the time series data, especially at the OTT and DLP sites.

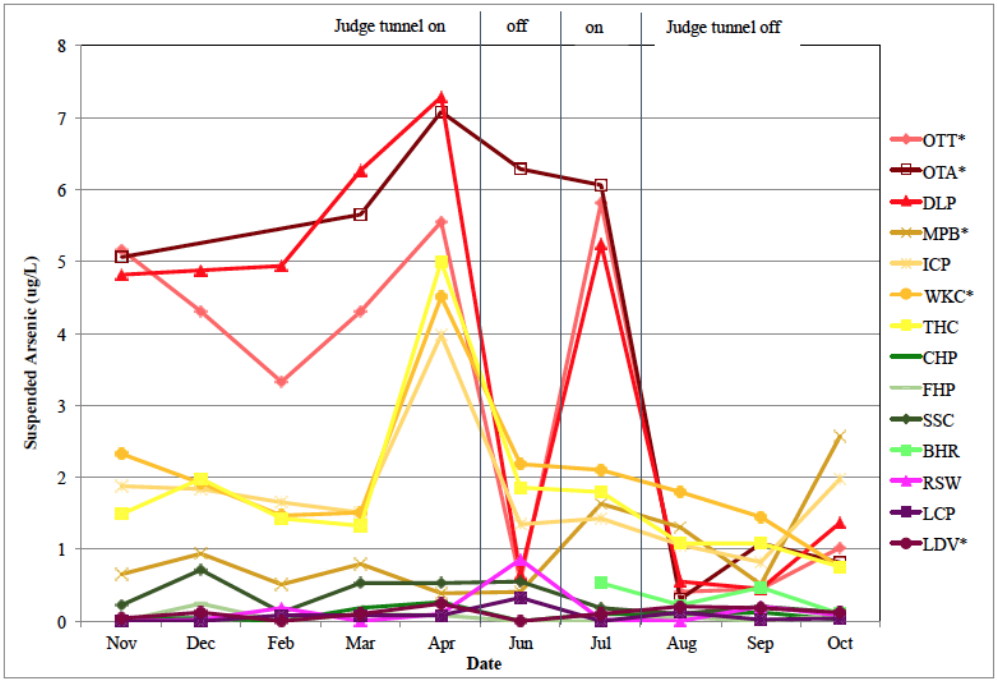


Figure 1. Time series data for suspended arsenic. Sites with an * are premise plumbing locations

Work Plan FY 15/FY16

Conduct additional lab experiments to investigate the role of sorption/desorption on release of metals from distribution solids.

Informational Resources

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

Publications: Results from this project were presented in one conference presentation and will be the focus of an entire special session at a forthcoming conference in Salt Lake City (WQTC, Nov 2015). A research report was completed for the Water Research Foundation Results will also be published in multiple peer-reviewed journal articles.

Mitigation of Methane Emissions from Septic Systems

Principal Investigators:
Judith L. Sims
Charles Miller
Ronald C. Sims
Alan Hodges (Student)
Celeste Hancock (Student)
Jason Peterson (Student)

Partners/Collaborators:

- *None*

Project Description

- **Need and Purpose:**

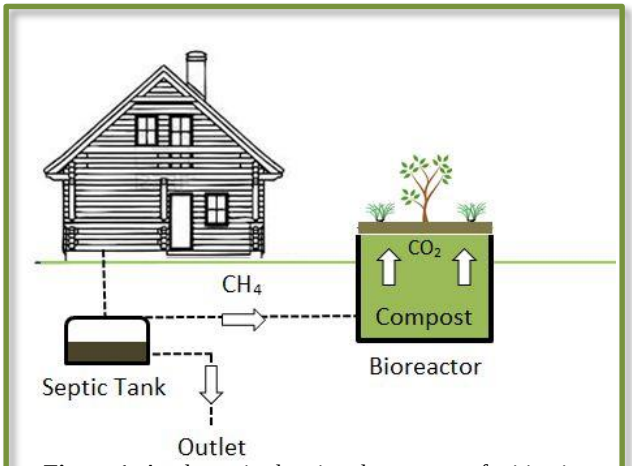


Figure 1. A schematic showing the process of mitigating methane at a local residence

Concerns with climate change have led to efforts to reduce greenhouse gas emissions (GHGs). Methane has been identified as a GHG that is over twenty times more effective at trapping heat in the atmosphere than carbon dioxide. Using assumptions developed by the Intergovernmental Panel on Climate Change (IPCC), the U.S. Environmental Protection Agency GHG inventory (2009) estimated that 76 percent of wastewater sector methane emissions in the United States are from onsite (septic) systems. This is due to the large number of individual septic systems in use and the anaerobic conditions present in septic tanks.

In addition, methane contributes to the formation of NH_4NO_3, which is a major component of particulate matter less than 2.5 microns ($PM_{2.5}$). $PM_{2.5}$ is an important air contaminant that contributes to the poor air quality that occurs in Cache Valley and in other areas of Utah during winter inversions.

A project funded by the Water Environment Research Foundation (*Evaluation of Greenhouse Gas Emissions from Septic Systems*, 2010) concluded that study is needed to develop technologies for the control of GHG emissions from on-site wastewater systems. In this project we are investigating the potential effectiveness of mitigating the impacts of methane produced in septic tanks by collecting the methane and treating it in a compost biofilter system where the methane can be converted to carbon dioxide, which can then be used by plants growing on the compost [Figure 1].

- **Benefits to the State:**

Figure 2: Bench Scale System

The project will provide direct benefit to the State of Utah, especially the Cache Valley area, by targeting an environmental source of methane for reduction. This can potentially reduce the amount of methane that is a precursor for the formation of $PM_{2.5}$, as well as GHG.

- **Geographic Areas:**

Study Area: Cache County.

Areas Benefited: Areas of Utah where air quality problems exist and septic systems are commonly used for on-site wastewater treatment.

- **Accomplishments:**

Findings: During FY14/FY5, we focused on construction of a bench scale compost biofilter system, as well as an initial evaluation of a site for a field scale installation of a full-scale compost biofilter system. The two systems will be used to examine the effectiveness of a compost biofilter for methane mitigation. The 10L bench scale system will be used to examine biofiltration of methane under varying temperature conditions and moisture levels using compost from the Logan Landfill [Figure 2]. The field-scale system will be a scaled-up compost biofilter [Figure 3] at a septic tank site in Benson, UT [Figure 4].

Results: The bench scale compost biofilter was constructed and began operation. We designed and obtained several DNA primer sequences to be used as genetic probes for methanotroph detection and analysis. We also developed an isothermal gas chromatography method to measure methane. An isothermal method allows for quick analysis of many samples by bypassing a lengthy oven cooling process. Additionally, progress was made toward development of a gas sampling apparatus to sample gas at the field-scale site.

Work Plan FY15/FY16

Influent and effluent gas samples will be monitored using the bench scale apparatus. The data will be used to compare the operation of the biofilters under varying temperature and moisture conditions and to establish a mathematical model for operation of future compost biofilters. The methanotrophic bacteria in the compost substrate will quantified throughout the lifecycle via cellular probing techniques. Using polymerase chain reaction (PCR) with these genetic probes and general probes for all bacteria, we will assess the changes in microbial diversity of the biofilters over time and under the various treatment conditions. The bench scale reactors will also be used to examine how inoculation of various species of previously characterized methanotrophs can affect the mitigation of methane in the compost biofilter.

Future work on the field scale system will include construction and installation of the compost biofilter connected to the full-scale septic tank. The system will include a 350 L compost biofilter, a venting/gas collection system, and a continuous monitoring system for ambient and compost temperature and compost moisture content. Parameters will be correlated with methane removal efficiency. We will also assess methane production within the septic tank using the Biochemical Methane Potential (BMP) Test.

Informational Resources

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

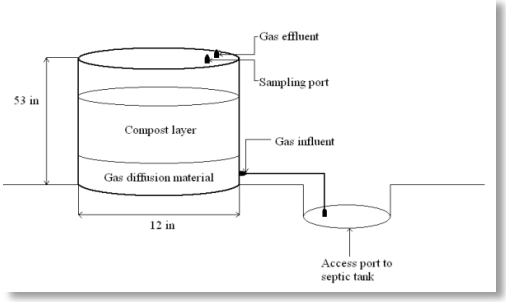


Figure 3. Field Scale System

Figure 4. Field Scale Site in Benson, UT

Solar Disinfection of Drinking Water by Point-of-Use Inactivation of Intestinal Pathogens

Principal Investigators:
David K. Stevens
Darwin L. Sorensen
Maryana Azmi (Student)

Partners/Collaborators:
- *None*

Project Description

- **Need and Purpose:**

  This study is to further the development of simple, point-of-use methods using solar disinfection to decontaminate household drinking water sources. The purpose is to develop and assess low cost methods of water disinfection for use in low income urban households without access to treated drinking water and for emergency situations in which municipal water treatment systems have been compromised (e.g. in Trenton, UT in 2014 where water supply springs were found to be in direct contact with surface water contaminated by harmful bacteria). One large scale example of the need for this technology is the approximately 2 million or so persons using untreated water from the Nile River near Khartoum, Sudan, for culinary purposes.

- **Benefits to the State:**

  Specific benefits to the State of Utah of the point-of-use disinfection process include:

  - Guidance for use of point-of-use emergency water treatment systems when municipal water systems are compromised, e.g., after an earthquake or other natural disaster.

  - Preliminary data collection for use of solar radiation, abundant in Utah, as a primary disinfectant alternative to chlorine, ozone, or mechanical ultraviolet disinfection systems.

  - Information concerning the effect of solar radiation on the disease-causing protozoans cryptosporidium parvum and giardia common in Utah water supplies.

- **Geographic Areas:**

  Study Area: This project will be carried out in Logan, UT, Cache County.

  Areas Benefited: Statewide.

- **Accomplishments**:

  Findings/Results: The following project elements have been completed: a review of the literature, development of procedures, and identification of specific organisms to be used for the assessment. Experiments will begin in FY 15-16.

Work Plan FY15/FY16

The major outcome of the project will be a modern database for managing information relating to the combined point-of-use filtration/solar disinfection system. Results will be integrated with previous studies. The final results of the project will be presented at the USU Spring Runoff conference and, potentially, at annual Intermountain AWWA or AWRA chapter conferences.

Informational Resources

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

Treatment of Wastewater Algae for Bioenergy

Principal Investigators:
Ronald C. Sims
Charles Miller
Yousef Soboh (PhD student)
Tyler Marlar (B.S. student)

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

Project Description

- **Need and Purpose:**

  Production of bioenergy from renewable wastewater resources is needed to replace non-sustainable petroleum-based chemicals. Wastewater cultivated algae represent a promising substrate for biofuel production. There are approximately 7,000 wastewater treatment lagoons and pond systems in the US, with many such systems in Utah serving rural and smaller communities. This project uses anaerobic treatment, specifically the Upflow Anaerobic Sludge Blanket (UASB) system, for the transformation of algae into bioenergy in the form of methane. Algae cultivated on municipal wastewater in the Logan City wastewater treatment lagoons were fed to a UASB system to produce methane, which can then be used as a local source of heat and power for the wastewater plant. The Logan City lagoon system for the cultivation of algae is shown in Figure 1.

- **Benefits to the State:**

  Alternative energy sources using wastewater in local treatment systems provide a path from waste-to-valuable biofuels and result in greater energy independence and a positive economic impacts for rural communities in Utah. Utilizing wastewater-derived algae biomass to produce biofuel also eliminates the need for disposal in landfills.

- **Geographic Areas:**

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

  Areas Benefited: All areas of the state of Utah, especially rural communities and cities where wastes will be utilized as sources of nutrients to grow algae, which will then be transformed into bioenergy for heat and power.

- **Accomplishments:**

  Findings: Bioenergy in the form of methane was successfully produced in UASB bioreactors at laboratory scale using algae that was cultivated in the city of Logan Lagoons system. A blend of algae and other waste materials rich in carbon content produced biogas with 80-90% methane content. The UASB system also removed 80% of the chemicals that deplete a receiving stream (river or lake) of oxygen. Figure 2 shows the 1,000 gallon pilot Upflow Anaerobic Sludge Blanket pilot bioreactor at the Logan City wastewater treatment plant.

Results: The results demonstrate that high value bioenergy can be produced using low value waste-grown algae. Blending algae with other carbon-rich wastes, for example cheese and other food wastes, is expected to increase the production of biomethane that can use be used as a local and renewable source of bioenergy for the heat and power requirements of a community.

Work Plan FY15/FY16

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 bioenergy production.

Informational Resources

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

Publications

Soboh, Y. (2015). Upflow Anaerobic Sludge Blanket Reactor Co-Digestion of Algae and Acetate to Produce Methane. Ph.D. Dissertation. Utah State University Biological Engineering Department, Utah State University, Logan, UT.

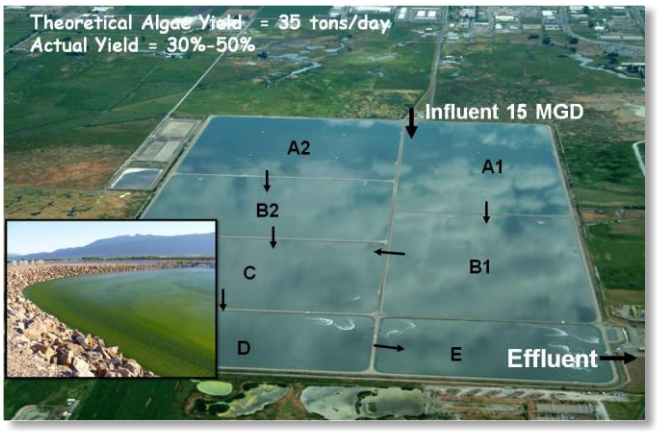


Figure 1. Logan City Lagoon system for the cultivation of algae resulting from the treatment of municipal wastewater

Figure 2. Upflow Anaerobic Sludge Blanket bioreactors for the production of biomethane from blending wastewater grown algae and carbon-rich wastes for production of heat and power

Wastewater Operator Certification Council

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 Wastewater Operator Certification Council (The Council) is to provide environmental stewardship, financial integrity, safety, and quality service to benefit the environment, residents, businesses, and employees of the State of Utah. The Council comprises representatives from various water reclamation facilities within the state of Utah as well as equipment vendors, university researchers, and environmental regulators.

- **Benefits to the State:**

  The Council is dedicated to the professional growth of its members and the preservation and enhancement of the water environment in the state of Utah. The Council specifically benefits the state by facilitating:

  1. Opportunities for interaction and professional growth of WOCC 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. A focus on diverse water quality issues within the State.

- **Geographic Areas:**

  Study Area: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled Council meetings throughout FY14/FY15 and provided review and comment on all items relevant to his area of expertise. The PI also proctored semi-annual certification exams.

Work Plan FY15/FY16

Continued involvement in decision-making through attendance at quarterly Council Meetings.
Continued proctoring of semi-annual wastewater operator certification exams.

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

Informational Resources

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

Environmental Quality Management and Remediation

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

Project Name	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Biogeochemistry in TCE Contaminated Aquifers in Northern Utah	$ 151,779.75	$ 44,362.28	$ 47,471.89
Cache Valley's Vertical Meteorological and Pollutant Profiles and Application to Additional Areas in Utah	$ 39,352.35	$ 15,150.00	$ 15,604.50
Comparison of Wintertime Indoor and Outdoor PM2.5, and Vehicle Cold Start and Hot Start Emissions	$ 51,179.73	$ 52,715.12	$ 54,296.58
Evaluation of Duckweed as a Technology for Management of Nutrients and Pharmaceutical Contaminants in Municipal Wastewater Systems	$ 51,463.22	$ 53,007.10	$ 54,597.33
Impact of Biochar Additions to Soil on Contaminant Mobility and Fate for Groundwater Protection	$ 32,603.59	$ 33,581.70	$ 34,589.15
Impact of Metals and Metal Ions on Soils and Plants	$ 41,612.91	$ 42,861.30	$ 44,147.14
Nitrogen Cycling, Oxygen Demand, and Nitrate Reduction to Ammonia in Silver Creek below the Water Reclamation Facility	$ 118,036.84	$ 121,577.95	$ 125,225.28
Pharmaceuticals and Personal Care Products (PPCPs) in the Sediments, Sediment Dwelling Organisms and Plants in East Canyon Creek, Utah	$ 29,423.69	$ 30,306.40	$ 31,215.59
Phytoremediation Evaluation Site for Quantifying the Fate of Trichloroethylene (TCE) Taken Up by Trees	$ 34,396.20	$ 35,428.09	$ 36,490.93
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$ 10,256.63	$ 10,564.33	$ 4,741.70
Remediation of Chlorinated Solvent Contamination of Groundwater	$ 23,279.57	$ -	$ -
Designated Projects		$ 266,817.91	$ 57,500.00
Undesignated Projects		$ 108,431.18	$ 12,000.00
Total	**$ 67,932.40**	**$ 421,241.51**	**$ 110,732.63**

Biogeochemistry in TCE Contaminated Aquifers in Northern Utah

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Babur Mirza (Research biologist))
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), a widely used industrial solvent, is frequently encountered as an environmental contaminant and 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. Extensive areas of groundwater contamination exist in the industrialized world and in Utah. TCE contaminates aquifers at Hill Air Force Base (AFB), Dugway Proving Ground (DPG), and other industrial sites along the Wasatch Front. Both private and Department of Defense industrial complexes are required to remediate this contamination.

  Biostimulation remediation of TCE includes adding organic materials to the aquifer. Microbial respiration removes oxygen from the aquifer 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 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 carbon 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 were sacrificed at specified times to observe biogeochemical and microbial progression leading to complete dechlorination as affected by the addition of either whey or lactate as the carbon source compared to a no carbon control.

- **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 contaminate 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: The aquifer solids collected from Hill Air Force Base were packed into small glass columns (7.6 cm diameter and 7.6 cm in height) (Figure 1) and were fed with TCE containing groundwater from the site. The treatments included whey and lactate, with a no added carbon control. All columns were bioaugmented with a culture containing known dechlorinating bacteria. One set of columns (in triplicate) were sacrificed when the monitored effluent from the columns displayed conditions defining (1) iron reduction, (2) dechlorination to cis-DCE, (3) dechlorination to vinly chloride, and (4) production of ethene (Figure 2). The aquifer solids and the pore water were analyzed for TCE degradation products, water quality, and geochemical properties. Each carbon source produced reducing conditions [nitrate depletion, Fe(II) production, $sulfate_4$ reduction, and sulfide production], These were the driving forces for TCE dechlorination (Figure 2). As reduction, and therefore As mobilization, was also observed. Conditions developed with carbon addition are conducive for full dechlorination of TCE, as well as As solubilization. This results in remediation of TCE but pollution of groundwater by As.

The sediments are presently being analyzed to identify the active microbial community involved in partial and full reductive dechlorination using bio-molecular methods. The bacterial makeup of the microbial communities in each column with time will 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.

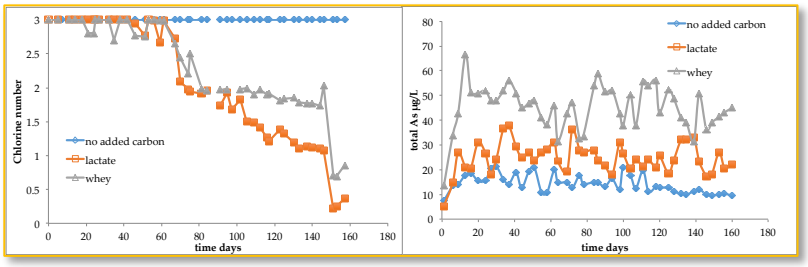
Work Plan FY 15-FY16

Microbial analysis will be the focus for FY15-FY16. The microbial ecology that develops under each stage of the dechlorination process will be described, along with geochemical characterization to define optimal conditions for full dechlorination of TCE. This project has supported two MS students. Suzy Smith (MS completed summer 2015) and Sarah Kissell (defending thesis fall 2015).

Informational Resources

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

Figure 1. Set-up of small column study for testing sequential microbial processing of TCE under different conditions of biostimulation



Figures 2-3: Biomass and metal (copper and zinc) mass in the aboveground plant tissue at the Green Meadows field demonstration site per unit area from 2011 to 2014. Error bars represent ± standard error. Letters represent significant differences based on Tukey HSD ($P<0.05$)

Cache Valley's Vertical Meteorological and 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*
- ***State:*** *Utah Division of Air Quality (UDAQ), Air Monitoring Center (AMC), University of Utah, Weber State University*

Project Description:

- **Need and Purpose:**

  The USEPA recently lowered the 8-hr ozone standard from 75 ppb to 70 ppb. This means the more densely populated areas in Utah, including most of the Wasatch Front, Cache Valley, and St. George are more likely to violate the new regulation. A key to finding solutions to avoid exceeding this standard is the ability to effectively monitor and understand the behavior of the vertical structure of both meteorological parameters and the relevant pollutant species. This project is developing and testing light airborne measurement systems to examine the vertical structure of pollutants. The instrument package is adaptable to different platforms [e.g. tethered balloons and unmanned aerial vehicles (UAVs)]. The need to understand both temporal and spatial O_3 formation, along with transport and transformation behaviors has provided an opportunity to apply techniques developed under this project and to implement comparison studies with other investigators. During 2015, the UAV/O_3 system was further optimized and used in as a part of a larger study entitled "The Great Salt Lake Summer Ozone Study" (GSLSO_3S).

- **Benefits to the State:**

  Research and development of effective methods for understanding the vertical and horizontal behavior of locally generated and regionally transported pollutants are of key importance in developing remediation strategies, and may be applicable to other air quality issues, as well. Additional air quality benefits may be achieved as more instruments to measure $PM_{2.5}$, NO_x, CO, and CO are adapted to the test platform.

- **Geographic Areas:**

  Study Areas: During this most recent period, flight profiles were conducted over a portion of the Great Salt Lake. The specific east-west transect was off the southern-most tip of Promontory Point, the only area for which we were able to obtain FAA flight approval.

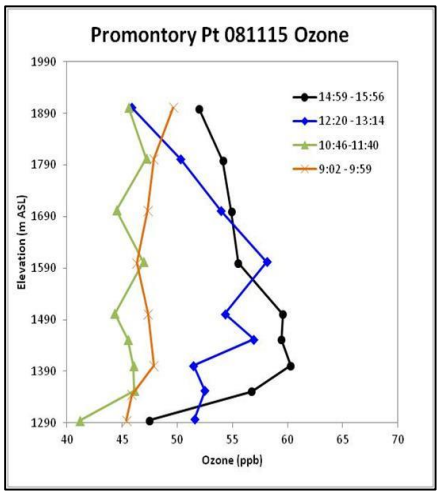
  Areas Benefited: Work over the past couple of years primarily took place in the Uintah Basin and in the Cache Valley, in conjunction with a large study organized by the Utah Division of Air Quality involving many cooperating agencies and universities. The area along the Wasatch Front was the focus of this year's study.

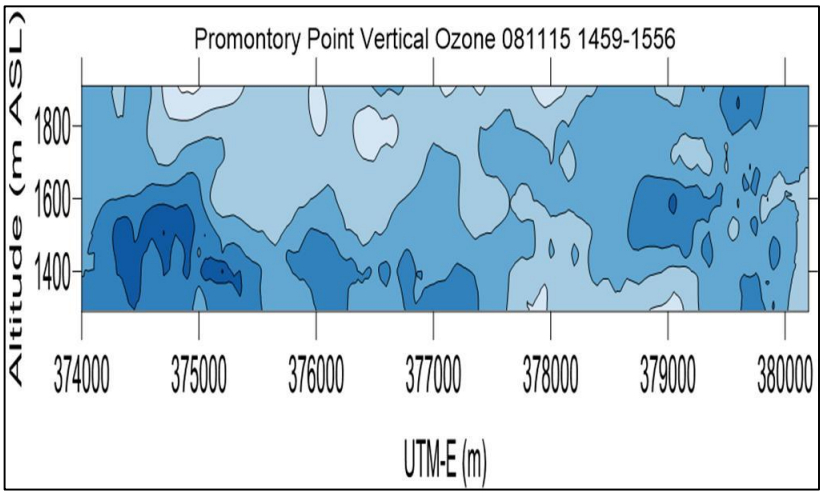
- **Accomplishments:**

  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 a new autonomous unmanned aerial vehicle (UAV) platform. The "Minion" airframe is a new modification to the Utah Water Research Laboratory's (UWRL) AggieAir UAV program. When the UAV systems are modified, the pollutant measurement systems must be modified as well. The study also included a second real-time sensor (O_3/met.) package borrowed from NOAA's Earth Research Systems Laboratory and used as part of a tethered balloon system by one of the cooperating investigators (Dr. John Sohl, Weber State University).

Results: The graph below (left) shows the average vertical O_3 profiles for three flights throughout the day on August 11, 2015. The morning flights showed relatively consistent O_3 concentrations throughout the profile; as the day progressed, more ozone was either formed or transported to lower and near-ground elevations. The figure on the right shows the concentration contours for the observed "ozone curtain" from approximately 3:00 to 4:00 p.m. on the same day. The observed concentration ranged from about 45 ppb (light blue) to 70 ppb (dark blue). The figure shows moderate levels of O_3 on the eastside (near the Wasatch corridor – right side of the figure), while towards the middle (over the Salt Lake) there is a build-up or storage of near-ground O_3. This phenomenon could be significant in ultimate O_3 behavior within the region.





Work Plan FY15/FY16

Work on developing protocols for economically and accurately measuring vertical ozone and meteorological profiles will continue in FY15/FY16. We also pursue other funding opportunities to aid in the continued adaptation of the instrument systems to the UAV-based platform. We also plan to use the UAV instruments for further studies within Cache Valley and along the Wasatch Front. These studies may also include other small measurement packages, as previously described.

Informational Resources

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

Comparison of Wintertime Indoor and Outdoor $PM_{2.5}$, and Vehicle Cold Start and Hot Start Emissions

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

Partners/Collaborators:

- ***Local:*** *The City of Logan, USU, 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 are needed to address the $PM_{2.5}$ and O_3 issues within the Cache Valley and along the Wasatch Front, especially during the wintertime conditions of northern Utah. Recommendations include limiting outdoor exposure times (e.g. stay indoors) and automotive anti-idling programs, as well as the related issue of hot start vs. cold starts. Unfortunately, limited data are available to evaluate the benefit of either of these strategies, particularly as they apply to the vehicle fleet representative of Cache Valley and the Wasatch Front. This project combines research funded by the Utah State Division of Air Quality (UDAQ) to expand the overall scope of the research. The project also collaborated with Logan and USU's Community Bridge Initiative (CBI) project to couple the idle/emissions research with potential impacts on suspected high idle areas.

- **Benefits to the State:**

  Ultimately, accurately assessing the pollutant emissions, ambient and indoor behaviors relevant to the Cache Valley and Wasatch Front will help to identify the most effective remediation scenarios and facilitate the development of information that can be provided to the general public through local and statewide outreach programs.

- **Geographic Areas:**

  Study Area: The majority of the automobile emissions setup testing took place at the UWRL, with some additional comparative testing at WSU's National Center for Automobile Science and Technology. In addition, the CBI program examined the idling impacts at Cache Valley schools. The indoor vs. outdoor study area consisted of various private, commercial, and governmental buildings within the Cache Valley.

  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. Air quality research partnerships have also been established among UDAQ, USU/UWRL, WSU and U of U.

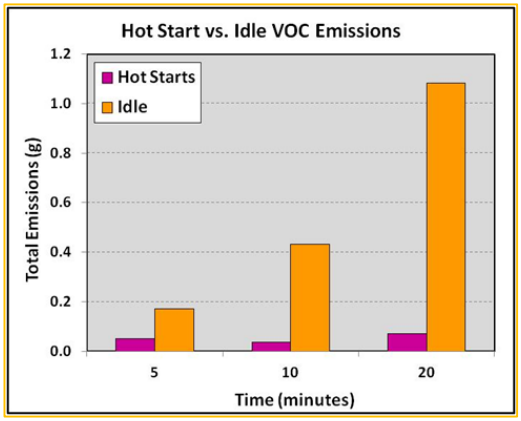
- **Accomplishments:**

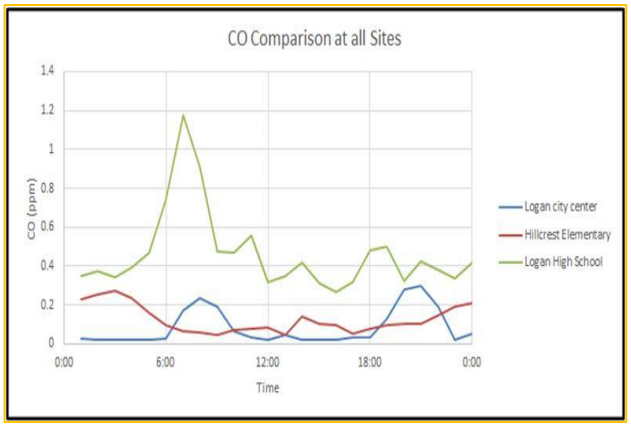
  Findings: The automobile emissions studies conducted at UWRL found significant differences between cold (≈95%) and hot starts (≈5%) across the tested vehicles. Additionally, significant

differences were found in the idling emissions of the tested vehicles. Unfortunately, owing to last year's mild winter, the idling studies at the Cache Valley schools were inconclusive.

As a continuation of previous years' investigations, outdoor vs. indoor $PM_{2.5}$ concentrations were measured at additional facilities in the Cache Valley and were added to the previous year's database. Results showed that at even the maximum outdoor levels observed, the indoor air never exceed the National Ambient Air Quality Standard (35 $\mu g/m^3$).

Results: One of the main findings of the automobile emissions studies was that idling a vehicle during a short stop produced more emissions than shutting off and restarting. As an example, as shown in the left-hand chart, a warmed up vehicle that is started after being shut off for five minutes produced about four (4) times less emissions than if the vehicle had been left to idle. The difference becomes even greater as the time periods are extended. The figure on the right shows the average hourly carbon monoxide (CO) concentrations at the Logan regulatory site compared to potentially high idle areas at Logan High School (LHS) and Hillcrest Elementary School (HES). Although the meteorological conditions were not ideal, significant increases were observed at LHS. Still, the observed levels were well below the current ambient air quality standards. It should also be noted that strong winds were observed at the HES location, while LHS was more meteorologically stagnant.





Work Plan FY15/FY16

The work accomplished in FY14/FY15 filled some critical gaps in knowledge and expanded the scope of the project's research fields. During the next winter season, the idling area studies will be reexamined, if appropriate meteorological conditions are observed (e.g. inversion periods). Related work will also continue in the upcoming year and additional funding resources will be pursued.

Informational Resources

The automobile emissions research was presented at a state-wide conference, and again at two international conferences in FY15/FY16. A final report and multiple manuscripts are in preparation, along with a public informational flyer in cooperation with UDAQ. 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, Phone: (435) 797-1585, E-mail: randy.martin@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, which have lagoon wastewater treatment systems currently in place. In addition, work is ongoing to quantify the energy recovery potential of harvested duckweed biomass via anaerobic digestion, and the 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.

- **Geographic Areas:**

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

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

- **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 are 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 lbs. 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.

Two intermediate scale anaerobic digesters of 5 L volume were grown on 100% duckweed solids feedstock until the digester performance stabilized. The results showed a fairly stable average gas production of 270 mL for each gram of dried duckweed (Figure 2). With methane composition at ≥ 70%, the digesters yielded ≥ 189 mL CH4/g dried duckweed feed, corresponding to 40% of the theoretical maximum methane yield from this biomass feed.

During the experiment, feed concentration was increased in order to increase the amount of residual organic carbon in the digester's effluent that could serve as a substitute carbon source for heterotrophic algae growth. However, increases in duckweed concentration were limited due to maximum solids concentrations that could feasibly be added to the digesters. The high carbon removal efficiency of the duckweed-fed digesters and a physical maximum limit of feed concentration made a high residual organic carbon content in the duckweed digester effluent unachievable. Therefore, one of the digesters was changed to whey powder feed containing significantly higher amounts of carbon. Currently, one digester is operating fully on duckweed, while the other is operating fully on whey powder. Studies are on-going to increase the feed of whey powder, while keeping pH stable to produce a carbon enriched effluent that supports heterotrophic algae growth. Production of heterotrophic algae to average concentrations of approximately 8.9 g/L (peak concentrations > 25 g/L) has been achieved on pure glucose substrate (Figure 3); testing of other carbon sources (whey solution and effluent from whey based anaerobic digester) for continued heterotrophic algae production will commence in early FY16.

Work Plan FY15/FY16

A whey-based anaerobic digester effluent will be evaluated for production of heterotrophic algae during FY16, along with the analysis of whey solution used directly for the growth of heterotrophic algae. A comprehensive analysis of solids destruction, nutrient uptake, energy transformation efficiency, and final effluent quality will be completed for both the duckweed fed and whey fed digesters, and an evaluation of the growth rate and lipid content in the heterotrophic algae grown with different feedstocks (glucose/whey) will be completed.

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.

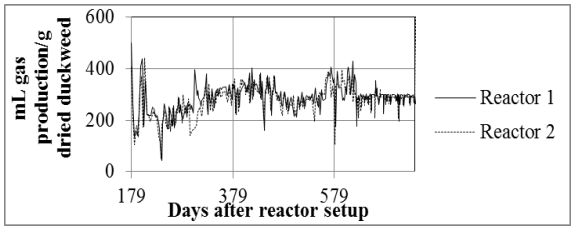


Figure 2. Total gas production from lab scale digester, mL/g dry duckweed added

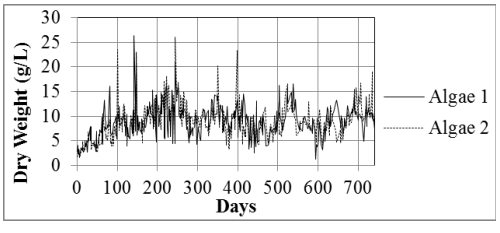


Figure 3. Heterotrophic algae reactor solids concentration during the study

Impact of Biochar Additions to Soil on Contaminant Mobility and Fate for Groundwater Protection

Principal Investigator
William J. Doucette

Partners/Collaborators
- ***Local:*** *Darren McAvoy, USU extension program and Utah Biomass Resources Group (UBRG)*

Project Description

- **Need and Purpose:**

  Biochar refers to the solid residue remaining after the pyrolytic decomposition (i.e. heating under a limited supply of oxygen) of biomass materials. It is often a byproduct formed during the production of bio-oil and syngas. Potential feedstocks include low-value forest and crop residues.

  Because of its long-term stability, biochar has the potential to be used for carbon sequestration applications. Its sorptive properties have also made it a candidate to improve soil fertility and moisture holding capacity, as a type of "filter" for contaminant removal, and as a soil amendment for bioavailability and leachability reduction.

  The Utah Biomass Resources Group (UBRG) is trying to help build a sustainable biomass utilization industry in Utah. The development of woody biomass for energy would help Utah develop a local renewable source of energy and potentially reduce the cost of many forest management projects. Using woody biomass for energy can substantially reduce open burning and air pollution.

  The focus of this project is to investigate the potential use of biochar as a soil amendment to improve plant growth conditions while limiting contaminant leachability (metals and organics) to groundwater and bioavailability to plants. Potential applications of biochar soil amendments would be in agriculture, mine reclamation, and septic tank effluent drain fields.

- **Benefits to the State:**

  Research showing the successful use of biochar generated from waste biomass as soil amendments would potential benefit the state in a variety of ways including: the minimization of biomass waste associated with forest and agricultural industries, improved reclamation of contaminated mine sites, and enhanced groundwater protection associated with septic tank use.

- **Geographic Areas:**

  Study Area: Logan, Utah (Greenhouse and laboratory facilities).

  Areas Benefited: Biochar is a resource available throughout much of the state and its use as a soil amendment could potentially benefit all counties in the state.

- **Accomplishments**: Initial plant uptake (wheat) experiments are being conduct using hydroponic and pressure chamber systems. Batch sorption studies are also being conducted to look at the relationship between sorption and plant availability.

- **Findings:** Preliminary hydroponic experiments have been conducted to look at the potential impact of biochar on plant health related to nutrient availability.

Work Plan FY15/FY16

Continue plant uptake and sorption studies to examine the impact of biochar amendments on the mobility of nutrients and contaminants.

Informational Resources

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

Biochar slurry plant uptake studies with wheat

Environmental Quality Management and Remediation

Impact of Metals and Metal Ions on Soils and Plants

Principal Investigators:
Joan E. McLean
Anne Anderson (Biology)
David Britt (Biological Engineering)
Astrid Jacobson (Plants, Soils, and Climate)
Paul McManus (Graduate student)
Joshua Hortin (Graduate student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Copper oxide nanoparticles (CuO NPs) are manufactured for use in a variety of applications in medicine, food safety, personal care products, and agriculture. One beneficial use of CuO NPs is as an antimicrobial. The accidental or intentional application of CuO NPs on agricultural crops, such as wheat, however, may lead to adverse effects on plants and soil microbial ecosystems. Plants need Cu as a micronutrient, but elevated levels of bioavailable Cu is highly toxic to plants. This project investigates the bioavailability and toxicity of CuO NPs on wheat. Many factors present either in the soil or produced by the plant roots, such as soil pH, salt content, organic matter content, and Cu complexing ligands, influence the behavior of NPs by altering their surface properties and solubility. This study looks at how properties of agricultural soils in Utah specifically influence the bioavailability of CuO NPs to wheat plants.

- **Benefits to the State:**

  Although the research focuses on CuO NPs, it is also relevant to metal pollution in general. 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.

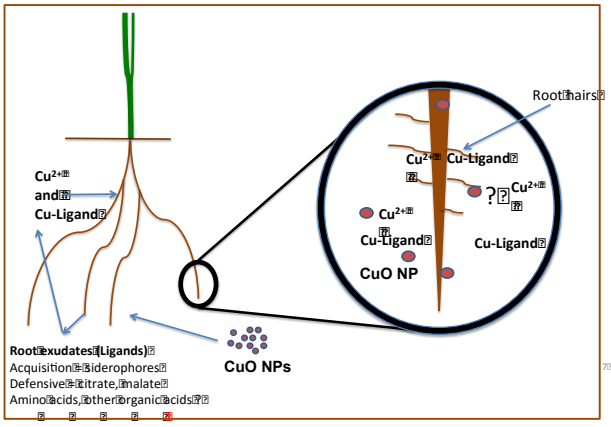
- **Geographic Areas:**

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

  Areas Benefited: All counties in Utah.

- **Accomplishments:**

  Findings: Soil organic matter and organic root exudates from wheat affect the release of Cu ions from CuO NPs, which impacts dissolution of the NPs and differential bioavailability of micronutrients.



NPs, Cu^{2+} and copper complexes at the root interface

Results: Wheat plants grown in sand dosed with CuO NPs were analyzed for organic root exudates (Figure 1) that formed the most stable complexes with copper, including low molecular weight organic acids, amino acids, and the siderophore, deoxymugeinic acid (DMA). During FY14/FY15 a novel method was developed for the detection and quantification of DMA and copper-DMA complexes that will be refined in FY15/FY16. DMA could be detected in wheat root exudates; the presence of CuO NPs increased the concentration of copper-DMA complexes (Figure 2), a strong complex that will modulate plant uptake of Cu affecting Cu toxicity.
To determine the effects of soil components on the stability of CuO NPs, soil pore waters (SPWs), with and without plants, were incubated with CuO NPs to determine which soil components influenced the NP dissolution. Contrary to predictions of geochemical modeling, CuO NP dissolution decreased with increasing soil organic matter (Figure 3), while soil organic matter enhanced dissolution until the soil organic matter inhibited dissolution at higher concentrations, possibly by coating of the nanoparticles with fulvic acid. Organisms in the soil enhanced dissolution of CuO NPs, although the effect could not be isolated to wheat alone. This shows that bacterial and fungal communities play an important role in the CuO NP rhizosphere system.

McManus, P., A. Jacobson, D. Britt. A. Anderson, J.E. McLean (2015). Rhizosphere dissolution of CuO nanoparticles by wheat root exudates in a sand matrix. *Annual ASC meetings of the American Chemical Society*, Boston, MA.

Horton, J. (2015). The stability and toxicity of engineered nanoparticles with respect to agriculture, wastewater treatment systems, and landfills. *Regional meeting of the American Society of Civil Engineering*, Albuquerque, NM (first place in student paper competition).

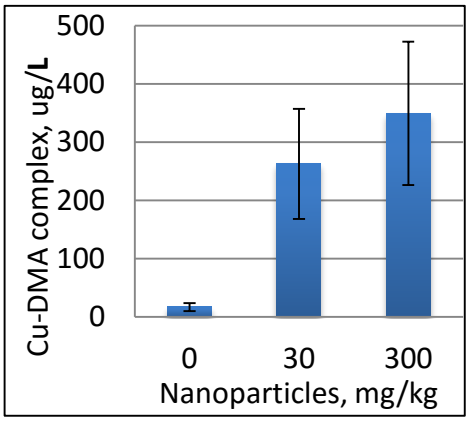


Figure 2. Presence of copper-DMA complexes with soil increasing CuO NP dose

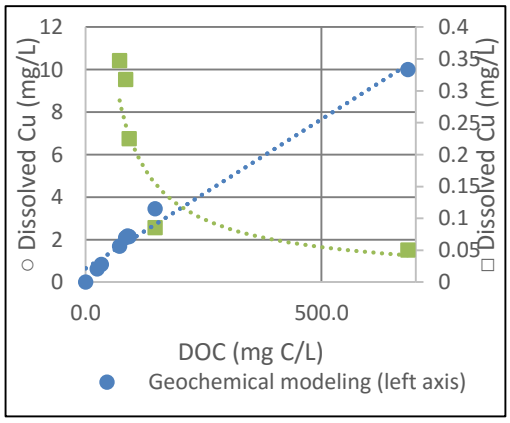


Figure 3. Dissolved organic carbon (a measure of soil organic matter in the SPWs) vs. predicted dissolved

Work Plan FY15/FY16

Studies will continue to examine the bioavailability of the copper complexes discovered in FY14/FY15, as well as the importance of specific physiochemical properties of soil organic matter on the varying effects that were observed in FY14/FY15. The method for detecting copper-DMA and other complexes will be refined and reported in FY15/FY16.

Informational Resources

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

Nitrogen Cycling, Oxygen Demand, and Nitrate Reduction to Ammonia in Silver Creek Below the Water Reclamation Facility

Principal Investigators:
R. Ryan Dupont
Darwin L. Sorensen
Chelsea Stewardson (Student)
Jesse Fleri (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:**

In March 16, 2011, 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." Part of the state framework ensures 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 established 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. Many of Utah's wastewater treatment facilities may need to demonstrate through 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 to provide the necessary reducing power, 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 impact on observed oxygen depletion. Findings from Silver Creek will aid in formulating recommendations to UDWQ regarding modeling and monitoring that may be necessary to accurately determine impacts to Utah streams from nitrogen discharges from wastewater treatment plants.

Figure 1. In Situ Benthic Chambers and Piezometers at the Silver Creek

- **Benefits to the State:**

As Utah begins regulating nitrogen loading to streams, deeper insights into the in-stream processing of nitrogen from wastewater treatment plants, and validated methods to improve the detection of significant nitrogen transformation processes and measurement of nitrogen transformation rates, 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.

- **Accomplishments:**

  Findings: Benthic in-situ chamber studies conducted below the SCWRF treated wastewater effluent discharge point in late August to early September 2014, late November to early December 2014, and June 2015 showed that wastewater effluent dominated conditions within Silver Creek over a wide range of seasonal conditions. Piezometers were installed in June 2015 to monitor vertical groundwater flow (Figure 1). Data from the studies are being analyzed for denitrification, nitrogen assimilation (Figure 2), anaerobic ammonia oxidation, and DNRA using isotope-pairing techniques. Isotope analyses for water, sediment, and macrophytic biomass samples from the June 2015 study are currently underway and suggest rapid N assimilation by stream macrophytes, very low nitrification rates, and rapid denitrification. Laboratory-scale studies using nitrapyrin inhibition, and long-term BOD and BOD TrakII tests have also been completed, and the results are being compared with nitrogen transformation rates observed from in-stream in situ methods.

  Results: Preliminary results from in situ chamber studies showed rapid and significant nitrogen uptake by stream macrophytes (Figure 2), and potential for significant denitrification rates within 1 hr. of nitrate introduction into Silver Creek that decline thereafter. Oxygen depletion has been historically recorded in the stream from July through October. BOD tests showed that the depletion may mainly be attributed to sediment oxygen demand. The increased oxygen demand downstream of the treatment plant discharge (Figure 3) is presumably due to enriched macrophyte growth and subsequent decomposition in response to the treatment plant discharge. A detailed understanding of the fate of nitrogen within the stream ecosystem through analysis and interpretation of the in situ chamber and the laboratory data should shed light on the true impact of SCWRF wastewater effluent on Silver Creek.

Work Plan FY15/FY16

We will analyze data from the June 2015 in situ benthic chamber study and quantify the significance and rate of various nitrogen transformation reactions in the water, soil, and macrophyte compartments of Silver Creek. Results will be used to update transformation rate measurement and water quality modeling approaches for Utah 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.

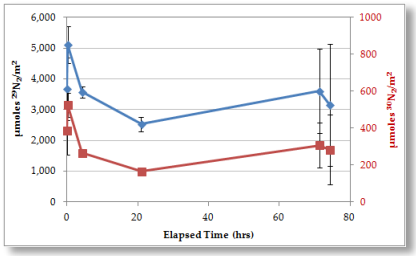


Figure 2. Macrophytic chamber N, November to December 2014

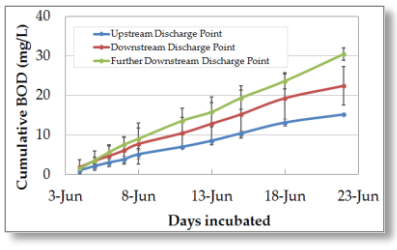


Figure 3. Sediment reactor long-term BOD results

Pharmaceuticals and Personal Care Products (PPCPs) in the Sediments, Sediment Dwelling Organisms and Plants in East Canyon Creek, Utah

Principal Investigator:
William J. Doucette

Partners/Collaborators:
- ***Local:*** *Michael Luers, Snyderville Basin Water Reclamation District*

Project Description

- **Need and Purpose:**

The occurrence of pharmaceuticals and personal care products (PPCPs) in surface waters is a growing concern. In addition to prescription drugs, over-the-counter medications, lotions, fragrances, and soaps, the term PPCPs has been adopted to represent a wide variety of chemicals used in consumer products, including plasticizers and fire retardants. Wastewater effluents have been shown to be a major source of PPCPs in surface waters since most PPCPs are disposed of, directly or indirectly, into domestic sewage systems that are not specifically designed to treat them.

The Synderville WWTP effluent discharges directly into East Canyon Creek, Utah, and during the late summer, the effluent can be the major component of the total stream flow. Several PPCPs were identified in fish collected from East Canyon Creek, Utah, downstream of the Synderville wastewater treatment plant (WWTP) in November and December 2008 (Baylor University). The same research group plans additional monitoring of PPCPs in fish this summer.

To better understand the potential impact of PPCPs originating from the Synderville WWTP, the main objectives of this proposed research are to determine the seasonal variation in PPCP loading to East Canyon creek from the Synderville WWTP and determine the extent of PPCP concentrations in the sediments, sediment dwelling organisms, and aquatic plants downstream from plant.

Water sample collection in East Canyon Creek, UT

- **Benefits to the State:**

Results from this study will contribute to our overall understanding of environmental fate and impact of PPCPs originating from WWTPs. It will also provide important information on the seasonal variability of PPCP loading to the East Canyon Creek. The sediment, sediment organism and plant concentration data will help delineate potential routes of exposure to East Canyon Creek fish. This project will have a direct and positive impact on Utah citizens because WWTP are located throughout the state of Utah. An improved understanding of the fate of PPCP in surface waters by regulatory agencies such as the Utah DEQ will also enable the more efficient expenditure of public dollars based on risk management prioritization that will be made possible by this information.

- **Geographic Areas:**

  Study Area: East Canyon Creek, Utah.

  Areas Benefited: PCPPs in wastewater effluents is a statewide issue, so all counties in the state would potentially benefit.

- **Accomplishments**: Water, sediment and plant samples were collected from the point where the WWTP discharges into East Canyon Creek (Site 0) at and one upstream (Site -1) and two downstream locations (Sites +1, +2).

Plant sample collection in East Canyon Creek, UT

- **Findings:** As shown in Figure 1, several PPCPs were identified at Sites q, +1 and +2, but not at Site -1, strongly suggesting that the WWTP was the source of these compounds. Sediment and plant samples are currently being extracted an analyzed.

Work Plan FY15/FY16

Continue additional sampling of water, sediments and plants. Examine the relationship between PPCP concentrations in water; sediment and plants to better understand the fate of these compounds in effluent dominated rivers.

Informational Resources

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

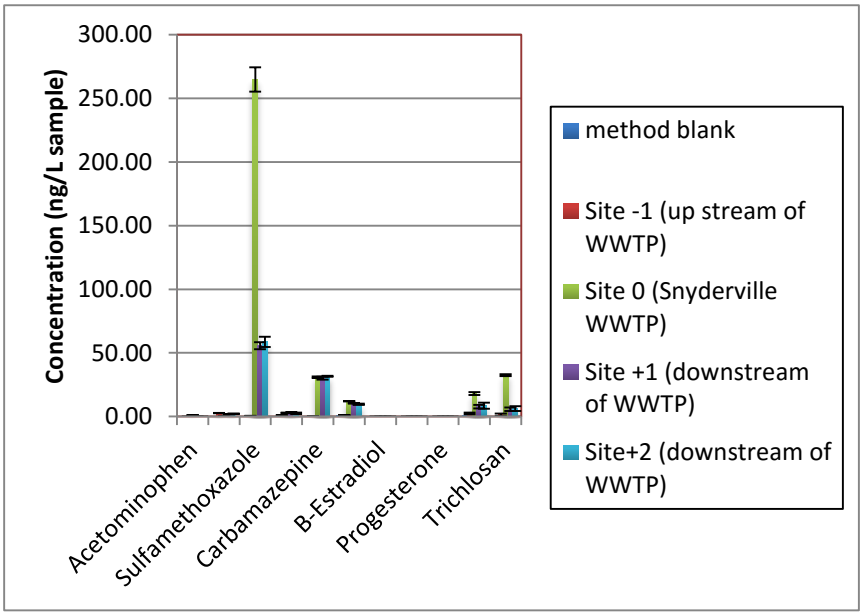


Figure 1. Graph showing the concentration of 11 PPCP at four locations within East Canyon Creek, Utah

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

Principal Investigators:
William J. Doucette
Oliver Diamond

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

Project Description

- **Need and Purpose:**

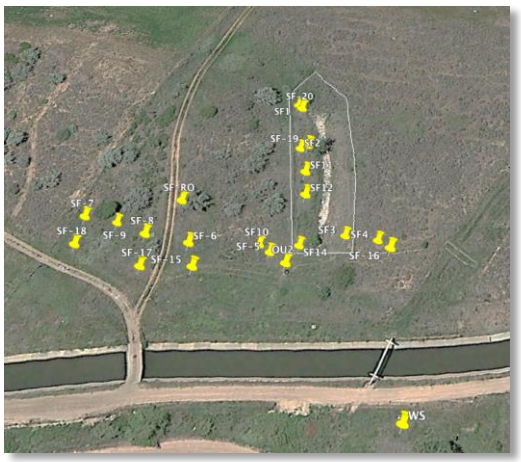
  Chlorinated volatile organic compounds (CVOCs) are found at many locations in the State of Utah, including several communities surrounding Hill Air Force Base. Phytoremediation using fast growing trees is promoted as a low cost, sustainable remediation alternative for the clean-up of shallow groundwater contaminated with CVOCs like trichloroethylene (TCE). The uptake by trees and the subsequent volatilization from leaves into the atmosphere is thought to be a significant removal mechanism for TCE. Once in the atmosphere hydroxyl radicals rapidly degrade TCE. Trees also can metabolize TCE into less problematic compounds. Tree sampling has been used to cheaply delineate groundwater plumes, as well.

  One of the main limitations preventing the implementation of phytoremediation 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 data quantifying the removal.

  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 mass of TCE and other CVOCs removed annually 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 can be used statewide, so all counties in the state could benefit.

- **Accomplishments:**

  Findings: Approximately 60 poplar poles were obtained from the Utah State University (USU) research farm and planted on a seep area between the Hill AFB boundary and the Weber Canal within OU2 during April 2013 and 2014. To minimize the risk of erosion on the steep hillside, the poles were planted in holes

augured to near the depth of the shallow groundwater (4 feet) and only limited watering of the poplar was conducted. However, the hot, dry springs resulted in the survival of only 25% of the planted trees after 2 years.

Leaf, trunk, and soil volatilization flux samples were collected and analyzed for TCE and other CVOCs during the 2013 and 2014 growing seasons. Since the newly planted poplar trees were too small to collect core samples in 2013, tree core samples were collected from several mature trees that were located near the newly planted trees.

- **Results:** TCE was found in the tree core and volatilization flux samples. Comparison with historical data collected at the site shows that TCE concentrations vary over time but are generally declining and that the tree core concentrations follow the groundwater concentrations. This suggests that tree core sampling could be a more cost effective approach to the delineation of groundwater contamination than traditional groundwater well installation.

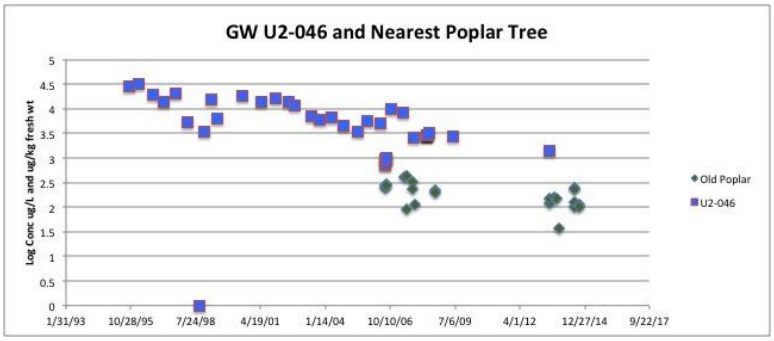


Figure 1. Relationship between groundwater and tree core concentrations over time

Work Plan FY 15-FY16

We plan to summarize data collected during 2013 and 2014 and use a Thiessen approach to extrapolate the individual sample or flux measurements to the entire site. These data will be used, along with similar data collected from other HAFB locations and air force bases having similar climates, to develop a model that can predict the potential effectiveness of phytoremediation at other sites within the State of Utah.

Informational Resources

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

Poplar pole being planted

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 Roginski, Environmental Management Directorate, Hill AFB*

Project Description

- **Need and Purpose:**

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

  This project used RT_PCR instrumentation to facilitate development and implementation of routine quantitative molecular biology capabilities of the Utah Water Research Laboratory's Environmental Quality Lab (EQL). This is needed to support advanced molecular biology research that generates 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 454 pyrosequencing. With these tools, the make-up of impacted microbial communities and their interactions in natural systems and the response of microbial communities to engineered modification of contaminated environments can be explored.

- **Benefits to the State:**

  RT-PCR instrumentation provides quantitative capabilities for the low-level detection of specific microorganisms and functional genes in environmental samples. Applications of 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 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.
  4. Analyze the community composition and function associated with biofilms accumulating within the potable water distribution system in Park City.

- **Geographic Areas:**

  Study Area: 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.

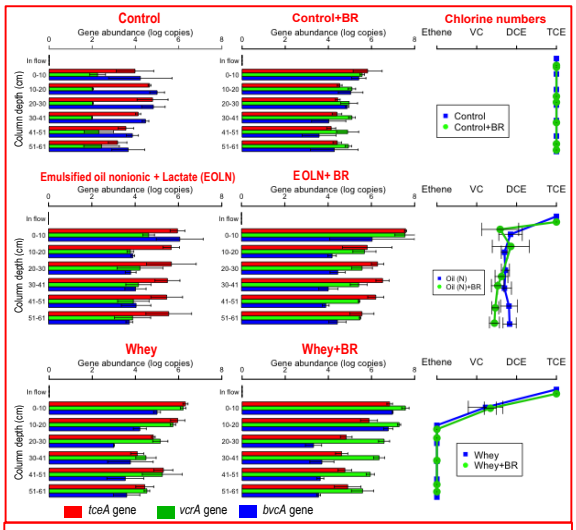


Figure 1. RT-PCR results of small-scale flow through columns evaluating the impact of carbon donor on TCE remediation

- **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 studies that (1) track the progress of remediation and the growth and maintenance of remediation cultures applied at a chlorinated solvent site at Hill AFB; (2) evaluate the microbial community composition and diversity of groundwater plumes adjacent to Hill AFB; (3) identify the sources of algal blooms and surface water impacts in Pineview Reservoir; (4) evaluate the presence and abundance of arsenic reducing species in soil and groundwater adjacent to the Logan City Landfill; (5) assess the composition and diversity of bacterial, archeal, and fungal communities associated with poplar plants in a phyto-remediation study at Hill AFB; (6) evaluate the presence, abundance, and expression of functional genes associated with TCE transformation in both large-scale and small-scale flow through column studies related to soil and groundwater contamination at OU5 at Hill AFB; and (7) conduct 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 FY15/FY16

Ongoing projects: Expand the range of organisms and functional genes and improve specificity of target primer for organisms of interest that can be quantified using RT-PCR methods. Focused studies to improve recovery of DNA from complex environmental media, and lower detection limits of the method. Recently funded projects: (1) investigate 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) identify 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.

Remediation of Chlorinated Solvent Contamination of Groundwater

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Darwin L. Sorensen
Babur Mirza (Research Biologist)
Suzy Smith (MS student)

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

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, the Bachman Road (BR) 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: Previous findings showed that full dechlorination of TCE only occurs with the addition of whey as the carbon source, promoting the necessary geochemically reducing conditions. The overall microbial communities and the specific bacterial species *Dehalococcoides (Dhc* spp.), the only bacteria that are known to be capable of converting TCE to non-toxic ethene, as established under different TCE dehalogenating systems, were characterized through high throughput DNA sequencing method. We observed a shift in both the overall microbial communities and *Dhc* spp. in response to the application of different carbon amendments, which influenced geochemical conditions. A decrease

in *Proteobacteria* related sequences in combination with the increase in *Dhc* spp. resulted in complete reductive dechlorination. These findings provided valuable insights on the establishment of different bacterial groups and shifts within the *Dhc* spp. in relation to different TCE dehalogenating systems.

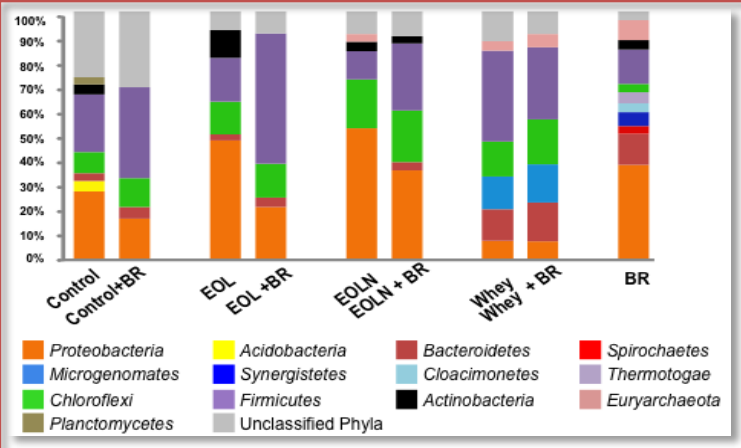


Figure 1: Relative distribution of overall bacterial phylum established across different TCE dehalogenation systems. Each bar represents 18,000 16s rRNA gene sequences

Results: Continuously TCE fed columns, established under different TCE dehalogenating stages, were characterized for the overall microbial community structure and variations in the *Dhc* spp. 16S rRNA gene based characterization of overall microbial communities at the phylum level showed that *Proteobacteria* and *Firmicutes* were the dominant bacterial groups across different treatments. These ranged over 30-60% of total sequences (Fig. 1). Members of phyla *Chloroflexi*, one of the most important bacterial phylum in context of TCE dehalogenation, showed relatively equal distribution across different treatments (Fig. 1). However, sequences related to *Dhc* were considerably dissimilar across different TCE dehalogenating systems.

Overall, different microbial community structure was established in response to different biostimulation treatments and TCE dehalogenation stages. Total bacterial subsampled sequences (142,920) could be grouped into 11,042 OTUs at the 97% sequence similarity level. Differences in the taxonomic microbial community structure assessed by NMDS analysis at 97% DNA similarity showed a distinct clustering of samples from different column samples grouped by the biostimulation treatment or TCE dehalogenation stage (Fig. 2).

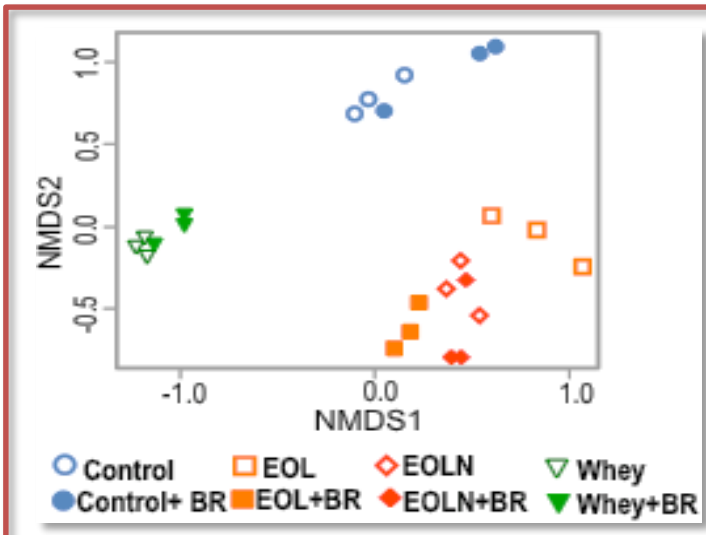


Figure 2. Nonmetric multidimensional scaling representation of the 16S rRNA gene sequence based on the Bray-Curtis similarity index of overall bacterial communities structure based on 97% DNA similarity. OTUs represented by >5 sequences were used. Same color symbols represent the same carbon treatment and open and closed symbols represents nonaugmented and bioaugmented columns, respectively

Work Plan FY 15-16

This project is completed. Findings from this project are being prepared for publication.

Informational Resources

Contact: Ms. Joan E. McLean, Phone: (435) 797-3199, E-Mail: joan.mclean@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	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Assessment of Utah 319 Projects for Controlling Non-point Source Water Pollution	$ 22,541.24	$ 23,217.48	$ 23,914.00
Estimating Water Loss from Rural Lands Using Remote Sensing and Complementary Methods	$ 46,305.33	$ -	$ -
Incorporation of Heat into Solute Models	$ 56,163.14	$ 57,848.03	$ 59,583.48
Influence of Groundwater/Surface Water Interactions in High Gradient Mountain Streams	$ 61,561.63	$ -	$ -
“Lab-on-a-Chip”—Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$ 65,777.44	$ 65,777.44	$ -
Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies	$ 70,563.46	$ -	$ -
Release of Arsenic from Aquifer Solids under Anaerobic Conditions	$ 54,362.92	$ 55,993.81	$ 57,673.62
Source Water Protection from Potential Phosphorus Mining Impacts in the Uintah Basin	$ 11,397.29	$ 11,739.21	$ 12,091.38
Technical Support for Bear River System Data Acquisition	$ 13,203.62	$ 13,599.73	$ 14,007.72
Water Allocation and Salinity Issues of the Sevier River Basin	$ 5,624.41	$ -	$ -
Designated Projects		$ 460,141.70	$ 56,700.00
Undesignated Projects		$ 171,010.00	$ 10,000.00
Total	**$ 407,500.48**	**$ 859,327.40**	**$ 233,970.20**

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 (student)

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:**

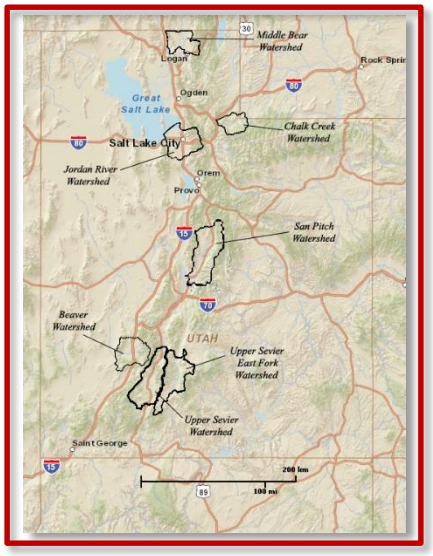
  Some evidence indicates that public efforts to reduce NPS water pollution in Utah have been successful. A comprehensive water quality monitoring program tracks current conditions and water quality trends for all 14,250 miles of rivers and streams, and nearly 3,000 lakes and reservoirs in Utah (UDEQ 2009). 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 that 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 FY15/FY16

Completion of student dissertation and publications.

Informational Resources

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

Estimating Water Loss from Rural Lands Using Remote Sensing and Complementary Methods

Principal Investigators:
Jagath J. Kaluarachchi
Homin Kim (PhD student)

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  Previous work conducted at Utah Water Research Laboratory developed a novel method (Anayah, 2014) to estimate total water loss from agricultural and non-agricultural lands using the complementary methods. Classical methods of estimating evapotranspiration (ET) are valid for water loss estimates from lands covered with vegetation such as crops. However, water loss occurs from others surfaces, too, such as bare land, open water surfaces, etc. Promising results of our earlier study (modified GG model, Anayah, 2014) and complementary methods were used only point data from meteorological stations. The modified GG model is an extension of the earlier work of Granger and Gray (1989) who developed one form of the complementary methods. The data required are mostly temperature, relative humidity, wind speed, and sunlight hours. The estimates provide regional water loss from lands under a variety of physical and climatic conditions. On comparison with many other recent studies, the results showed vast improvements, but the results under arid conditions were similar or slightly better than previous studies. Therefore, there is opportunity to further improve the modified GG model. The focus of this work is to use limited remote sensing information, primarily, vegetation cover information combined with the modified GG model to develop a hybrid method to estimate total water loss from regional lands with emphasis on arid lands.

- **Benefits to the State:**

  Given the importance of rural agriculture and rural livelihoods in Utah, where water is typically limited, accurate water loss estimates from both from agricultural and non-agricultural lands are important in water resources management. Classical methods to compute ET from agricultural lands are available, but data needs are detailed and complex. Remote sensing data from satellites and corresponding methods require advanced knowledge and trained personnel to provide good estimates of ET. On the other hand, an approach using these complementary methods have high validity, given the limited data requirements, for use in regional estimates with meteorological data only. The methodology derived from this work is useful for Utah, where good estimates can be obtained at a relatively fast pace and with limited resources.

- **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: As indicated earlier, Phase I of this work will use vegetation cover information from remote sensing data combined with the modified GG model to develop a new hybrid model to estimate total water loss from rural lands. The primary reason for this hybrid model is to improve estimates from arid regions where the use of other methods did not improve accuracy. Since the complementary methods do not discriminate between agricultural or non-agricultural lands, the estimates are independent of land cover. The vegetation cover is represented by using the normalized difference vegetation index (NDVI) typically derived from various remote sensing products such as LandSat data.

Results: Methods for estimating evapotranspiration (E_T) that use complementary methods are simple, practical and provide valuable regional E_T estimates with only point meteorological data only. The Budyko framework has been successfully used to predict the long-term annual water balance as a function of E_P and precipitation. According to Yang et al. (2006), the Budyko hypothesis is consistent with the Bouchet hypothesis which is based on the complementary relationship.

Given the limitation of not accurately predicting E_T in dry regions, the goal of this work is to extend the model of Anayah (2014) to combine the complementary relationship and the Budyko approach for improved estimation of E_T. For the purpose of model development and application, 75 sites from the AmeriFlux database covering the US were identified and divided as 39 sites of dry regions and 36 sites of wet regions based on the aridity index from UNEP (1992).

Figure 1 shows that the proposed hybrid model (called GG-NDVI) produced a higher frequency of low root mean square (E_{RMS}) values than the modified GG model of Anayah (2014). This observation is more prominent in the dry class of the observations compared to the wet class.

In general, the GG-NDVI model reduces mean E_{RMS} by about 24% compared to the modified GG model. Increasing wetness leads to increadsed model accuracy. Lastly, E_T is directly proportional to the aridity index of dry regions. However, the increasing aridity index leads to decreasing E_T in wet regions. These trends were seen in recent studies from Han et al. (2014) and Roderick et al. (2009). Although this study applied the Budyko framework in the modified GG model, the GG-NDVI model shows similar results with other complementary relationship studies as well. Therefore, we may conclude that the GG-NDVI model maintains the characteristics of both the complementary relationship and the Budyko hypothesis.

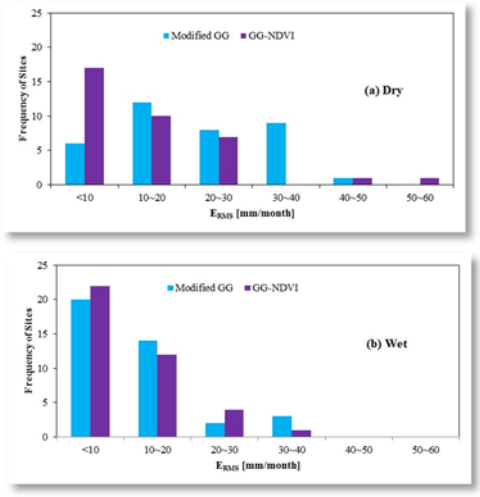


Figure 1. Histogram of ERMS values of GG-NDVI and the modified GG models for (a) dry and (b) wet sites.

Work Plan FY14/FY15

Work will continue on this enhanced hybrid model to further improve ET estimation, especially compared with remote sensing methods. While this hybrid GG-NDVI model uses NDVI values from remote sensing data, the model is primarily driven from complementary methods and local data. Future comparisons will only include remote sensing methods and data.

Informational Resources

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

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 and have been tested against observed solute data within various systems. 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. Three papers have been published from this focus area, a PhD dissertation was completed, and another paper is currently in review. In 2014, an MS thesis was completed that focused on the heat transport processes within beaver dams. Another MS student has submitted a journal article to Hydrologic and Earth Systems Sciences (HESS) on the influence of beaver dams on hydraulics. A post-doctoral student also published an article investigating the influences of beaver dams on local hydrology and thermal regimes (Figure 1). Additionally, 27 presentations of results have been delivered by faculty and students.

Work Plan FY14/FY15

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. Additionally, we continue to collect data to understand the evolution of dams and the associated ecosystem impacts.

Informational Resources

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

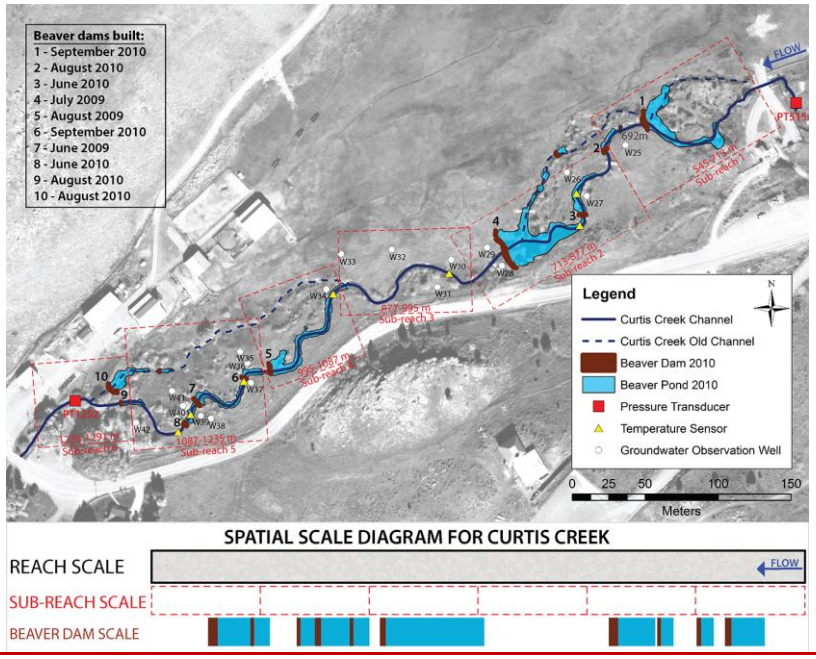


Figure 1. Aerial image from 2006 and beaver dams constructed between 2009 and 2010. The main beaver dams are numbered from 1 to 10 from upstream to downstream and the time of dam construction is noted in the table. The spatial scales investigated are illustrated below the map. The most downstream beaver dam and beaver pond are located in the old channel but overlap in the Beaver Dam Scale schematic in this figure. Taken from Majerova et al. 2015

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 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 unimpacted mountain 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 gain and loss data collected within this study will complement iUTAH efforts by providing information longitudinally within each system during different seasons.

- **Geographic Areas:**

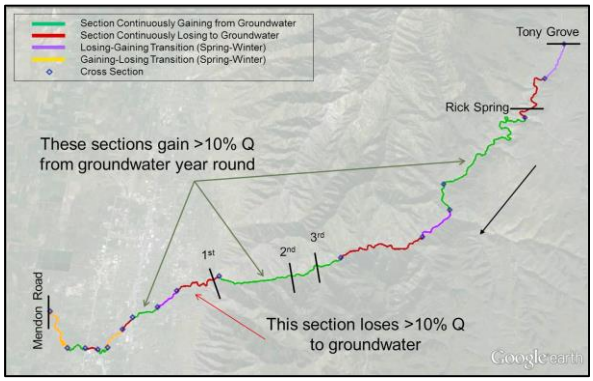
  Study Area: Logan River, Logan, UT; Red Butte Creek, Salt Lake City, UT; Provo River, Heber and Provo, UT.

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.

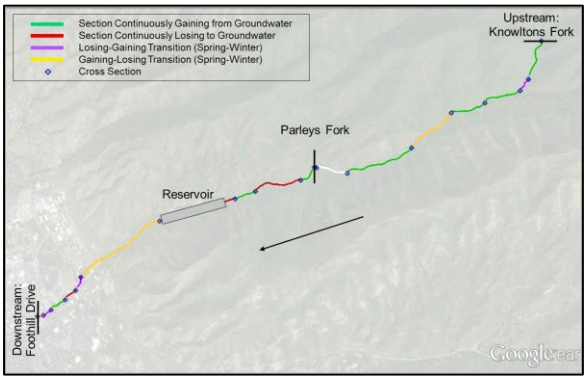
- **Accomplishments:**

Findings: Data have been gathered at many sites for five different time periods in the Logan River and Red Butte Creek over the last two years. Some data have also been collected within the Provo River in 2013-14. The typical data collected are flow information, and more recently, a broad variety of different constituents.

Results: The data collection supports iUTAH efforts to: (1) interpret the biochemical data collected longitudinally within the iUTAH study watersheds; and (2) conduct other variable scale water balance modeling efforts within iUTAH to understand the implications of climate change on hydrology within the state of Utah using. As part of this effort, we are identifying areas with consistent groundwater influences and areas where there are changes over time (see figure below). An undergraduate (BS) and two graduate (PhD and MS) students are working on this project, and we have joined with a number of collaborators at the University of Utah to expand the scope of this research by investigating catchment scale biogeochemical responses.



Logan River



Red Butte Creek

Work Plan FY15/FY16

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

Barnes, M.L., T. Stout, H. Tennant, B.T. Neilson (2015). Groundwater – Surface Water Interactions in Three Utah Watersheds, April, 2015. *Utah State University Spring Runoff Conference*. Logan, UT.

Tennant, H, M.L. Barnes, T. Stout, B.T. Neilson (2015). Methods and Techniques for Measuring Discharge in Three Utah Watersheds. *iUTAH Summer Symposium*, July. Midway, UT.

"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 continued the optimization of design and fabrication for a low-cost on-chip microfluidic based chip device that integrates working, counter, and reference electrodes. This device was tested for detection of heavy metal ion (Pb^{2+}) in standard ion solution. These results indicate a sensor device detection limit down 15 ppb (EPA standard for lead in drinking water is 15 ppb) in the range of 0 ~100 ppb. This work has been published in a refereed paper in 2015, and the student co-author successfully defended his M.S. thesis in April 2015.

  Results:
  1) In summer of 2015, a conference call was arranged among USU Intellectual Property Services, Dr. Zhou, and the CEO of Innovastics, LLC, Lewisville, TX, who expressed interest to license Dr. Zhou's patented sensor technology.
  2) We continued to optimize the sensor design and fabrication of this on-chip device and tested it in water samples. As shown in Figures 1–2 below, our sensor was able to detect Pb^{2+} ions in a concentration range of 0~100 ppb.

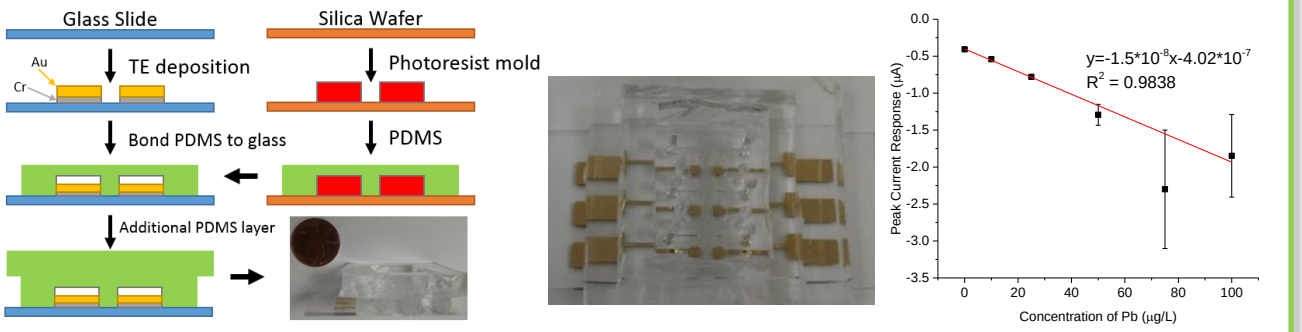


Figure 1. Microfabricated on-chip device that integrates the working electrode (gold), counter electrode (Pt), and reference electrode (Ag/AgCl) for detection of Pb^{2+} ion concentration in water sample in 0~100 ppb

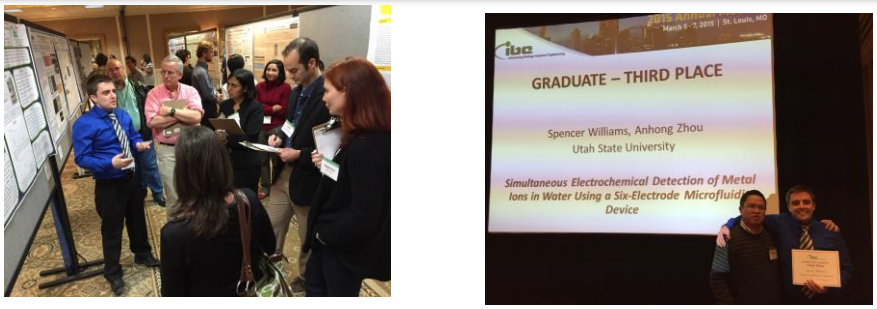


Figure 2. M.S. student Spencer Williams presented his microfluidic device based water ion sensors to (left) the judges of Graduate Student Poster Competition and received 3rd place award in the 2015 Institute of Biological Engineering meeting at St. Louis, MO, March 5-7, 2015

Work Plan FY15/FY16

- Design and fabricate ionophore for Calcium (Ca^{2+}) sensor.
- Work closely with USU Intellectual Property Services to license this sensor technology to industry.
- Continue optimization of on-chip device for (Cd^{2+}) detection in water samples, and submit the manuscript for publication.

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:

Zhang, W., H. Zhang, S. Williams, and A. Zhou (2015). Microfabricated three-electrode on-chip PDMS device with a vibration motor for stripping voltammetric detection of heavy metal ions, *Talanta*, 2015, 132, 321–326.

Williams, S., H. Zhang, W. Zhang, A. Zhou, S Williams, and A. Zhou (2015). Simultaneous Electrochemical Detection of Metal Ions in Water Using a Six-Electrode Microfluidic Device, *2015 Annual Institute of Biological Engineering Meeting*, St. Louis, MO, March 5-7, 2015. This poster received 3rd Place Graduate Student Poster Competition Award. http://www.ibe.org/_resources/pdfs/awards/Student_Poster_Competition_2015.pdf.

Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont, Joan McLean
Malgorzata Rycewicz-Borecki (PhD student)
Trixie Rife (PhD student)
Sarah Guzman (MS student)

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 program aims to minimize discharge volumes and pollutant loadings from urbanized areas entering receiving water bodies and to address the increased water quality problems and 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 characterize the effectiveness of vegetative species within storm water management facilities. This study measured biomass production and water quality improvement in a controlled laboratory environment and is also 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 and pollutant uptake for seven vegetative species was quantified in the laboratory under simulated (frequency and duration) rainfall events. The field demonstration site (the Green Meadows subdivision storm water detention area in Logan) is producing quantitative water quality improvement effectiveness data for plant production and contaminant removal in response to periodic plant harvesting for three species. This is compared to naturally propagated weed species and non-vegetated control plots.

- **Benefits to the State:**

  This study is providing storm water nutrient and metal removal effectiveness of local species that Utah municipalities can use to optimize stormwater 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 who are 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.

Long-term field-scale performance monitoring at the Green Meadows field demonstration site during FY11-FY14 provided contaminant removal performance data during summer and fall 2014. These data continue to indicate significant storm water retention and infiltration capacity within the collection system, but no surface discharge provided maximum pollutant removal. All data collected were added to the database of nutrient and metal uptake and harvesting performance.

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 FY11 through FY14 growing seasons. With no surface discharge from the planted areas, maximum nu
these systems. Biomass significantly increased every year from
cattail, but did not increase from 2013 to 2014 indicating that tl
levels after 2 to 3 years of growth (Figure 1). The naturally see
provided significantly higher biomass than other single test spe
densities did not vary among any of the planted treatments.

Citric acid was added to the site to investigate the potential for increased metal and nutrient uptake into the harvestable plant tissue. It was found to increase metal solubility in the soil-water, but did not significantly increase uptake into the aboveground tissue. However, species differences were found in metal uptake performance. The sedge treatment took up significantly more Cu and Zn in the aboveground plant tissue than sunflower and cattail in 2014 (Figure 1), indicating that species selection can have a significant impact on metal uptake, and on-going control of metal accumulation in storm water treatments systems.

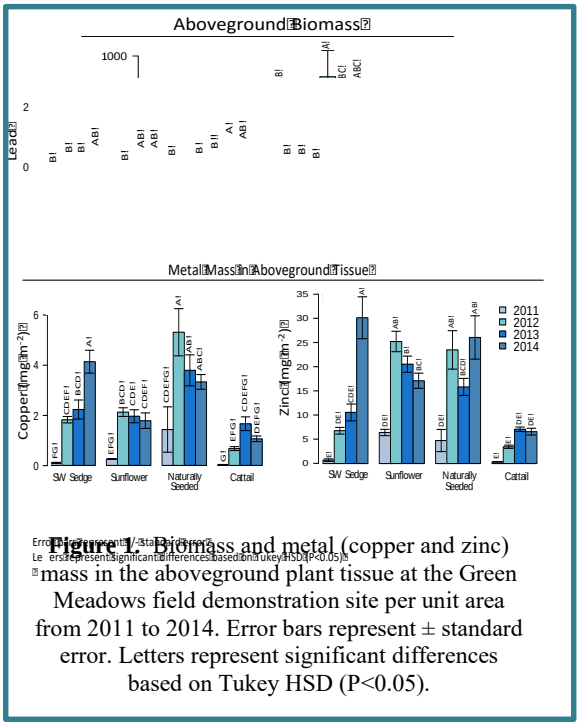


Figure 1. Biomass and metal (copper and zinc) mass in the aboveground plant tissue at the Green Meadows field demonstration site per unit area from 2011 to 2014. Error bars represent ± standard error. Letters represent significant differences based on Tukey HSD (P<0.05).

Outreach activities included on-site facility tours by members of the iUTAH Green Infrastructure Research Facility planning committee and of iUTAH Summer Water Quality Symposium in Logan in summer 2014.

Work Plan FY15/FY16

Field plant harvesting and soil sampling from late fall 2015 will be added to the database of nutrient and metal uptake and harvesting performance for the site. A study to investigate the effectiveness of green infrastructure modifications to conventional curb and gutter stormwater systems in order to intercept and treat the first flush of contaminants in stormwater will be carried out during FY15.

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)
Allia 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. Arsenic solubilization is enhanced under reducing condition due to the utilization of arsenic for microbial respiration. This study investigates conditions that lead to arsenic release to groundwater at a sampling location in the Cache Valley Basin. This report focuses on the bacteria present in the aquifer that use arsenic for respiration. These bacteria can be identified by the presence of the arsenate reducing gene (*arrA*).

- **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: Arsenate reductase (*arrA*) gene specific PCR primers were developed using the GenBank database. These primers were tested for the amplification of *arrA* gene from groundwater wells and sediments material from the Cache Valley Basin. Subsequent DNA sequencing of amplified PCR product confirmed specificity of the newly developed PCR primers. Unlike previously available primers for *arrA* gene, these primers allowed us direct amplification from both groundwater and sediments samples. These primers were also used to establish a procedure for the quantification of the *arrA* gene through qPCR.

Results: Arsenate reductase gene (*arrA*) primers developed in the current study has resulted in successful amplification of this gene both from groundwater and sediments samples of the Cache Valley Basin. PCR amplification resulted in a single band of expected size (Fig. 1) suggesting specificity of these primers. Subsequent DNA sequencing of amplified PCR product through high throughput sequencing confirmed that all amplified product belonged to *arrA* gene. These primers were also tested for the quantification of *arrA* gene abundance in a sediment core collected in the Cache Valley Basin, from the soil surface to depth of groundwater. Figure 2 displays the distribution of the *arrA* gene with depth and the corresponding profile of reduced arsenic. (*Meng X. 2015. Redox controlled biogeochemical processes affecting arsenic solubility in sediments from a basin-fill aquifer in Northern Utah. PhD Dissertation Utah State University*.)

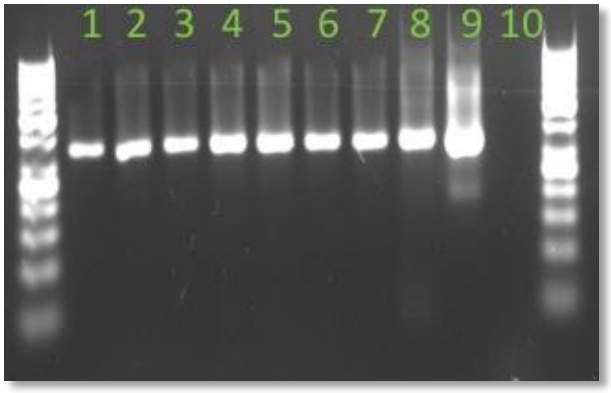


Figure 1. Arsenate reductase gene (arrA) amplification from groundwater (1-3) and sediments (4-8). Wells 9 and 10 in gel represents amplification from the positive and negative control samples. 1kb DNA ladder was used in the first and last well to get an idea about size of amplified product. Amplified PCR product was about 500-bp

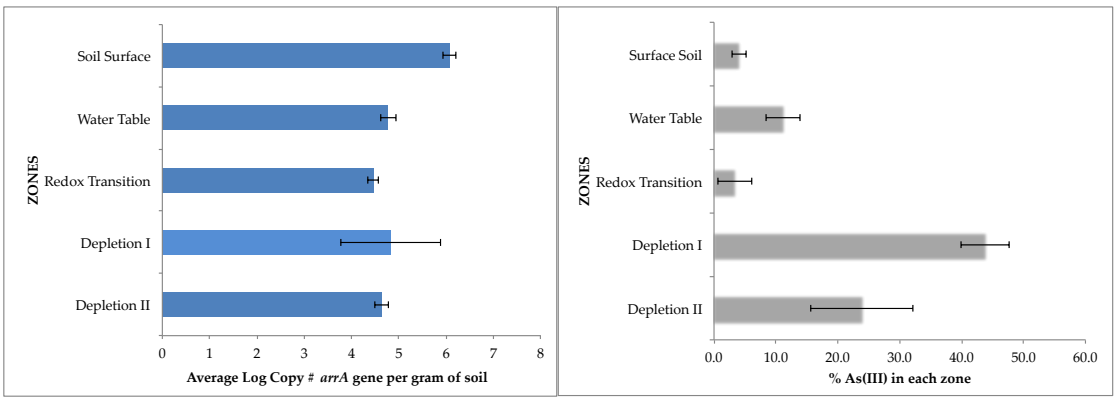


Figure 2. (A) Relative abundance of arrA gene in the sediments at the NP9 site by zones. Abundance was quantified through qPCR using arrA gene specific primers developed in this current fiscal year. (B) Corresponding profile of the % of reduced arsenic (III) in each zone

Work Plan FY15/FY16

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, Phone: (435) 797-3199, E-Mail: joan.mclean@usu.edu.

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

Principal Investigators:
David K. Stevens
Joan 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 city's water supply at Ashley Springs with (1) non-point source runoff that could contaminate the water supply with sediment and inorganic pollutants and (2) 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 on the ridges surrounding Ashley Creek. Removal of ~20 meters of overburden cap rock and the phosphorus-bearing ore will expose buried materials to weathering. This will create a significant risk for release of sediment and toxic anions, such as selenium and arsenic, and 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 force the city to seek alternative sources. This project is collecting and assessing data to provide the City of Vernal and Uintah County with resources and tools to deal with this possible threat to Ashley Springs.

- **Benefits to the State:**

  The data and information from this project 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 for analytical models; collection of water quality data near source water protection zones where such data are not available; incorporating data in a database system to produce data summaries and reports; 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:

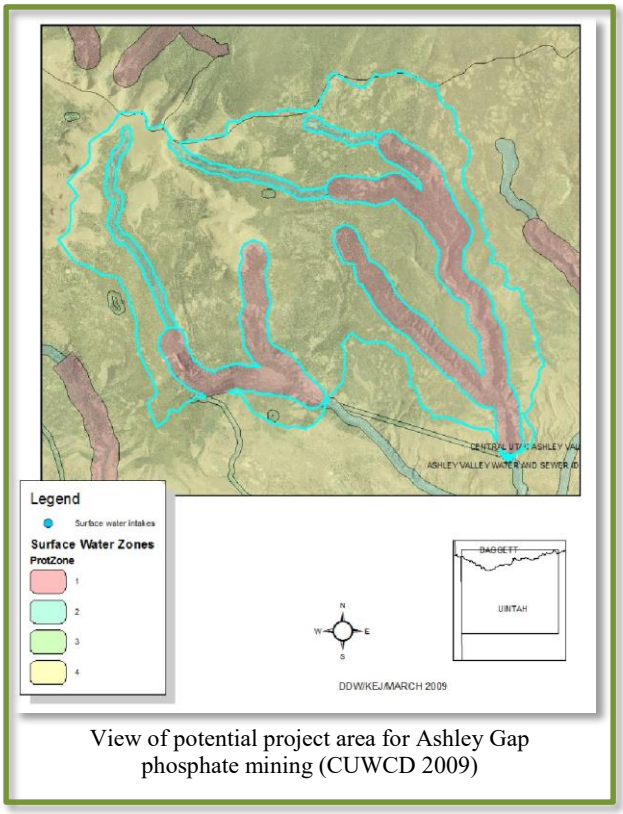
Assess Data Needs—Existing data have been collected, reviewed, and warehoused in spreadsheets for assessment purposes. An existing database that includes hydrologic and water quality data in Ashley Creek and Dry Fork through 2003 has been updated through 2012. Additional land use, topography, weather and other data have been collected. Once existing data are 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 land use in effect in 2009. The Zone 1 protection area (the most critical) is shown shaded in red on the map below, 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 geology 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 FY 15/FY16

- Complete and deploy the 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 suitable plan changes.
- 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, Telephone: (435) 797 3229, Email: david.stevens@usu.edu

Technical Support for Bear River System Data Acquisition

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

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

Project Description

- **Need and Purpose:**

  This project provides 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 and provides field and analytical support for the Middle Bear River, Little Bear River, the Logan River, and Spring Creek water quality monitoring stations. The stations comprise a complete basin-wide network for assessment of nutrient loads and other water quality measures for Cutler Reservoir and the Cutler Reservoir TMDL implementation. Previous work supported monitoring in Mud Lake (near 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 a successful graduate student dissertation, two manuscripts submitted for publication, and 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, providing needed insight for sediment transport in the Bear River Basin, other parts of Utah, and the Intermountain West region. Two bathymetric studies of Mud Lake (2009 and 2014) have helped to determine sediment accumulation 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.
- Continued development of 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.
- Completed publications for Mud Lake statistical learning theory model of sediment loading. Three papers have been accepted in Environmental Engineering Science, and the ASCE Journal of Environmental Engineering.
- 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.
- Completed of 2nd Mud Lake Bathymetric data collection in July 2015.

Work Plan FY15/FY16

This project was completed in 2015 with completion of the bathymetric study report.

Informational Resources

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

Website: http://www.bearriverinfo.org

Publications:

Batt, H.A., (*). 2015. Can Suspended Fine Sediment Transport in Shallow Lakes Be Predicted Using MVRVM With Limited Observations? *J. Environ. Engrg*. Div., ASCE. DOI: 10.1061/(ASCE)EE.1943-7870.0001003.

Batt, H.A., (*). 2014. How to Utilize Relevance Vectors to Collect Required Data for Modeling Water Quality Constituents, and Fine Sediment in Natural Systems? Case Study: Mud Lake, Idaho. *J. Environ. Engrg.* Div., ASCE. DOI: 10.1061/(ASCE)EE.1943-7870.0000858.

Batt, H.A., (*). 2013. Relevance Vector Machine Models of Suspended Fine Sediment Transport in a Shallow Lake - I -data Collection. *Environ. Engrg. Sci*. 2012WR012866.

Water Allocation and Salinity Issues of the Sevier River Basin

Principal Investigators:
Jagath J. Kaluarachchi
Daeha Kim (PhD 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 and 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 produced from spring runoff of winter snowfall. 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 usually occurs in May and June. Since the expected spring runoff is estimated using prior year 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 using early spring snowfall measurements.

- **Benefits to the State:**

  Given the importance 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, 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: Some gauging stations in the main channel of the Sevier River do not represent natural flow due to flow alterations and reservoir operations, making it difficult to calibrate a hydrologic model using altered streamflow data directly. We used natural flow generated by regionalization methods for ungauged watersheds to compute water use and level of alteration by comparing generated natural flow with observed data. This FDC method uses the current precipitation index in lumped and distributed tank models combined with a 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: A radiance use efficiency (RUE) based RS model for estimating aboveground biomass (AGB) with Landsat images and regional crop information was developed. 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. Phase 3: Worked to develop a hydro-economic analysis to identify the farmer profitability in pre-season decision making under the conditions of variable crop prices and yields. This approach of considering price and yield variability has not been undertaken in prior research studies and could be very valuable for farmers in preseason decision-making.

Results: Variable crop prices and yields are practical difficulties in developing land and water allocation strategies using a hybrid framework of hydro-economic analysis. Phase 3 used a novel approach to overcome the difficulties by incorporating variable crop prices and yields into a risk-based economic model. The FAO AquaCrop and a simple linear regression model were used to quantify crop yields, prices, and variability through standard deviations. The economic model integrated the agro-hydrologic and economic components to provide single-season land and water allocation strategies for salinity-affected farms in south central Utah.

The hydro-economic analysis produced alfalfa dominant land and water allocations when surface water is sufficiently available. As more surface water was available, more alfalfa cultivation was recommended due to the high prevailing price and low production costs of alfalfa. Under a limited surface water volume, the recommendation is to rent water rights to farms with soils having high maize productivity. This risk-averse behavior leads to land and water allocation strategies with less variable profits. Also, salinity stress severely degrades water productivity. In general, the novel framework proposed in this study provides resource allocation strategies with simultaneous consideration of crop prices, yields, and variability so that producers do not need to confront several price or climate scenarios for their decision-making. With an estimate of surface water availability, producers can obtain corresponding land and water allocation strategies that reflect variable crop prices and yields.

Work Plan FY15/FY16

The work on this project is completed.

Informational Resources

Contact: Dr. Jagath J. Kaluarachchi, Phone: (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	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Improving Stream Flow Forecasting	$ 40,290.32	$ 43,670.27	$ -
Labyrinth Weir Research	$ 47,810.13	$ 49,244.43	$ -
Open Channel and Closed Conduit Field Flow Measurement, Maintenance, and Upgrade for the State of Utah	$ 11,620.62	$ 11,969.24	$ 13,484.66
Physical Model Study of the Weber Basin Bifurcation Structure	$ 2,108.00	$ -	$ -
Sediment Management for Small Reservoirs: Logan First Dam Study	$ 1,695.77	$ 1,746.64	$ 1,799.04
Designated Projects		$ 20,500.00	$ 10,500.00
Undesignated Projects		$ 10,000.00	$ 5,000.00
Total	**$ 103,524.84**	**$ 137,130.58**	**$ 30,783.70**

Improving Stream Flow Forecasting

Principal Investigators:
Andres M. Ticlavilca
Mac McKee

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Climate change and extreme climatic events will require adaptations in behavior and decision-making, either in response to or in anticipation of new conditions. Appropriate responses to change will be more effective if better information about future water resources conditions are available, including information about future stream flow quantities and timing. Since irrigated agriculture in the state of Utah depends heavily on adequate water supplies and related water rights administration, accurate and timely knowledge is critical to effective adaptation to climate variability in order to preserve resilient, vital rural economies. Hence, accurate long-term forecasts of future precipitation and stream flow quantities can be of great potential economic value in Utah, especially to the agriculture industry. 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 such as occurred in the spring runoff period of 2011. Previous work (FY13/FY14) tested short- and long-term streamflow forecasting based on statistical methods and advanced modeling approaches such as machine learning models and wavelet decomposition. The results of this work showed that short- and long-term stream flow forecasting can be improved in Utah with the use of advance modeling approaches. A wavelet cross correlation was proposed for the next step of the project (FY14/FY15). These new methods are able to incorporate important information from trends of the climate time series into models that learn these patterns to produce improved streamflow predictions at different time scales.

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: Cache County, Sevier River Basin, Uinta 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 improved in Utah by a significant percentage with the use of the advance modeling approaches such as those developed by this project.

  Results: Products generated by the project this year include:

  - Significant improvements in the technology to provide short- and long-term forecast of stream flow in Utah.
  - The results of this project were presented at the 2015 AGU Joint Assembly Meeting, Montreal, Canada.
  - A peer-reviewed journal paper was published in Hydrological Processes.

Work Plan FY15/FY16

Proposals for external funding to extend the methodology in order to make it of greater benefit to the state.

Informational Resources

Contact: Andres M. Ticlavilca, Phone (435) 757 0851, Email: andres.ticlavilca@usu.edu

Publication:

Maslova, I., A.M. Ticlavilca, and M. McKee (2015). Adjusting wavelet-based multiresolution analysis boundary conditions for long-term streamflow forecasting. *Hydrological Processes*. DOI: 10.1002/hyp.10564

Presentation:

Ticlavilca, A.M., I. Maslova, and M. McKee (2015). Wavelet-based cross-correlation analysis of Pacific Ocean climate data and streamflow for long-term streamflow forecasting. *AGU Joint Assembly Meeting*, Montreal, Canada.

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. In many cases, the goal of reservoir flood routing is to maximize the outflow discharge using highly efficient flow control structures such as labyrinth weirs in order to maximize dam safety and minimize upstream flooding. In some cases, the maximum outflow through the spillway should be limited during more frequent lower-magnitude flood events to minimize downstream flooding impacts. This study included work on (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.

  1) Labyrinth weir hydraulic inefficiencies have been attributed to the colliding flows at the upstream apex (typically a trapezoidal weir wall geometry in plan view). The apex width should be sufficiently wide to be "constructible" (sufficient room for concrete form work) while mitigating overall weir length reduction with wider apexes. Laboratory tests were conducted to evaluate the influence of apex geometry variation on hydraulic efficiency.
  2) Under certain conditions, the water jet (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 and negative environmental impacts. Laboratory tests are developing a better understanding of nappe vibration behavior and mitigation methods.

- **Benefits to the State:**

  The results of this study may provide spillway upgrade alternatives and prove useful in increasing the sustainability of existing dams with undersized spillways. Labyrinth weirs are a commonly used alternative to a linear weir 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 currently 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 effects of weir type (linear ogee crest weir, labyrinth weir, staged labyrinth weir) on peak reservoir outflow discharges were evaluated using a numerical flood routing computer model and a generic reservoir. Results found 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. This paper was submitted in 2014 and resubmitted to a different journal in 2015 for review.

(b) Two peer reviewed journal papers evaluating the effect of labyrinth weir apex width on discharge efficiency will be completed and submitted in 2015-16.

(a) Two peer reviewed papers were under development regarding unstable nappe flow behavior in collaboration with the University of Liege, Belgium in 2015. The papers will be submitted in 2015-16 for review.

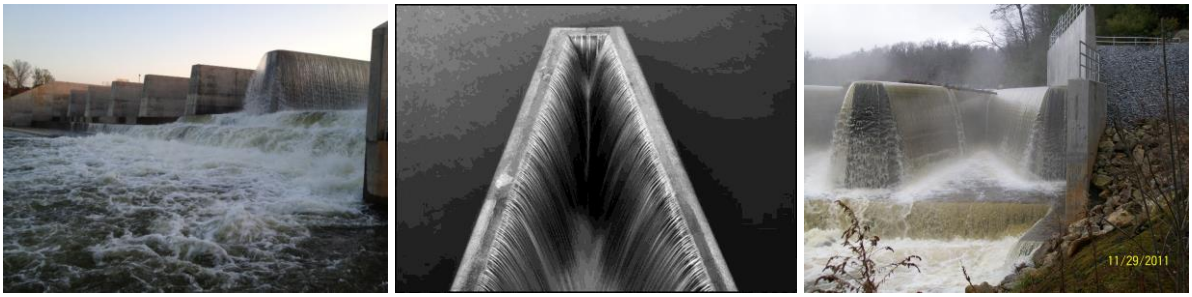
(b) New unstable nappe flow behavior research was conducted in 2014-15. Using the Particle Image Velcometry system, the air flow patterns in the air cavity behind the nappe were investigated, specifically near the crest. A unique velocity profiling test was set up inside the nappe where the free water surface acted as a reflective boundary and projected the laser light and data collection beyond the direct line of sight of the laser. Three peer reviewed journal papers are currently underway and will be submitted in 2016.

Work Plan FY15/FY16

In FY16, we will primarily focus on evaluating size-scale effects for linear and non-linear weirs. As the size scale decreases, the relative influence of surface tension and viscous effects become more significant, relative to the usually dominant gravitational and inertial forces that drive free-surface flow problems. We hope to identify the effects of model scale on head-discharge relationships, nappe trajectory, and air entrainment for a variety of laboratory scale models. The largest weir models will be 3 ft tall and will represent the prototype scale. All other weirs will be geometrically similar at smaller scales.

Informational Resources

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



(a) **(b)** **(c)**

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 245 flow measurement device assessments have been performed as of August 21, 2015. These devices include 141 Parshall flumes, 21 ramp flumes, 4 cutthroat flume, 28 weirs, 27 rated sections, 5 sluice gates, 11 ultrasonic meters and 5 magnetic meters. Only 31.4% of the tested devices measured flow within manufacturer design specifications. The remaining 68.6% 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 FY15/FY16

- 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, Telephone: (435) 797 3214, Email: steve.barfuss@usu.edu.
Mr. Jordan C. Jarrett, Telephone: (435) 797 3231, Email: jordan.jarrett@usu.edu.

Examples of Flow Measurement Devices Tested in Utah

Physical Model Study of the Weber Basin Bifurcation Structure

Principal Investigators:
Steven L. Barfuss
Zac Sharp
Brad Clawson

Partners/Collaborators:
- ***State:*** *Jeremy Williams, Carollo Engineers, Inc. Salt Lake City, Utah*

Project Description

- **Need and Purpose:**

  A physical model study of the Weber Basin Water Conservancy District's (WBWCD) water supply bifurcation structure was performed at the Utah Water Research Laboratory (UWRL) in order to (1) provide a means for evaluating the capacity of the initial USBR design, (2) observe the conditions under which air is most likely to be entrained into the Weber and Davis Aqueducts, and (3) to investigate structure operational procedures and potential modifications to the structure that might improve the hydraulic performance of the bifurcation. As part of the physical model study, structure head loss characteristics were examined under a wide range of operating conditions (including the USBR design conditions) to determine the conditions that minimized head losses and air entrainment. A few structural modifications were also tested in an effort to further reduce the possibility of air becoming entrained in the WBWCD system.

- **Benefits to the State:**

  The Weber Basin Water Conservancy District has found that the Davis Aqueduct (which runs south along the Wasatch front in an 84-inch pipeline for a distance of 22 miles) and the Weber Aqueduct (which carries water in a 48-inch pipeline to the north from the bifurcation structure) do not reach their design capacity. The Gateway canal carries Weber River water to the Gateway tunnel on the East side of the Wasatch Front. A bifurcation structure is located at the outlet portal of the Gateway tunnel to distribute water to each aqueduct. Since the observed capacity of the Davis Aqueduct (292 cfs) is significantly lower than its design capacity of 355 cfs, it appears that this aqueduct, which seldom runs full, is experiencing some air binding downstream of the bifurcation. The Weber Aqueduct occasionally runs full; however, this aqueduct has also seen notable reductions in flow capacity from its design point of 80 cfs to 67 cfs. A physical model was used to document the problem and then find viable solutions for operation that would increase the capacity of each aqueduct.

- **Geographic Areas:**

  Study Area: Weber Basin Water Conservancy District.

  Areas Benefited: Weber Basin Water Conservancy District.

- **Accomplishments**:

  Findings: The model study showed that the bifurcation structure has sufficient capacity to meet the design flows to both the Weber and Davis Aqueducts. However, it was determined that the operation of the structure significantly affects the actual capacity. Using the data presented in the

study, efficient operational scenarios can be developed that maximize the capacity of the system. Model results also demonstrated that certain water levels in the structure draw much more air into the aqueducts than other water levels and that care should be taken to avoid certain hydraulic conditions.

Results:

- Members of the WBWCD observed the physical model operating conditions that will improve the capacity of the Davis and Weber Aqueducts by reducing the amount of air being drawn into the each pipeline.

- A test report was provided to Carollo Engineers in SLC, UT, documenting model study results.

Work Plan FY15/FY16

The study has been completed.

Informational Resources

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

Physical model study of the Weber Basin Water Conservancy District's bifurcation structure

Sediment Management for Small Reservoirs: Logan First Dam Study

Principal Investigators:
Amber S. Jones
Mac McKee

Partners/Collaborators:
- ***Local:*** *Ben Barrett 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. This method, however, can severely damage 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 to 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 FY 15/FY16

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 2016. 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, Telephone: (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	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Education Program for Homeowners and Other Users of Septic Systems in Utah	$ 14,223.20	$ 16,422.02	$ 16,914.68
Intermountain Section American Water Works Association (IMS-AWWA) Scholarship and Student Outreach Committee	$ 2,033.58	$ 2,094.59	$ 2,157.43
Manuals for On-Site Wastewater Treatment Best Practices	$ 11,899.55	$ 12,256.54	$ 12,624.23
Salt Lake Valley Solid Waste Management Council	$ 2,057.55	$ 2,119.27	$ 2,182.85
State of Utah Drinking Water Board	$ 4,175.96	$ -	$ -
Statewide Nutrient Criteria Development: Core Advisory Team	$ 1,190.00	$ -	$ -
Support for State Watershed Modeling and TMDL Plans:Tools to Assist in Nutrient Criteria Development Using QUAL2Kw	$ 2,600.56	$ 3,904.28	$ 4,021.41
Utah On-Site Wastewater Treatment Training Program	$ 11,899.55	$ 12,256.54	$ 12,624.23
Weber-Morgan Health Department Wastewater Advisory Committee	$ 1,720.51	$ -	$ -
Designated Projects		$ -	$ -
Undesignated Projects		$ 7,500.00	$ 7,500.00
Total	**$ 51,800.46**	**$ 56,553.24**	**$ 58,024.83**

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

Principal Investigators:
Judith L. Sims

Partners/Collaborators:

- ***Local:*** *Utah Local Health Departments*
- ***State:*** *Utah Division of Water Quality, Utah Department of Environmental 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. Effective educational tools for ensuring that septic systems are adequately operated and maintained would help the users to better understand their role in protecting public health and the environment. If septic system users had information focusing on their responsibilities for their septic systems as personal wastewater treatment plants, they would be better prepared to fulfill their roles as environmental stewards, and 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 were 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.

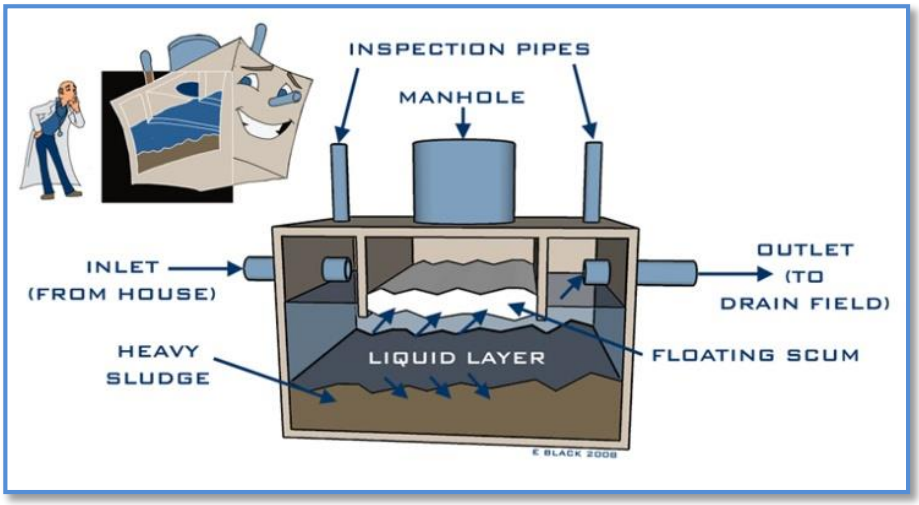
Results: Based on our investigations, we identified the following topics as essential for our educational program:

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

During FY14/FY15 we began developing and writing the documents and presentations associated with the topics identified as being critical.



Work Plan FY15/FY16

During FY15/FY16, 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 and 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.

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: 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.

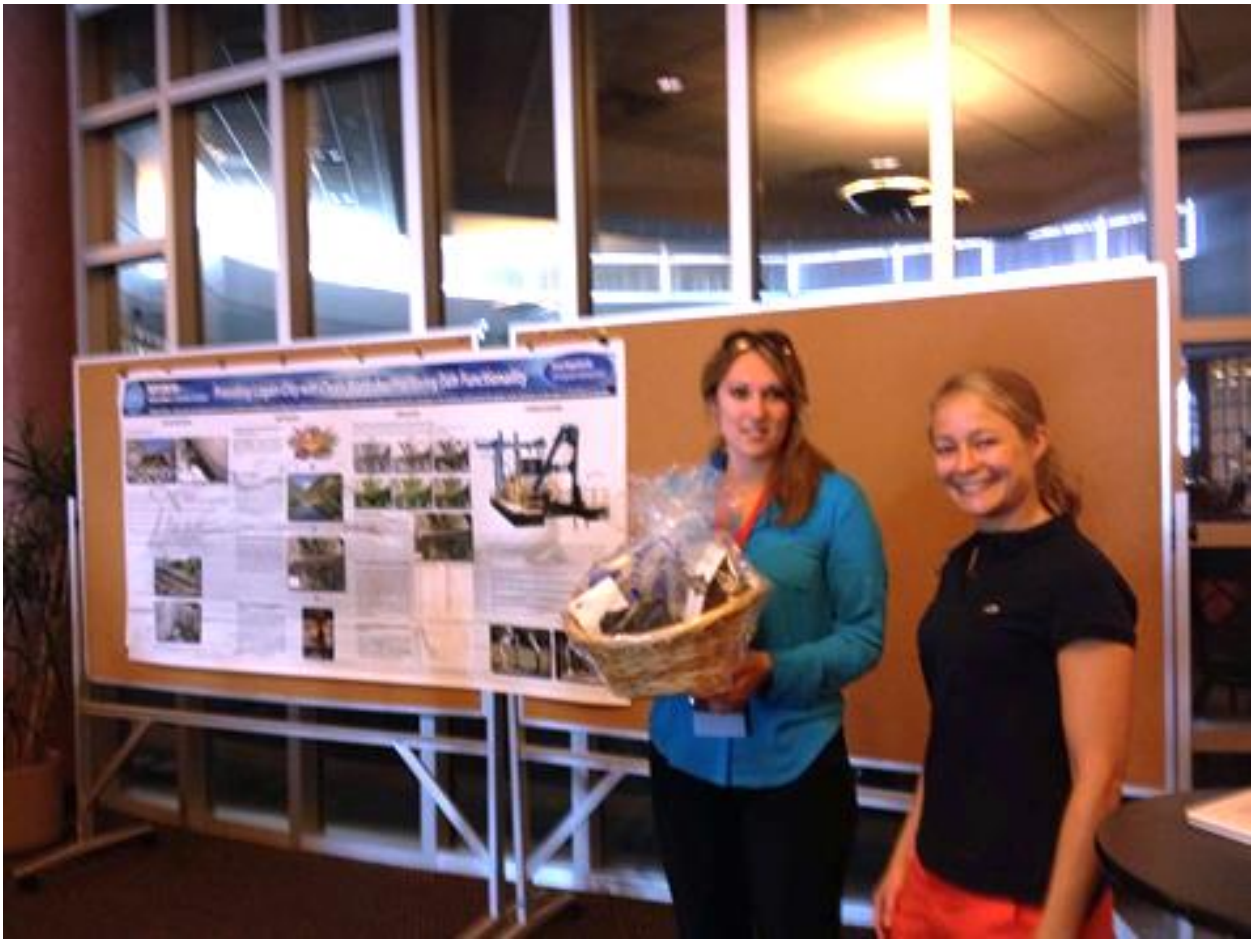
  Areas Benefited: Statewide—students at any college or university in Utah or southern Idaho are eligible.

- **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 2014 semester. Two students are studying at Utah State University, one at BYU, and one at University of Utah. A total of 15 applications were received this year. The Fresh Ideas poster contest was also a great success. The winner received funding to present her poster at the national AWWA conference in Anaheim CA in June 2015.

Work Plan FY15/FY16

Participation in IMS-AWWA meetings and activities will continue. At least four scholarships will be awarded in Fall Semester 2015, and the Fresh Ideas Poster Contest will take place on September 17-18, 2015 in Logan UT.



Winner of the 2014 Fresh Ideas Poster Contest

Informational Resources

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

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

Manuals for On-Site Wastewater Treatment Best Practices

Principal Investigators:
Judith L. Sims

Partners/Collaborators:
- ***State:*** *Engineering Section, Utah Division of Water Quality, Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

  In this project, we are developing best practice manuals for various aspects of on-site wastewater treatment methods and technologies. These manuals will enhance training workshops presented by the Utah On-Site Wastewater Treatment Training Program at Utah State University in support of the Utah mandatory certification program for on-site wastewater professionals (R317-11: *Certification Required to Design, Inspect and Maintain Underground Wastewater Disposal Systems, or Conduct Soil Evaluations or Percolation Tests for Underground Wastewater Disposal Systems*). These manuals will also serve as stand-alone guidance and educational tools.

- **Benefits to the State:**

  Expected benefits to Utah 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, nitrogen, and phosphorus) to ground water or through watershed base-flow to surface waters. High-quality and thorough educational materials will help Utah on-site professionals to develop and implement tools to reduce the flow of contaminants to water bodies from on-site systems.

- **Geographic Areas:**

  Study Area: Statewide.

  Areas Benefited: Entire State of Utah.

- **Accomplishments:**

  Findings: Three manuals, which reflect Levels 1, 2, and 3 of the certification program, are being prepared:

  1. Best Practices: Site and Soil Evaluation Procedures and Evaluation Techniques—Topics include soil evaluation procedures, identification of other critical site features and requirements, assessment of site feasibility, and guidance on the appropriate use of percolation testing in selected situations.

  2. Best Practices: Design, Installation, Inspection, and Operation & Maintenance of Conventional On-Site Wastewater Treatment Systems—Topics include septic tank selection, installation, and maintenance, absorption field distribution options (including pros and cons

of each type), design and installation of absorption systems (standard trenches, chambered trenches, bundled synthetic aggregates), absorption beds, deep wall trenches, and seepage pits, sizing and layout of systems, inspection of systems, and operation and maintenance of systems.

3. Best Practices: Design, Installation, Inspection, and Operation & Maintenance of Alternative On-Site Wastewater Treatment Systems—Topics include selection of the appropriate alternative system with regards to site and soil limitations, design guidance, installation, and maintenance considerations, inspection of systems, and operation and maintenance of systems.

Best practices are being developed from Utah regulatory materials, present Utah Training Program educational materials and tools, U.S. Environmental Protection guidance materials, and educational materials developed by the Consortium of Institutes for Decentralized Wastewater Treatment. The manuals developed through this project will focus on Utah regulations, practices, and needs.

Results: During FY14/FY15, we researched, developed, and outlined the topics that will be included in the manuals. We also began developing design worksheets, recording sheets for site and soil information, installation and inspection checklists, and operation & maintenance checklists. These worksheets and forms are being prepared specifically to address Utah guidance and practices.

Work Plan FY15/FY16

During FY15/FY16, we will complete the manuals of best practice and distribute two reference copies of each document to each of the thirteen Utah health departments and to the Utah Division of Water Quality on-site program. The documents will also be made available on-line through the USU Training Program web site.

Informational Resources

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

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, Debbie Lyons, Vicki Bennett, Salt Lake City Public Works; Dorothy Adams, 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 long-term environmental stewardship, financial integrity, safety, recycling education, and quality service to benefit the environment, residents, businesses, and employees of Salt Lake County.

  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 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 in the running of 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 review of proposals and development (FY2013/FY14) of a laboratory study investigating the impact of MSW shredding on solid waste compaction, degradability and methane production; investigation of 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; and analysis of the connection between curbside green waste collection and water quality impacts to the Jordan River from urban stormwater from 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 FY14/FY15 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, green waste collection/stormwater impacts, and cost of services analyses.

Work Plan FY15/FY16

Continue involvement in decision-making through attendance at monthly SLVSWMF Council meetings and respond to special project requests as they arise to support the SLVSWMF's mission and goals. Continue the evaluation of green waste management and urban stormwater pollutant generation and development of stormwater pollutant loading data to support analysis of curbside green waste program operations.

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 for drinking water management, as well as oversight of state and federal revolving loan funds, 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, 2014 to June 30, 2015, 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 FY15/FY16

Continued involvement on the Board through 2018.

Informational Resources

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

Website: http://www.deq.utah.gov/boards/drinkingwater/index.htm.

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 nutrient criteria for the waters of the state (http://www.nutrients.utah.gov/index.htm). The policy and procedures 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 USDA Forest 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 criteria 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: The Division of Water Quality has promulgated a Technology-Based Phosphorus Effluent Limits Rule (R317-1-3.3) and is in the process of formalizing numeric nutrient criteria for Utah's headwater streams. 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 other ecosystems of the state.

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 FY16.

Informational Resources

Contact: Dr. Darwin L. Sorensen, Telephone: (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, watershed and/or instream water quality models are 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. My role is 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 presentation and paper were prepared to communicate effective methods of model calibration for use within the TMDL program.
  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 published in the Journal of Water Resources Management and Planning in 2014 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 will be submitted to the Journal of Environmental Engineering.

Results:
Jordan River Temperature Modeling/Statewide Wasteload Allocation/Numeric Nutrient Criteria Studies: Data collection and the associated instream water quality modeling for nine streams below various wastewater treatment plants throughout the state was completed. The models were used to assist in determining their utility in developing nutrient criteria. They have also been used in the development of wasteload 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

This work is now complete.

Informational Resources

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

Representative Publications/Presentations:

Jordan River TMDL Model Review

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.

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, N. von Stackelberg, M. Shupryt, J. Ostermiller, G. Pelletier, and S.C. Chapra (2014). Development of minimalistic data collection strategy for QUAL2Kw. *Journal of Water Resources Management and Planning*, 10.1061/(ASCE)WR.1943-5452.0000488, 04014096. Posted online 11 Nov 2014.

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

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.

von Stackelberg, N.O., B.T. Neilson, and 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.

Utah On-Site Wastewater Treatment Training Program

Principal Investigators:
Judith L. Sims
Margaret Cashell
Brian Cowan
Richard Jex

Partners/Collaborators:

- ***Local:*** *Utah's 13 Local Health Departments; Utah On-Site Wastewater Association (UOWA)*
- ***State:*** *Division of Water Quality, Utah Department of Environmental Quality; Council of Local Environmental Health Directors (CLEHA)*

Project Description

- **Need and Purpose:**

  The Utah On-Site Wastewater Treatment Training Program was established in January 1998 in cooperation with the Utah Department of Environmental Quality (DEQ) and the thirteen Utah local health departments. It provides classroom and field (hands-on) training to Utah homeowners, regulators, designers, installers, pumpers, and other stakeholders in on-site wastewater treatment systems.

  Adequately protecting environmental health and enhancing user satisfaction are achieved through knowledgeable selection, competent design, correct installation, and proper operation of on-site systems. Applying the right technology in the right place requires accurate information and up-to-date training. Landowners, homeowners, developers, lenders, installers, regulators, planners, municipal authorities, and elected authorities are all stakeholders in Utah on-site issues and must have current information and training to address these matters responsibly.

  Utah will continue to grow, and as housing developments continue to expand into current open space, such developments may include areas of groundwater recharge, shallow soils, or shallow ground water. Current Utah rules allow the use of conventional septic tank systems, as well as eight alternative treatment systems that may be installed in areas where soils are unsuitable for conventional systems. Training those involved in the use of both conventional and alternative systems will ensure that these systems will work correctly.

- **Benefits to the State:**

  Continued population growth, along with associated housing developments, creates an increased need for accurate and thorough information regarding on-site wastewater treatment technologies. The Utah On-Site Wastewater Treatment Training Program addresses these challenges through such means as workshops and participation in educational conferences. Many of the soils in Utah are marginal or unacceptable for the use of conventional soil absorption systems due to high or fluctuating water tables, slowly permeable or highly permeable soil horizons, and extreme slopes, thus requiring the use of more advanced alternative systems. The On-Site Training Program provides the necessary education to utilize conventional and alternative systems in an effective manner that will protect both public health and the environment.

- **Geographic Areas:**

  Study Area: Entire State of Utah.

Areas Benefited: The entire state (29 counties and 13 local health departments).

- **Accomplishments:**

  Findings: A state legislative initiative introduced and passed as House Bill 14s during the 2001 Legislative Session mandated a certification program for persons involved in siting, designing, operating, and maintaining both conventional and alternative on-site systems. The certification program, administered by the Division of Water Quality in the Utah DEQ, involves mandatory training provided by the Utah On-Site Wastewater Treatment Training Program.

  The certification program includes three levels, each of which requires workshops and testing provided through the Utah Training Program: (1) Level 1: Soil Evaluation and Percolation Testing, (2) Level 2: Design, Inspection, and Maintenance of Conventional Systems, and (3) Level 3: Design, Operation, and Maintenance of Alternative Systems.

  Workshops are also provided for renewal of certification, as Level 1, Level 2, and Level 3 certifications expire after 3 years.

  Results: During FY 2014–2015 , two Level 1 workshops, two Level 2 workshops, and two Level 3 workshops were taught at various locations around the State of Utah, including Park City, Price, and Logan, as well as two Level 1 renewal workshops, two Level 2 renewal workshops, and two Level 3 renewal workshops.

Work Plan FY14/FY15

We will continue to provide workshops through FY2019/FY2020 in support of the mandatory State of Utah certification program for on-site wastewater professionals.

Informational Resources

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

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

Publications:

Sims, J.L., M. Cashell, B. Cowan, and R. Jex (2014, 2015). *Course Manuals for Levels 1, 2, and 3 Certification*. Utah Water Research Laboratory, Utah State University, Logan, UT.



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 (1) scientific, technical, and socioeconomic information to the Health Department staff that will inform their decisions and (2) 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 be used as guidance by 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 considered 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 of steeply sloped properties high in the Ogden River watershed.

Work Plan FY14/FY15

It is anticipated that Dr. Sorensen will continue to serve as member of the committee in FY16.

Informational Resources

Contact: Dr. Darwin L. Sorensen, Telephone: (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	FY2015 Actual Expenditures	FY2016 Budgeted Expenditures	FY2017 Planned Expenditures
Aggie Air Imagery Information Pipeline Improvements	$ 75,830.42	$ 78,105.33	$ -
Allocating Scarce Water for Utah Wetlands with Ecological Uncertainties	$ 31,889.45	$ 32,846.13	$ -
ASR Optimization Protocol and Decision Support	$ 19,399.98	$ 19,981.98	$ -
Bird Nest Aquifer Saline Injection Simulation, Optimization, and Economic Impact	$ 26,429.62	$ 27,222.51	$ 28,039.18
Crop Water Demand Monitoring and Forecasting	$ 7,921.61	$ 8,159.26	
Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management	$ 240,450.33	$ 247,663.84	$ 95,436.24
Evaluating Restoration Efforts Using Imagery from an Unmanned Aerial Vehicle (UAV)	$ 24,161.01	$ 24,885.84	$ -
Evaluation of Water Rights and Allocations on the Logan River	$ 8,391.80	$ -	$ -
Gain-Loss Study on the San Rafael River, South Central Utah	$ 37,769.98	$ 5,900.00	$ -
High Frequency Data and Cyberinfrastructure Tools to Investigate Instream Processes and Integrate High Resolution Modeling in Snowmelt Dominated Watersheds	$ 48,429.39	$ 49,882.27	$ -
Hydraulic and Thermal Characteristics in and Around Complex Habitat Structures in the Lower San Rafael River, South Central Utah	$ 11,866.55	$ 11,866.55	$ -
Impact of Urban Irrigated Agriculture on Utah's per capita Water Use	$ 30,835.68	$ 31,760.75	$ -
Improving Hydrologic Model Predictions and Modeling Technology	$ 11,037.69	$ -	$ -
Irrigation System Water Use Efficiency Using Field Evaluations and Remotely Sensed Evapotranspiration Estimates	$ 24,641.33	$ -	$ -
iUTAH - Innovative Urban Transitions and Arid Region Hydro-Sustainability	$ 112,679.13	$ 116,059.50	$ 119,541.29
Low Cost Vertical Take Off and Landing Remote Sensing Systems for Water Engineering	$ 189,526.46	$ 195,212.25	$ -
Near-Real-Time Orthorectification and Mosaicking of UAV Images	$ 26,148.85	$ 26,933.32	$ -
Organizing and Synthesizing Water Management Data to Speed Modeling	$ 21,387.55	$ 22,029.18	$ -
Quantifying the Flow Field in Baffled Fish Culverts	$ 8,138.49	$ 8,382.64	$ -
Real-Time Management of Irrigation Systems in the Sevier River Basin	$ 185,680.42	$ 191,250.83	$ -
UAV Remote Sensing Service Center	$ 136,506.32	$ 140,601.51	$ 52,744.68
Water Resources Modeling for Utah's Cache Valley	$ 32,975.85	$ 33,965.13	$ -
Designated Projects		$ 582,600.00	$ 91,537.12
Undesignated Projects		$ 213,626.50	$ 10,500.00
Total	**$ 1,312,097.91**	**$ 2,068,935.32**	**$ 397,798.51**

AggieAir Imagery Information Pipeline Improvements

Principal Investigators:
Todd Moon
Calvin Coopmans (Postdoc)

Partners/Collaborators:
State: *Utah Department of Environmental Quality*

Project Description:

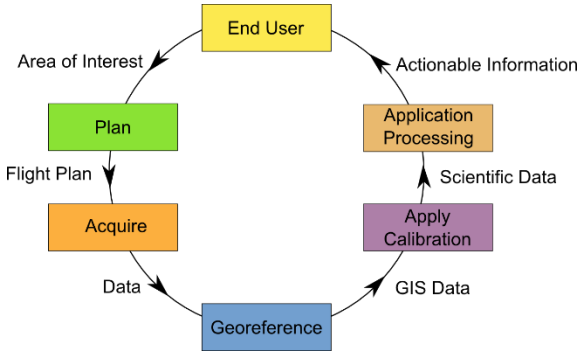
- **Need and Purpose:**

  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 orthrectification 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 project 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.



- **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.

- **Geographic Areas:**

  Study Areas: Statewide.

  Areas Benefited: Statewide.

- **Accomplishments:**

  Findings: Having better information about the true path the scientific cameras take during a flight mission is the overall solution to the pipeline and data quality problems. In this research, the first area for aircraft improvement is the information about the camera position and orientation provided by the navigation system; second is better correlation of the camera shutter timing with the navigation data; and third is a greater frame rate from cameras, which will provide more and better data about terrain covered by the imagery.

  Results: Addition of an improved inertial navigation system on the AggieAir craft has allowed vastly improved estimations of camera position during flight, and has directly contributed to the lowering of the time required to deliver usable scientific imagery. Also, an improved camera payload design has allowed the camera shutters to be electronically synchronized with each other as well as the navigation system. These improvements have been shown to speed up the image processing pipeline—currently on the order of 10%, or 2–4 hours speedup per mission overall.

Work Plan FY15/FY16

- Camera shutter speed-up: Due to technical issues with the scientific cameras, shutter speeds need to be increased for advanced estimation techniques such as optical flow to be employed. Work will be done with the camera manufacturer to improve this speed (1 image per second to more than 6 images per second).
- Implementation of advanced image processing algorithms: Once the camera frame rate is better than 4 frames/second it will be possible to use computer vision techniques to improve the camera path estimation and provide yet better estimations of the camera's position during a data collection mission.
- Addition of a high-accuracy (RTK) global positioning receiver: By upgrading and integrating a very high performance GPS receiver into the aircraft, higher-accuracy estimates of the camera's position relative to the ground will make further speedups possible. Currently an RTK receiver from Serpentrio is being evaluated.

Informational Resources

Contact: Dr. 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

Investigators:
David E. Rosenberg
Karin M. Kettenring
Omar Alminagorta, Ayman Alafifi (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 using 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 a federally-funded National Science Foundation (NSF) effort to extend the model into a Watershed Area of Suitable Habitat (WASH) model for the lower Bear River Basin that identifies numerous near-optimal water allocation strategies to improve wetland and riparian performance. Part III includes work for the federally funded iUTAH effort to study water user decisions in canals within the context of the larger coupled hydrologic, natural, and built water system.

- **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:
  - Wetland performance decreases markedly with higher invasive vegetation cover (Figure 1, dark blue squares). At higher cover levels, systems models that look at only the hydrologic habitat needs of priority species may overestimate performance and mischaracterize the relationship between wetland performance and water availability.
  - Refuge managers can double the area of suitable wetland habitat by more dynamically changing water levels, removing invasive vegetation early in the growing season, and partially controlling *Phgragmites* in a larger number of wetland units.

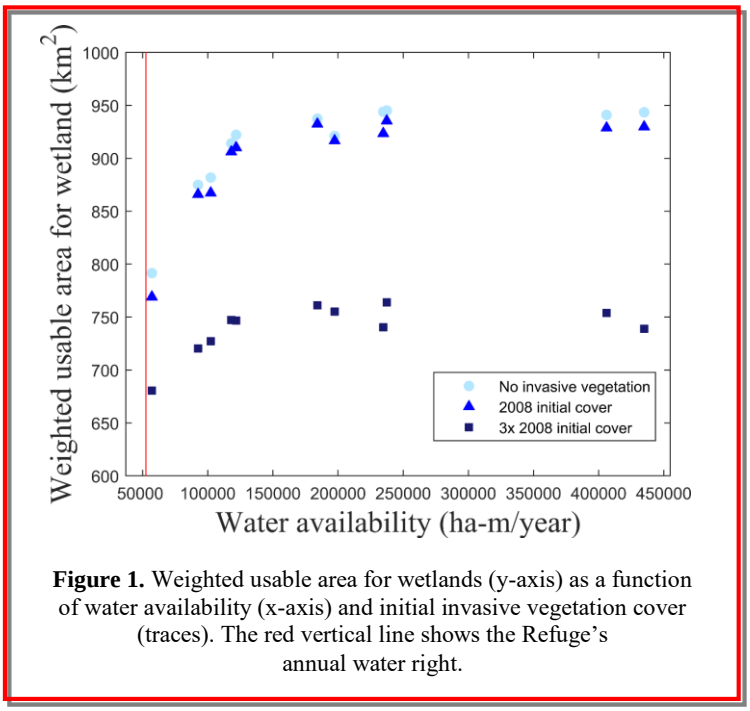


Figure 1. Weighted usable area for wetlands (y-axis) as a function of water availability (x-axis) and initial invasive vegetation cover (traces). The red vertical line shows the Refuge's annual water right.

  - PhD Student Alafifi completed a 3-month internship at ESRI in Redlands, CA where he coupled hydrologic and topologic data available in ESRI's Living Atlas of the World with the WASH model. The resulting maps quantify and show spatial and temporal ecological responses to alterations in flow regimes.
  - Published two articles: (1) "Blended near-optimal alternative generation, visualization, and interaction for water resources decision making" in *Water Resources Research*. 51 (4) 2047–2063. DOI: 10.1002/2013WR014667 http://onlinelibrary.wiley.com/doi/10.1002/2013WR014667/full, and (2) "iSAW: Integrating Structure, Actors, and Water to study socio-hydro-ecological systems," *Earth's Future*, 3(3), 110-132. http://dx.doi.org/10.1002/2014EF000295.
  - Presented near-optimal and Refuge management work at a number of meetings and conferences between Nov, 2014 and April 2015.

Work Plan FY15/FY16

- Share a more user-friendly Refuge model with Refuge managers.
- Complete WASH model for the lower Bear River and solicit feedback on results for stakeholders
- Undertake a third river trip with incoming freshmen Bear River Fellows and work with the Fellows through the year to process collected data and use the data in the WASH model.

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: https://github.com/dzeke/Blended-Near-Optimal-Tools.
Website: http://bearriverfellows.usu.edu/.

ASR Optimization Protocol and Decision Support

Principal Investigators:
Richard C. Peralta
Ali Forghani (MS student)

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. The JVWCD wishes to optimize management of the current 18 extraction/injection-well system. This includes considering economics and the amount of credit the State Engineer grants for water 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 is not extracted by ASR wells. JVWCD thinks it recovers more injectate than it receives credit for, wants accurate recovery estimates, and wants to know how best to inject and extract in time. Addressing these needs requires more accurately quantifying recovered injectate, and optimizing injection/extraction timing, subject to varying water availability, need, and cost. Software for the ASR optimization protocol is also desirable.

- **Benefits to the State:**

  To best integrate available water resource use, Utah water managers increasingly employ aquifer recharge (AR) and aquifer storage and recovery (ASR). Often, treated river water is injected into aquifers in the spring. Groundwater is extracted later when surface flow is low. ASR should be optimized with respect to cost, reliability, and related issues. Considerations are (1) how much injectate the recharging organization can physically recover, (2) how much credit the State Engineer gives the recharging organization, and (3) cost and timing of water need and availability. Optimal ASR strategies are situation-specific, but the development procedure is transferable. This project will aid JVWCD ASR use and promote ASR use by other entities.

- **Geographic Areas:**

  Study Areas: Jordan River Valley (part of Salt Lake County and parts of Utah cities of Bluffdale, Draper, Herriman, Kearns, Magna, Midvale, Riverton, South Jordan, South Salt Lake, Taylorsville-Bennion, West Jordan, White City).

  Areas Benefited: The above Utah cities, parts of Holladay, Sandy, unincorporated county areas, Granger-Hunter Improvement District, Willow Creek Country Club, and the Metropolitan Water District of SL and Sandy. The project aids entities worldwide that want to recharge aquifers thru wells for later extraction, especially if timing of surface water availability does not coincide with water need.

- **Accomplishments:**

  Findings: To accurately estimate recovery, it is necessary to use finer model discretizations than previous published models use. USGS model cells are 1848ft x 1848 ft in area and the smallest CH2MHill model cell in ASR area is 250ft x 250ft x 200ft. Both models use five layers to model principal aquifer. Ch2Mhill model uses uniform annual pumping rates. Our new temporally refined regional groundwater model for 1992–2014 defines transient groundwater levels more accurately by using reasonable transient monthly stresses derived from actual precipitation data, Division of Water Rights supply well pumping estimates, and USGS Modflow models (Lambert 1995 and Stolp 2007). For even greater accuracy, our new transient model for the ASR area that includes all ASR injection and extraction wells uses boundary conditions from the regional model, 154 ft x 154 ft cells, and 2009–2014 monthly stress rates. The most accurate will be the further refined ASR system model that uses 19 model layers to represent the principle aquifer; cells as small as 38 ft x 38 ft x 40 ft near well SLCWCD-8; and initial conditions that are equilibrium heads computed from average 1997–2001conditions (Stolp 2007).

  Results: The refined ASR system model simulates well SLCWCD-8 recovery efficiencies of about 95% if extracting within fifteen months of injection, assuming: (i) initial conditions are the equilibrium heads resulting from average 1997–2001 stresses; (ii) hydrogeologic parameters used within the USGS model; (iii) the SLCWCD-8 well is screened fully in regional model layers 6 and 7 (elevations 3910.1-3480.1 ft); and (iv) other wells pump at 1997–2001 yearly-average rates. For accuracy, we must modify assumptions (iii) and (iv).

Work Plan FY15/FY16

- Provide a better estimate of SLCWCD-8 recovery efficiency by simultaneously simulating monthly-varying pumping at the other study area wells, and considering accurate well screen intervals and partial penetration effects.
- Estimate well SLCWCD-8 recovery efficiency for different storage durations, grid sizes, and dispersivity and porosity values.
- Estimate total and individual recovery efficiencies of multiple ASR wells when operating simultaneously by using transport simulation within the ASR model.
- Perform optimizations using previously developed objective functions and constraints.
- Report results to Jordan Valley Conservancy District. Meet with Jordan Valley Conservancy District.

Informational Resources

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

Bird Nest Aquifer Saline Injection Simulation, Optimization, and Economic Impact

Principal Investigators:
Richard C. Peralta
Rick Lyons (MS student)
Saeid Masoudiashtiani (MS student)

Partners/Collaborators:
State: *Michael D. Vanden Berg, P.G., Utah Geological Survey*

Project Description:

- **Need and Purpose:**

  Agencies are concerned about possible impacts of dramatic increases in Uintah Basin petroleum production. Oil and gas extraction also produces saline water. From 2001 to 2011, natural gas, crude oil, and saline water production increased 208%, 160%, and 86%, respectively. The proposed 25,000 petroleum wells in the Basin would produce a huge saline water volume requiring disposal. The preferred disposal method is subsurface injection. Gas producers propose to increase saline water injection into the Birds Nest Aquifer (BNA), which lies within the oil shale horizon and has solid hydrocarbon gilsonite veins that can affect groundwater flow. Within the BNA, the Gilsonite distribution and its effect on horizontal or vertical groundwater flow are not well known. The northwestern part of the BNA is eligible for saline water injection because current concentrations exceed 10,000 mg/L total dissolved solids (TDS). The southeastern BNA is not eligible for injection because it has less than 10,000 mg/L TDS. The Utah Geological Survey (UGS) and US Bureau of Land Management (BLM) think injection might harm existing groundwater supply wells, increase fresh water spring discharge, cause saline springs that contaminate surface waters, and harm gilsonite mining by flooding. No appropriate study models of area groundwater flow and contaminant transport are available to provide guidance to decision makers. Predicting injection impacts requires both porous and fractured media flow models, and predicting salinity concentrations requires a calibrated transport model.

- **Benefits to the State:**

  The project will provide critically needed information for Utah energy-development decisions having large economic, environmental, social, and political ramifications. This study will provide optimal safe saline injection strategies for collaboratively formed management scenarios for the Utah Division of Oil, Gas, and Mining (UDOGM), Utah Geological Survey (UGS). Each strategy is a spatial/temporal distribution of injected saline water, developed via a simulation-optimization (S-O) model that links simulation models and optimization algorithms. We will simulate to predict consequences and economic impacts of jointly formed predictive scenarios. A sample scenario maximizes 20-year injection at candidate wells, without causing excessive fresh water spring discharges, saline discharge at springs feeding surface waters, southward movement of 10,000 TDS fresh-saline water interface, and domestic well impacts. Collaborator interaction will help assure practical use of results, which will aid sustainable, safe development of Uintah Basin water and energy resources.

- **Geographic Areas:**

  Study Areas: Uintah Basin (Uintah, Duchesne, Carbon, Grand, Emery, and Wasatch Counties, and the cities of Vernal and Duchesne.

  Areas Benefited: Uintah Basin, primarily Uintah and Duchesne Counties, and Vernal and Duchesne. Developed method is applicable worldwide.

- **Accomplishments:**

  Findings: The UGS, UDOGM, Utah Department of Natural Resources (UDNR), and Utah Division of Water Rights (DWRi) provided much of the geologic and hydrogeologic information. Although many wells in the Duchesne and Uintah formations have data on groundwater level, model calibration also requires water level, flow, and pumping data. Secondary and intuitive data will be used to supplement the sparse primary data that are available.

  Results: Using data from a modeling report (Holmes and Kimball 1987), we formed a preliminary steady-state one-layer Modflow groundwater flow model of the Birds Nest aquifer in the southeastern Uintah Basin. Despite lacking some Holmes and Kimball data, our model computes flow directions and heads similar to those of Holmes and Kimball (1987). We formulated a 30-layer, 75-row, and 105-column grid for a porous media groundwater flow simulation model representing 11 subsurface Uintah Basin strata. Ten model layers represent the upper and lower BNA strata. Model layer top and bottom elevations are mainly from well construction logs and records. The model has estimated hydraulic parameters and some boundary conditions, such as water levels and discharge into Evacuation Creek.

Work Plan FY15FY16

We will finish reviewing DWRi and UDOGM well data, conduct a hydrogeologic tour, and consolidate estimates of fractures and gilsonite vein locations. We will provide data and prepare a basin porous media groundwater model, calibrate and analyze sensitivity for equilibrium conditions, begin preparing for transient simulation, and form a multilayer fractured flow model.

Informational Resources

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

Crop Water Demand Monitoring and Forecasting

Principal Investigators:
Alfonso Torres-Rua
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 levels is restricted to referential, delayed, and often inadequate data that do not represent actual crop water use. This can lead 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.

  This project is developing a practical, economical, and easy to use actionable information platform, the Crop and Water Monitoring and Information System (CWMIS), to provide near real-time records of crop status (water, yield, irrigation management). The information 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 Landsat satellite information for Utah, and web mapping technologies made available to users for immediate access.

- **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 efficiency and minimize over-irrigation. At the irrigation district scale, water managers can use total actual crop water use to identify issues in the system, such as losses due to scheduling, water irrigation, storage and conveyance. At the basin scale, availability of historical records of accurate actual crop water use can support better management of water sources (surface, rainfall, and groundwater) and all water uses (agricultural, urban, ecological, and industrial) and water sources (surface, rainfall, and groundwater).

- **Geographic Areas:**

  Study Area: Central Utah, Millard County.

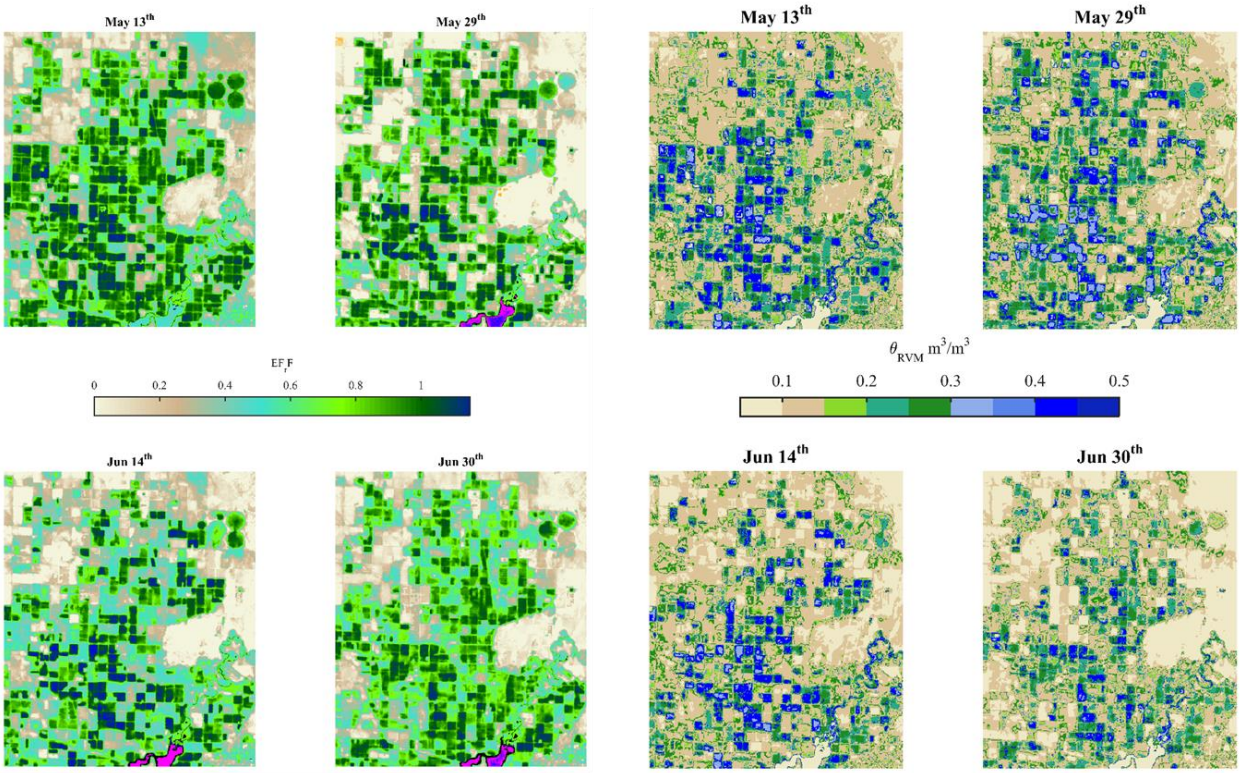
  Areas Benefited: Lower Sevier River Basin, Central Utah, Millard County.

- **Accomplishments:**

  Findings: The initial phase of enhancing CWMIS-produced information on soil water content using satellite information, particularly for Central Utah, has been completed. A continuation of investigations into soil water content estimation at other depths (one and two foot deep) using satellite information is currently underway. The addition of soil water content estimates, along with current

crop water use at satellite pixel level (100 ft.) at farm scale, will allow for direct estimations of irrigation water needs to producers on their computers or smartphones.

Results: The results obtained indicate accurate estimates of surface soil water content for the crop types found in Utah (alfalfa, corn, small grains) for each Landsat data set (available every 8/16 days). Because most agriculture is similar across the state, the model has direct application in agricultural lands at other basins and sub-basins.



Left: Display of Crop Water Use (Evapotranspiration fraction - ETrF) using Landsat information for the Lower Sevier River Basin. Right: Estimates of Surface Soil Water Content (θ_{RVM} - in cubic meters of water per cubic meters of soil) for the same dates. High amounts of soil water content are related with the closeness of an irrigation event on the farm. Total acreage of agricultural land in every image = 10 000 acres.

Work Plan FY 15-16

For FY15/FY16, soil water content at different depths will be incorporated into CWMIS for modeling irrigation water. The resulting models will be incorporated into CWMIS workflow of information available to users.

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 are not updated 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 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 for more efficient irrigation. This data can also help canal operators to manage water more effectively or wetland managers to manage invasive plant species. If these invasive plant species are left unchecked, they can take over native plant species, destroy bird habitat, and use excessive amounts of water.

  Aggieair can also 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 market this technology.

- **Geographic Areas:**

  Study Area: Most of the test flights 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 the last year, many improvements have been made to the Minion system. The biggest improvement is a new payload system (Fig. 1) which includes better visual and near infrared cameras, an incident light sensor, and a new payload computer. The new cameras are scientific grade cameras from Lumenera. In comparison to the old Canon cameras, the new Lumenera cameras have a better spectral response, a much higher frame rate, more precise control over exposure, and true raw data. These features have increased the scientific quality of our images, and made it easier to mosaic the images in a map. The incident light sensor has also

increased the quality of our images by giving us high-frequency data about the incident light coming from the sun during the flight. The new payload computer has more processing power to handle the data coming from the Lumenera cameras. Even though the new payload is more expensive initially, it saves time with processing and will pay for itself quickly.

To carry the new payload, the Minion UAV platform also needed an upgrade (Figs. 2 & 3). To handle the additional weight, the wingspan was increased to 9 feet and more power was added to the propulsion system. In addition to enabling use of the new payload, these changes to Minion have also made it faster and more stable.

Work Plan FY15/FY16

- AggieAir 3.0 (Fig. 2).
- Finish new avionics and power board
- Work on new ground station software

Informational Resources

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

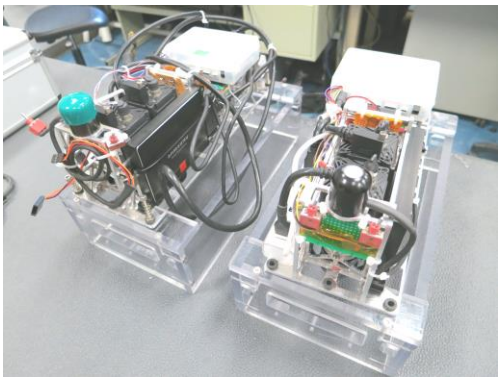


Figure 1. The new three camera payload with Lumenera Cameras

Figure 2. A launch of the Minion aircraft with 9' wing

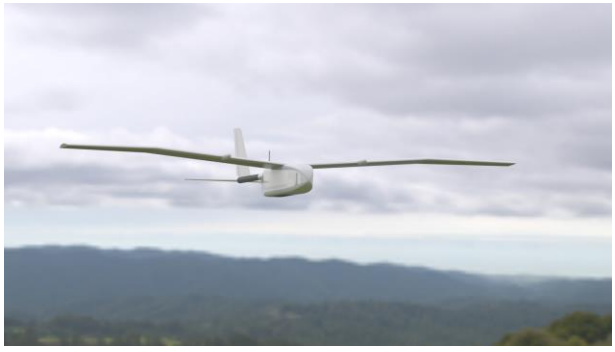


Figure 3. Rendered model of Fixed Wing 3.0

Evaluating Restoration Efforts Using Imagery from an Unmanned Aerial Vehicle (UAV)

Principal Investigators:
Mac McKee
Bethany Neilson
Ian Gowing

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

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, the San Rafael Restoration Committee wants 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 for 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 results on the accuracy and limitations of using inexpensive UAV platforms to provide data, such as digital elevation and terrain models, instead 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 in order to address the issue of thermal regime within the San Rafael River.

- **Benefits to the State:**

  The San Rafael River is recognized as being in a severely degraded state and 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 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:** San Rafael River, Emery County, Utah.

  Study Area: Emery County.

  Areas Benefited: Emery County and state-wide 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 the early part of August 2015 in anticipation of the proposed flights later in the month. Theses temperature sensors were positioned approximately every two river miles, beginning at the confluence with the Green River. The data from these sensors will help calibrate the thermal imagery being captured. UAV flights took place during August 2015 when river flow conditions on the San Rafael were near perfect to allow the capture of partial in stream channel morphology (14 cfs – 8 cfs) and full riparian high-resolution imagery.

  Results: All UAV flights have been flown and all imagery has been captured.

Work Plan FY15/FY16

Image processing and data analysis will occur September 2015 through February 2016. Data analysis will compare DEM's and DTM's created using AggieAir imagery to that of LIDAR imagery being flown in late fall 2015. Additional analysis will focus on calculating evapotranspiration from tamarisk for the lower San Rafael River, based on the acquired aerial imagery and local weather station data.

Additionally, the imagery will be used to monitor and evaluate a variety of restoration efforts currently on-going by both state and federal agencies, including the monitoring of Beaver Assist Structures positioned within the river channel to enhance channel change/migration and fish habitat. Thermal imagery from AggieAir will provide crucial information for analyzing instream river temperatures during low flow conditions and will improve understanding of river connectivity.

Informational Resources

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

Evaluation of Water Rights and Allocations on the Logan River

Principal Investigators:
Michael C. Johnson
McKenna Lee Sumrak

Partners/Collaborators:

- ***Local****: Rick Reese, Peter Kung, Logan River Water Users*
- ***Local:*** *Mark Nielsen, Logan City*
- ***County:*** *Bob Fotheringham, Cache County*
- ***State:*** *Wil Atkin, Water Rights*

Project Description

- **Need and Purpose:**

  The Logan River is a significant resource available to the residents of Cache Valley. It provides drinking water, irrigation water, recreation, and hydro-electric power. The river is most heavily used during the growing season, the same time period when the availability of water is the most limited. Over the course of nearly 100 years, water has been allocated subject to the Kimball Decree (1922). The president of the Logan River Water Users Association requested assistance for him and the Logan River Water Users Board in understanding how to interpret that decrease and guidance on the basis of present water allocations.

- **Benefits to the State:**

  Assisting the Logan River Water Users Association to better understand water rights and allocations on the Logan River will facilitate improved management of the river for those who derive benefit from the water.

- **Geographic Areas:**

  Study Area: The study area included all diversions from the Logan River from 2nd Dam to the Crocket Diversion in Cache County.

  Areas Benefited: Cache County.

- **Accomplishments:**

  Two reports were prepared for the Logan River Water Users: "Summary of Logan River Water Rights History" and "Logan River Water Rights" which were provided to the Logan River Water Users Association.

  Findings: Perhaps the most significant finding was that many current water users on the Logan River do not understand how their water right functions under current state law. For example, water rights date back to 1860, and at least two decrees have been issued, including one amendment. The Call and Kimball decrees established the legally binding right to use the water on the Logan River, and the Kimball decree's revised "Schedule A" establishes how water is to be allocated when river flow falls below a certain level and provides a table of allocation for each right that is dependent on the total river flow.

Results: The study results spell out in clear terms the current status of water rights on the Logan River, and also identify how the state's proposed determination may impact water rights.

Recommendations: A procedure was provided to equitably distribute water based on water right allocations and show how the proposed determination would change water rights. It was also recommended that all water rights on the Logan River with the flow dependent allocation be posted on a web site.

Work Plan FY15/FY16

This project is complete.

Informational Resources

Contact:

Dr. Michael C. Johnson, Telephone: (435) 797-3176, E-mail: michael.johnson@usu.edu.
Mrs. McKenna Lee Sumrak, Telephone: (435) 890-2674, E-mail: mckenna.lee@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 – Utah Division of Wildlife*
- ***Federal**: Justin Jimenez – Bureau of Land Management*
- ***State**: Paul Birdsey – Utah Division of Wildlife*

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 water 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 resulted in a complete lack of flow for two months during the summer of 2007 (Budy et al. 2009).

  An initial Gain-Loss study was conduct on behalf of Emery Water Conservancy District during late 2011 early 2012 (Gowing et al. 2012). The study examined gains/losses within the San Rafael River during the winter months. The data analysis indicated that both net gains and net losses were relatively small in magnitude and compared to actual flow rates when data was collected.

  However, findings from recent studies (Gowing, I.M. et al. 2013) have demonstrated that river flows during the summer months are critical to 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 was achieved by re-establishing discharge measurement transects used in the original study along the San Rafael River and collecting flow data once or twice a month from March through August 2014. Data collected bi-monthly during critically low periods of river flow aided in monitoring and assessing net gains and losses and in investigating river connectivity.

- **Benefits to the State:**

  The San Rafael River is recognized as being in a severely degraded state 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 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:** San Rafael River, Emery County, Utah.

  Study Area: Emery County.

  Areas Benefited: Emery County and state-wide where river restoration projects are being implemented.

- **Accomplishments**:

  Findings: All data collection on the lower San Rafael occurred between May and August 2014 and is now complete. All instrumentation was removed from the river at the end of data collection. Data analysis due to discrepancies between measured flow data collected by Utah State University and estimated flow data provided by the USGS has been reconciled.

  Results: Data analysis illustrates that the lower reaches of the San Rafael River can be described as groundwater gaining reaches. Findings from this research may lead to a larger scale research study at the catchment scale in collaboration with DWR and BLM.

Work Plan FY15/FY16

Data analysis and interpretation are complete, and a final technical report including recommendations, was submitted at the end of October 2015.

Informational Resources

Contact: Mr. Ian Gowing, Telephone: (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)
Bryce Mihalevich (Student)

Partners/Collaborators:
***Local**: Logan City, Northwest Field Irrigation Company*

Project Description

- **Need and Purpose:**

  This project is advancing the capabilities of water data collection infrastructure and cyberinfrastructure for watersheds within the state of 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 are important to water managers within the snowmelt dominated watersheds of the western United States. The improved data analysis and visualization tools we develop have already been useful to hydrologists and watershed scientists broadly. In particular, high-frequency data collection in Cache Valley watersheds is facilitating an improved understanding of the spatial and temporal dynamics of nutrients and dissolved organic matter in snowmelt dominated watersheds. We are examining parameters defining stream metabolism for the region, extending capabilities to better estimate water quality constituent loading and timing, and testing implementation of hydrologic/water quality models in snowmelt dominated, heavily managed watersheds. We are evaluating current and emerging water monitoring 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 watersheds stressed by growing population, changing land use, and uncertain climate is essential to the State of Utah. This is difficult, however, given high uncertainty in the driving forces and the human-impacted, heavily managed nature of these systems. The monitoring and modeling techniques we are developing provide better information about the timing, magnitude, sources, and flow paths associated with water and constituent fluxes. The results will be of benefit to the Utah Division of Water Quality, local canal companies, and municipalities, and in general, any utility providing drinking water from stream and reservoir sources. It is also of use to stormwater managers, and other water managers and users throughout the state. This work is informing monitoring programs within the state regarding critical periods for water quality 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 are 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:**

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

Findings: Our work over the past year illustrated significant stormwater impacts to both the hydrology and water quality of combined urban/agricultural water conveyances (canals). Canal managers must reduce diversion flows to accommodate stormwater inputs and avoid flooding. At the same time, the reduction in water diverted from the river leads to canal flows that are predominantly made up of storm runoff from streets, gutters, parking lots, etc. with reduced water quality that may impact downstream canal water users. Current urban stormwater models generally lack mechanisms for accurately representing these types of water management activities, but accounting for them is critical to understanding and predicting system hydrology and water quality. Monitoring results show that major water quality constituent loading occurs during very brief periods during the year (e.g., spring snowmelt in the river systems and during storm events in stormwater-impacted urban water conveyances), underscoring the need for high frequency, continuous data collection.

Results: During the past year we developed a mobile water quality monitoring platform that is enabling us to make new measurements of the spatial distribution of water quality variables (e.g., how water quality changes along the length of a stream or canal) instead of the fixed sensor measurement locations to which we were previously limited. We also built out an enhanced monitoring network within the Northwest Field Canal system in Logan, UT to investigate stormwater impacts to combined agricultural/urban water conveyances. This first-of-a-kind canal monitoring system is revealing new information about impacts to flow and water quality from both storm events and from management of the system. We have an ongoing relationship with both Logan City and the Northwest Field Irrigation Company as collaborators on this work.

Work Plan FY15/FY16

We will continue to monitor streamflow and water quality at multiple sites within the Little Bear River to investigate water quality impacts within an agriculturally impacted river system. We will also continue our collaborations with Logan City and the Northwest Field Irrigation Company to operate our new monitoring sites within the Logan River/Northwest Field canal system, including monitoring canal flow, canal water quality, and the flow and quality of stormwater outfalls. We now have one full year of high frequency data at these urban water quality sites that we will use to test, calibrate, and increase the resolution of an existing stormwater model and investigate the benefits of these data for modeling urban water systems. Finally, we plan to continue our 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.
Websites: http://littlebearriver.usu.edu; http://gamut.iutahepscor.org.

Hydraulic and Thermal Characteristics in and around Complex Habitat Structures in the Lower San Rafael River, South Central Utah

Principal Investigators:
Ian Gowing
Bethany Neilson

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  This project is investigating Beaver Dam Assist Structures (BDA's) in terms of providing quality fish habitat for native fish populations throughout the San Rafael. Fish habitat within the lower San Rafael is known to be severely depleted / limited and these BDA structures could potentially enhance native fish abundance by providing more high-quality habitat. Previous research (fish-surveys) conducted by the Division of Wildlife Resources have related these structures with high fish abundance levels when compared to other habitat types within the San Rafael.
  This study examines what makes these structures preferred and/or more suitable habitat locations with respect to temperature and hydraulic variables, including depth, mean column velocity and substrate/cover. Such variables will be analyzed during fish surveys conducted by the Division of Wildlife Resources. Temperature sensors will also be positioned throughout these structures to examine how temperature varies spatially and temporally, especially during critical periods of low flow. Temperature data from these sites will be analyzed alongside longitudinal temperature data being simultaneously collected along 55 miles of the San Rafael in order to establish if these locations provide more favorable thermal conditions. Data will also be collected to determine whether these structures reduce the overall incised nature of the river channel.

- **Benefits to the State:**

  The San Rafael River is recognized as being in a severely degraded state 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 for 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:** San Rafael River, Emery County, Utah.

  Study Area: Emery County.

  Areas Benefited: Emery County and state-wide where river restoration projects are being implemented.

- **Accomplishments**:

  Findings: Fieldwork commenced May 2015; an intensive study site was identified and a topographic survey was completed in and around the BDA structure using GPS. Temperature sensors and a pressure transducer were installed, and three groundwater wells were completed. A second intensive site was identified July 2015. Similar instrumentation was installed, and two groundwater wells were completed. A topographic survey was completed in August 2015. Both drift and benthic samples were also collected at both intensive sites.

  Results: Preliminary data analysis is on-going and will continue through the end of 2015.

Work Plan FY15/FY16

Instrumentation will be returned to the river next May through August 2016 for further data collection. Additional topographic surveys will be completed at both sites. Fish surveys and additional bug surveys will also be completed. Temperature monitoring will commence next May through August 2016.

Informational Resources

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

Impact of Urban Irrigated Agriculture on Utah's per Capita Water Use

Principal Investigators:
L. Niel Allen
Arthur Tyler Pratt (student)

Partners/Collaborators:
Local: *20 irrigators of urban agriculture in Cache County*
State: *Todd Adams, Utah Division of Water Resources*

Project Description:

- **Need and Purpose:**

  About 80% of Utah's total diverted water is for agriculture irrigation. The other 20% is for municipal, domestic, commercial, and industrial water use, of which it is estimated the over 60% is for urban irrigation. Many of Utah's communities and cities have unmetered secondary water systems that deliver to both agriculture and urban water users. In other communities private water systems from canals provide irrigation water for lawns, gardens, small pastures, and agriculture in and around urban areas. These water uses, along with the confusion in definitions of non-agriculture water and agriculture water, complicate the accounting process. Hence, a better understanding of the water use in unmetered urban irrigated agriculture is needed. A significant amount of the reduction in per capita water use may come from better accounting and management of urban agriculture irrigation. This research project aims to create a clearer picture of urban agricultural irrigation by determining typical quantities of water used, and evaluating irrigation systems efficiencies to determine areas for potential improvements.

- **Benefits to the State:**

  The results of this study can be used to better understand water use in Utah, particularly the portion of water that is used for irrigation in urban agriculture or undefined irrigation water use. A better understanding of urban irrigation water use will help the Utah Division of Water Resources better manage the State's water and provide direction for accounting and reporting of water use. The results will also identify management practices to better utilize Utah's water supply.

- **Geographic Areas:**

  Study Areas: Utah urban/small farm irrigated areas in Logan, North Logan, Smithfield, Hyde Park, Mendon, Nibley, Richmond, Benson, Paradise, and Levan.

  Areas Benefited: State-wide.

- **Accomplishments:**

  Findings: The project began in fall 2014, and data collection began in summer 2015. Accomplishments include conducting literature review, interviewing local organizations and irrigation companies to find participants, installing water measurement equipment in the field, and collecting field measurements. Twenty collaborators that fit the criteria of urban agriculture were selected, and the data for their total water usage are being collected for the 2015 irrigation season. The irrigated areas include community gardens, small acreage commercial farms, backyard pastures, gardens, orchards, and small alfalfa fields. Water measurement devices installed include flumes and weirs for three surface irrigation systems, flow meters for nine piped

systems utilizing sprinkler or drip systems, and pressure switch data loggers or manual data at eight sprinkler locations where the installation of a meter was not practical or feasible. Additionally, irrigated agriculture areas in and surrounding Logan, Utah were mapped and quantified using ArcMap.

Although data collection is in progress and has not been analyzed, the following findings were observed.

- There were no water measurement devices on the selected fields.
- Most irrigation systems were in need of repair.
- Irrigations were conducted and scheduled based on the irrigators' experience and/or availability of water from irrigation companies. We were not aware of any of the participating irrigators who utilized reported evapotranspiration or soil moisture monitoring

Installed water meters

Results: The study is still in the data collection phase and the results will be determined in fall and winter of 2015.

Work Plan FY15/FY16

Measuring and monitoring irrigation deliveries will continue through the summer and fall 2015. Irrigation system evaluations are being conducted for the fields being monitored. The evaluations include irrigation application rates and uniformity, system layout, irrigation schedules, quantity and flow rate of leaks, quantity and destination of return flows, crop data (type, planting and harvest dates), and field observations. Using climate data from the Utah Climate Center, crop irrigation requirements will be calculated for all the fields so that irrigation efficiencies can be calculated. We will prepare a report of findings, a thesis, and a technical paper based on the research.

Informational Resources

Contact: Dr. L. Niel Allen, Phone (435) 797 3926, E-mail: n.allen@usu.edu.

Website: http://extension.usu.edu/irrigation/.

Improving Hydrologic Model Predictions and Modeling Technology

Principal Investigators:
David G. Tarboton
Avirup Sen Gupta (Former student)
Nazmus Sazib (Student)

Partners/Collaborators:
Colorado Basin River Forecast Center
U.S. Army Corps of Engineers
Stroud Watershed Research Center

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. These changes include changes in the cycles and patterns of streamflow important to stream ecosystems. 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 is also advancing the technology in support of hydrologic modeling.

- **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 streamflow for flood forecasting, water supply and stream ecosystems.

- **Geographic Areas:**

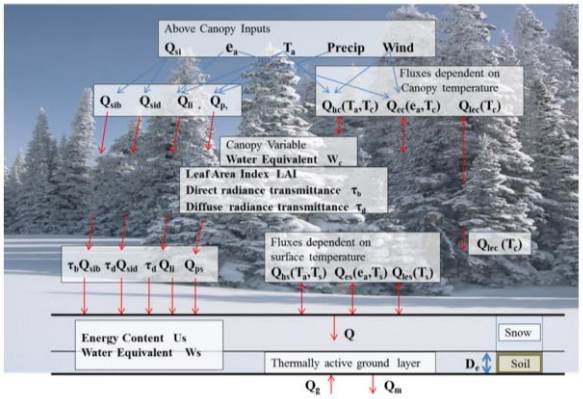
  Study Area: The study area is the semi-arid Western U.S., particularly Utah. Model evaluation used data from the USU TW Daniels Experimental Forest, and SNOTEL and USGS stream gages across Utah and the Western US.

  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 (UEB) Snowmelt model, (2) streamflow modeling to evaluate the potential effects of climate change on ecologically relevant aspects of streamflow regime, (3) development of data services to support input data preparation for hydrologic models, and (4) enhancements to hydrologic terrain analysis tools to support efficient watershed delineation for hydrologic modeling.

Results: A gridded version of the Utah Energy Balance Snowmelt model has been developed to better represent the spatial variability of snowmelt processes (Sen Gupta, 2014). This includes its integration into the EPA BASINS modeling framework (Sen Gupta et al., 2015) and the development of tools to derive inputs from climate reanalysis data (https://bitbucket.org/AvirupSenGupta/msdh.usu). UEB is being used in studies of flood and water supply forecasting in partnership with the Colorado Basin River Forecast Center in Salt Lake City. Beyond snowmelt the TOPNET model is being applied to examine climate change effects on streamflow regime variables of ecological importance. This problem has been previously studied from a statistical perspective (Dhungel, 2014) but the predictive basis of statistical models is weak for changed conditions, so we are approaching the problem using physically based modeling. This requires the capability to efficiently prepare model input data. Hence, we have worked on data services to provide web based tools for watershed delineation and model input preparation, for both UEB and TOPNET. We have also expanded the capability of our TAUDEM tools, in partnership with the US Army Corps of Engineers and Stroud Watershed Research Center.



Utah Energy Balance Snowmelt Model

Work Plan FY15/FY16

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. We will also continue to evaluate and refine the use of UEB for flood and water supply forecasting, and will continue to improve information technology tools to enable these models to be run efficiently over large areas by taking advantage of server/cloud computing platforms where possible.

Informational Resources

Contact: Dr. David G. Tarboton, Telephone: (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.

Sen Gupta, A., (2014), "Improving the Physical Processes and Model Integration Functionality of an Energy Balance Model for Snow and Glacier Melt," Ph.D. Thesis, Civil and Environmental Engineering, Utah State University, http://digitalcommons.usu.edu/etd/3875, 213 pp.

Sen Gupta, A., D. G. Tarboton, P. Hummel, M. E. Brown and S. Habib, (2015), "Integration of an energy balance snowmelt model into an open source modeling framework," Environmental Modelling & Software, 68: 205-218, http://dx.doi.org/10.1016/j.envsoft.2015.02.017.

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 existing 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 irrigation and its 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 healthy river systems and other uses. The methodology being developed can be used in other irrigated areas of the state.

- **Geographic Areas:**

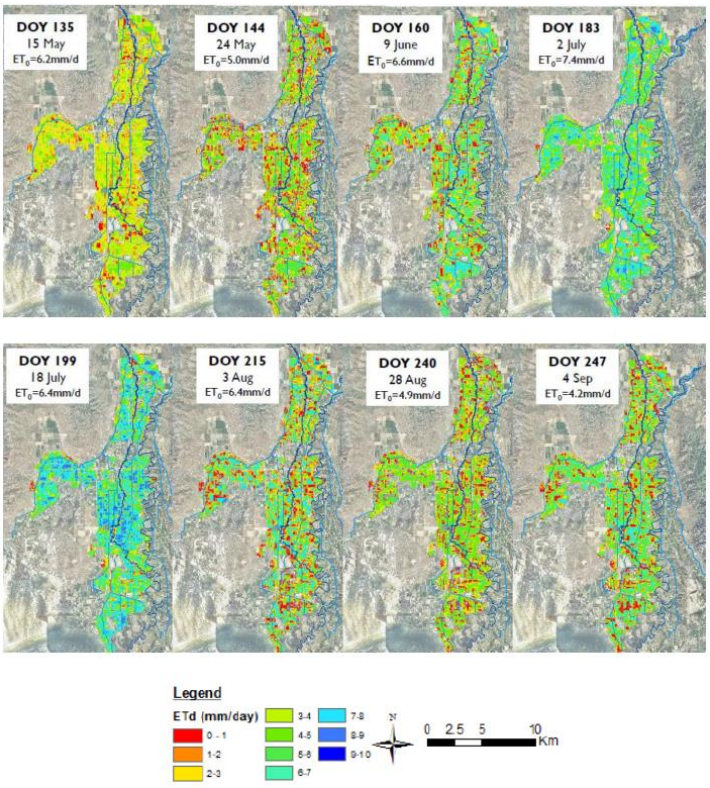
  Study Area: Bear River Canal Company in Box Elder County.

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

- **Accomplishments:**

  Findings: Spatial evapotranspiration (ET) 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. Additionally, the spatial ET data was used to calibrate the Ador irrigation system simulation model and the current irrigation schedule. 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. Results from the field evaluations aided the Ador simulations.

Results: Evapotranspiration estimates were calculated with the METRIC surface energy balance model and applied for multi-temporal satellite imagery from Landsat 5 TM and Landsat 8 products. Weather station and irrigation diversion data were used to compute the water use and system efficiency in past years from 2003 to 2014. These results indicate the difference in irrigation system management for dry, normal, and wet years. Seasonal ET estimates were only impacted in a dry year when preceded by a dry year (2nd dry year).



Results from spatial ET estimates during the 2013 growing season using remote sensing data for the Bear River Canal company

Field irrigation management was analyzed using the Ador model, which simulates water flow in the irrigation system infrastructure and on-field irrigation events. The field evaluation data collected on different soil types was used as input in the model to characterize the infiltration. Spatial ET from remote sensing was a valuable dataset to calibrate the model and include the spatial variability of the irrigation system. Results from current scenario simulations were discussed with local farmers and the canal company managers. Findings were presented at the Bear River Canal Company annual shareholders meeting.

Work Plan FY15/FY16

Ador simulations of alternative irrigation management strategies such as a change in water delivery schedule or an additional reservoir for the canal company will continue, along with analysis of the impact on surrounding water users for the different strategies. Results will be published in additional scientific journals and presented to the local farmers and canal company managers in meetings.

Informational Resources

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

Publications:

van Opstal, J.D., C.M.U. Neale, and S. Lecina (2014). Improvements in irrigation system modelling when using remotely sensed ET for calibration. *Proceedings SPIE 9239*, *Remote Sensing for Agriculture, Ecosystems, and Hydrology XVI American Geophysical Union*, San Francisco CA (Oral presentation), 2014, Irrigation dynamics and tactics: Developing a sustainable and profitable irrigation strategy for agricultural areas.

iUTAH – Innovative Urban Transitions and Arid Region Hydro-Sustainability

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

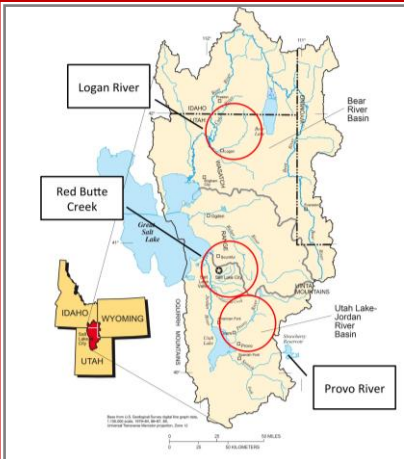
Partners/Collaborators:

- ***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 urban and natural ecosystems. Freshwater resources face 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 the most growth occurring along the narrow Wasatch Range Metropolitan Area (WRMA). Growth is expected to significantly increase water demand that will require water transfers, infrastructure investments, and efficiency programs. The overarching goal for the iUTAH project is to enhance Utah's research capabilities and sustainable water decision-making through strategic investments in the state's physical, human, and cyberscience infrastructure. Transdisciplinary teams of natural and social scientists are carrying 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.



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

- **Benefits to the State:**

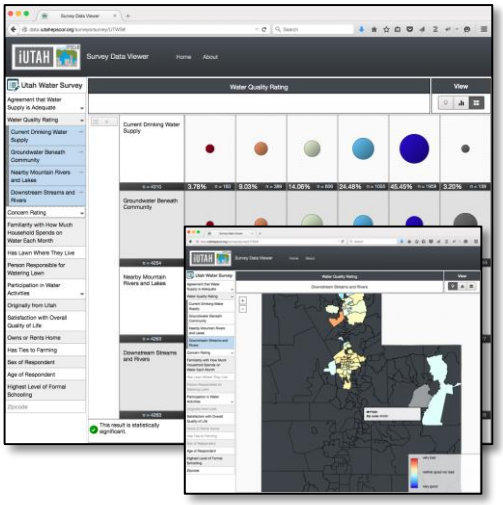
The innovative and transformational activities in this project include (1) the development of fully integrated hydrologic and social sciences observatories that encompass whole watersheds along an urbanizing land use gradient; (2) strategic activities designed to build a community of scholars across 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 that our research directly addresses societal needs and will translate and communicate the 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. This can be facilitated by 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 existing strengths in water and urban and ecological sciences while expanding expertise needed in the social sciences to understand complex, human-dominated systems. iUTAH's infrastructure investments have created a common research platform to facilitate statewide science collaboration and enhance our ability to compete for major new interdisciplinary funding opportunities.

- **Geographic Areas:**

  Study Area: Logan River, Red Butte Creek, Provo River, WRMA.
  Areas Benefited: Logan River, Red Butte Creek, Provo River, WRMA, urbanizing areas.

- **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 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 limited understanding of human water use behavior, at both the individual and organizational scale, makes it difficult to generate future water availability scenarios for important Utah water systems.



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

  Results: (1) designed/built hydrologic observatories in the Logan River, Red Butte Creek, and the Provo River that further understanding of human mediated hydrologic systems within northern Utah along a gradient of urbanization; (2) developed computer hardware and software cyberinfrastructure required to facilitate data collection within these observatories, including innovative new data management and visualization software; (3) helped design/develop social science observatories for these same systems; (4) integrated primary data collection into coupled interdisciplinary models to better represent the human mediated hydrology of western water systems, (5) provided more information directly relevant to future water availability scenarios and decision making; and (6) developed new partnerships among the major research and undergraduate institutions within the state.

Work Plan FY15/FY16

Continue work on the cyberinfrastructure aspects of the iUTAH project, focusing on software systems that will enable iUTAH scientists and partners to share and collaborate around water resources data and next-generation, coupled models of the state's hydrologic systems; (2) develop new tools to analyze/visualize social science datasets created by iUTAH partners; (3) conduct primary research using collected data (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

Contacts:
Dr. Jeffery S. Horsburgh, Telephone: (435) 797-2946, E-mail: jeff.horsburgh@usu.edu.
Dr. David Rosenberg, Telephone: (435) 797-8689, E-mail: david.rosenberg@usu.edu.
Dr. Bethany Neilson, Telephone: (435) 797-7369, E-mail: bethany.neilson@usu.edu.

Website: http://www.iutahepscor.org, http://data.iutahepscor.org, http://gamut.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 for 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. This project's goal 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 highly successful in collecting detailed aerial imagery needed 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 and 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: This year, the new autopilot code (RT Paparazzi) was finished and is currently being used for the VTOL system. The code is still being tested, so resources have been allocated to work on other aspects of the system (i.e. VTOL frame and payload cage). The latest version of the frame, call the Arc (Fig. 1), is designed to carry the same payload currently flying on the fixed wing Minion platform. This payload weights around 4.5 lbs, which is heavy for a VTOL system, so the frame needed to be upgraded, along with the motors and propellers. In addition to developing the frame, a payload cage (Fig. 2) is currently being designed to hold the same payload design as Minion.

  One of the difficulties of developing a VTOL system is tuning the autopilot. In addition to the other developments, a hardware-in-the-loop (HIL) simulator has also been developed to assist with tuning. Given a physical model of the aircraft, the HIL simulator can simulate a flight with the actual hardware that will be used, and the autopilot can be tuned without flying. This will prevent dangerous flight conditions and reduce the number of crashes new platforms are subjected to during early stages of development.

Work Plan FY15/FY16

- Finish Arc development.
- Finish RT Paparazzi autopilot development
- Finish Payload cage design and
- Fly VTOL

Informational Resources

Contact: Dr. Austin Jensen, Telephone: (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. New VTOL Arc Frame

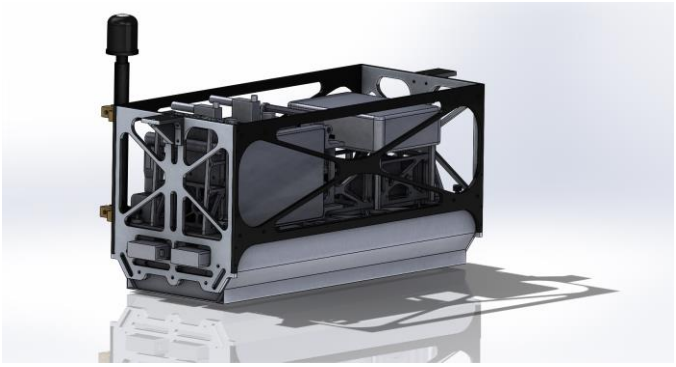


Figure 2. VTOL Payload cage

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:**

  Acquiring an accurate orthorectified mosaic map from the images captured by a UAV (Unmanned Aerial Vehicle) system is a time-consuming and expensive process. Partly due to delays in the acquisition process, it is difficult to provide Utah water managers and farmers with timely and useful information. Resources of money and manpower are also wasted because the delayed orthorectified mosa
  ic maps cannot be used to their full potential. Hence, there is an urgent need for a more efficient process to generate accurate orthorectified mosaic maps 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) provide 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 inputs, and (2) provide researchers in Utah with the spatial or temporal view of water quality needed for accurate assessment of water bodies.

- **Geographic Areas:**

  Study Area: Utah area at UTM, NAD83, Zone 12.
  Areas Benefited: Precision agriculture, vegetation mapping, and stream and river applications to benefit Utah farmers and water managers statewide.

- **Accomplishments**:

  Findings: We determined that the MinEigen corner detector based matching method is the best matching method for the current data set because it employs the projective transformation to implement the georeferencing, rectification, and mosaicking process. Using a base map or the NAIP image of the same 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 represents a significantly reduction. We also found that the Procrustes analysis method can be used on the generated mosaic map to update the GPS data, which can be further used to calibrate camera.

  Results: Figure 1 shows the encouraging experimental results generated from the proposed algorithm by using different base maps as the references. We produced this mosaic map in about 30 minutes, which is significantly less than the current running time of the other software (e.g., about one to two weeks) to generate the comparable mosaic map.

Figure 2 shows the promising results of the mosaic maps for the same aerial image set generated by applying the direct georeferencing method on the original and updated GPS data, respectively. It clearly demonstrates the effectiveness of the Procrustes analysis method since the mosaic map generated using the updated GPS data has a better quality than the mosaic map generated using the original GPS data. On the other hand, it also indicates the noisy nature of the GPS data and the necessity to update these data to further improve any georeferencing method.

Figure 1. Mosaic maps generated from the aerial image set containing 158 images captured on June 17, 2013 by (left) using the high-resolution base map as a reference. (right) using the 2014 NAIP image as a reference. (Due to the difference of resolution in reference images, the sizes of the final mosaic maps are different.)

Figure 2. The mosaic maps generated from the aerial image set captured on June 17, 2013 by applying the direct georeferencing method on two kinds of data: (left) original GPS data. (right) updated GPS data.

Work Plan FY15/FY16

Further improve the accuracy of the mosaic map and the running time to generate the mosaic map when a few NAIP, Google Earth, or other imagery sources are used as reference maps.

Informational Resources

Contact: Dr. Xiaojun Qi, Telephone: (435) 797-8155, Email: Xiaojun.Qi@usu.edu.
Website: http://aggieair.usu.edu/imagery.

Organizing and Synthesizing Water Management Data to Speed Modeling

Investigators:
Faculty: *David E. Rosenberg*
Students: *Adel, Abdallah, Omar Alminagorta*

Partners/Collaborators:
- ***Local:*** *Stephanie Duer, Salt Lake City Public Utilities*
- ***State:*** *Craig Miller, Utah Division of Water Resources*
- ***Business/Commercial:*** *Sarah Larsen, Western States Water Council; Jack Sieber, Stockholm Environment Institute*

Project Description

- **Need and Purpose:**

  Modeling of complex water systems requires multi-disciplinary data like hydrologic, ecologic, economic, operation, engineered infrastructure, network connectivity, and scenarios whose data currently reside at different places, are managed by different entities. These data vary in space in time and use different formats (e.g., shapefile, text files), data types (e.g., time series, parameters, text), terminology (e.g., dam vs reservoir), and domains (e.g., water supply, storm water management). Water managers and scientists must therefore spend considerable time to gather and organize their data before they can run a model or conduct an analysis. Thus, there is a need for a persistent informatics method to organize and integrate diverse water resources data.

- **Benefits to the State:**

  The project develops a persistent informatics tool to organize, integrate, and synthesize diverse water resources data. Use of the tool will decrease the time water managers, scientists, and engineers spend to gather and interpret their water management data and thus increase the time they spend doing modeling, analysis, and management. The tool will also allow managers and engineers to more quickly interpret water resources data correctly.

- **Geographic Areas:**

  Study Area: Lower Bear River and Salt Lake City Public Utilities service area; Cache, Box Elder, and Salt Lake Counties, Utah.

  Areas Benefited: Water managers and researchers statewide in all counties.

- **Accomplishments:**

  Findings and Results:

  - Designed the Water Management Data Model (WaM-DaM) as a flexible, modular, relational, location-independent tool that can store the data and metadata for different models, networks, scenarios, and the attributes that describe those data constructs. When importing data into the tool, users can either (i) use existing constructs, or (ii) define new constructs and use controlled vocabulary to relate new constructs to existing ones.

- Used the WaM-DaM tool to organize 5 national and regional datasets with approximately 2.3 million data values spanning the years 1800 to 2015.
- Used the organized data to answer multiple synthesis questions (see box, right) in the lower Bear River Basin.
- Presented work at the (i) Hydra Technical Meeting in Swindon, UK. December 2, 2014, and (ii) Utah Water Data Users Group, 2nd Meeting, Salt Lake City, Utah: Jan. 27, 2015.
- Drafting manuscript that describes the tool and application in the lower Bear River Basin.

Data Synthesis Questions Answered in the lower Bear River Basin, Utah

1. What are the available data structures, networks and scenarios? What are their domain and spatial reference?
2. What are the data value(s) of the attributes for a system component?
3. What is the source of the data for an attribute, who reported the data, and what method was used to generate the data value?
4. How are the infrastructure components in a network and scenario physically connected to each other?
5. What are the differences between two scenarios of a network?
6. What data are available data to expand the Water Evaluation and Planning (WEAP) model for the lower Bear River Model to the entire basin?

Work Plan FY15/FY16

- Submit first article on WaM-DaM data system design and use to the peer-reviewed journal *Environmental Modelling & Software*.
- Use WaM-DaM to serve common data to multiple water management models.
- Use WaM-DaM to serve data and run a water resources model on a high-performance computer.

Informational Resources

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

Website: http://ci-water.org/water_modeling/presentations/WaM-DaM_UWUG.pdf.
Website: https://github.com/amabdallah/WaM-DaM.

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 discharge capacity and fish passage. Consequently, the flow dynamics (turbulence) and the corresponding swimming behavior of fish to that 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. Hence, 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 was 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 were 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 the 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 baffled culverts using laboratory and CFD data.
- Provide UDOT with results and a peer-reviewed journal article summarizing the result of the study.

- **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 has been 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.

A brown trout navigating the baffled culvert during testing

- **Accomplishments:**

  Results: The fish experiments were completed in FY14. The CFD work was completed in FY15. Two papers were written and submitted to a journal in 2015. After some modifications, the papers will be resubmitted in early FY 16 to the Journal of Hydraulic Research. A conference paper will be written and submitted to the 6th International Symposium on Hydraulic Structures, which will be held in Portland, OR (June 2016).

Work Plan FY15/FY16

During FY15-16, we will investigate the influence of different baffle designs on the flow resistance (Manning's n coefficient) of baffled culverts.

Informational Resources

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

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

Principal Investigators:
Mac McKee
Alfonso Torres
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 means for obtaining and distributing information about the state of the water supply system. This project is developing and adding significant data analysis capability to support real-time and long-term water management information needs of the Sevier River Water Users Association (SRWUA).

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

- **Benefits to the State:**

  The data analysis, management and forecasting technologies applied in the Sevier River Basin in the past several years has improved the decision-relevant information available to system managers in support of 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 provide valuable information for farmers/ranchers in making better long-term decisions on investments in crops and livestock, especially in years where drought might be likely. Similarly, the short-term forecasting and remote sensing methods developed 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 system productivity.

- **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: The remote sensing tools and data-driven models developed by this project can improve real-time reservoir, canal, and on-farm operations in the Sevier River Basin by several percent.

Results: Accomplishments of the project this year include the following:

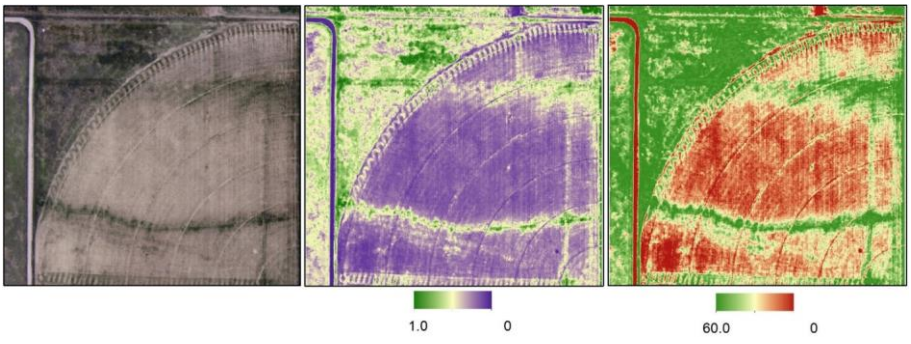
- Used UWRL autonomous aerial vehicle (UAV) flights over fields near Scipio, Utah from previous years to provide high-resolution maps of plant tissue nitrogen and chlorophyll and spatial ET measurements. Completed models to estimate soil moisture in irrigated areas using these remote sensing techniques, coupled with models to forecast changes in root zone soil moisture. Several publications that resulted from this work are now available.
- Assessed integration of high resolution imagery from flights by the AggieAir™ Flying Circus for fields near Scipio, Utah with satellite platforms (e.g. Landsat). The results of this assessment provided a sound methodology for spectral and spatial management of agricultural information from diverse imagery sources.
- Completed integration of algorithms for the crop and water monitoring information system (CWMIS) at farm and irrigation system levels in the Lower Sevier River. These algorithms allow for automated information delivery to farmers, water managers and policy makers within a basin.
- Used Landsat information to derive a methodology to estimate soil water content on farms in the Lower Sevier River Basin at the pixel level. When combined with spatial evapotranspiration analysis products, this information can support better irrigation water management decisions at farm and irrigation system levels. A journal article describing this work was submitted and is under review.
- Initiated conversations with the Utah Division of Water Resources for state-wide implementation of spatial evapotranspiration models for agricultural water management.

Work Plan FY15/FY16

- 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 current and future soil moisture levels for better management of center pivot irrigation systems in the Scipio and Lower Sevier River areas.

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 Remote Sensing Service Center

Principal Investigators:
Austin Jensen
Mac McKee

Partners/Collaborators:
Various end-users in Utah

Project Description

- **Need and Purpose:**

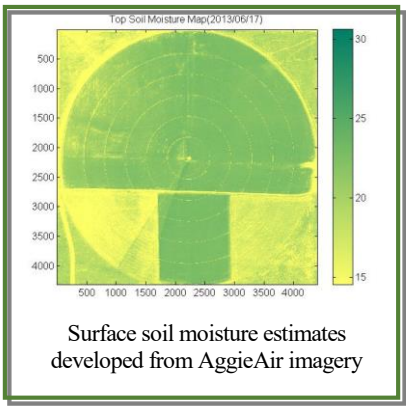
  Many current sources of remote sensing data, such as manned aircraft and satellite platforms, are too expensive, have low spatial resolution, or are not updated frequently enough to be practical for many applications. A low-cost, small unmanned aerial vehicle (UAV) called AggieAir™ has been developed to fill this need by providing inexpensive, multispectral aerial imagery quickly and frequently. In addition, AggieAir's does not need a runway for takeoff and landing so it can be deployed almost anywhere. AggieAir's capabilities are able to generate valuable data for research and support a variety of applications in agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, fish and wildlife tracking, and many others.

  AggieAir has become stable and robust platform that can now be used on a regular basis to provide aerial imagery and remote sensing data beneficial to these many applications. The funds generated from these applications will support 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 effectively and efficiently. The service center also provides feedback to help steer future AggieAir research and development activities in directions that are most beneficial.

- **Benefits to the State:**

  The data provided by the service center have the potential to help Utah save water and manage environmental resources more efficiently. The service center farmers a low-cost solution for mapping soil moisture so they can irrigate their crops more efficiently, and canal operators the data necessary to manage water diversions more effectively. The service center can map roads and highways to monitor the quality of the asphalt and to update road inventory information such as number of lanes, signs, culvert crossings, etc. The service center UAV's can also survey roads before, during, and after construction. 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 responsible for monitoring and managing water quality can now obtain accurate, high resolution thermal images showing temperature distributions along all reaches of a stream or river.

  The service center will directly and 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 allows us to test business models and gain the experience required to make this transition.



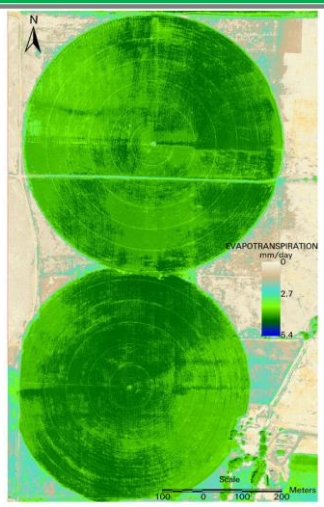
Surface soil moisture estimates developed from AggieAir imagery

- **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 included here show some of the maps generated by the AAFC and the analysis of the imagery needed to address water management problems in a variety of applications.



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

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, including Oklahoma State University and Texas State University. Licensing agreements are in place with private companies in Utah to manufacture AggieAir aircraft and avionics. Additional field crews have been trained to fly the UAVs and process collected imagery.

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. Work done by the AAFC has supported research to improve monitoring of watershed recovery investments, to increase our understanding of ozone production along the Wasatch Front and how it is influenced by the Great Salt Lake, and to benefit many other similar projects around the State. Personnel from the AAFC worked in collaboration with Box Elder County, ATK, and the Governor's Office of Economic Development to submit a proposal to build a UAV test site in Box Elder County. This proposal was funded, and work is proceeding to attract industries to the test site.

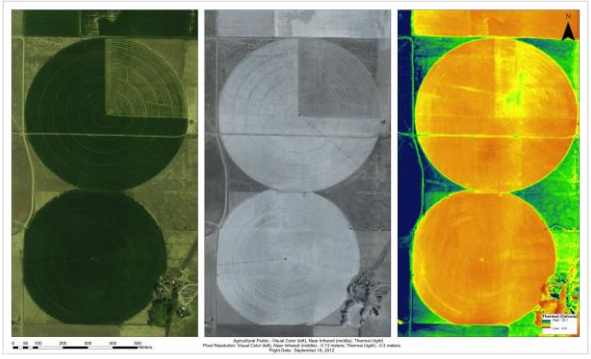
The AAFC obtained several Certificates of Authorization (COA) from the US Federal Aviation Authority (FAA) in the past year that certify the AggieAir platform is airworthy and authorize its use subject to FAA rules. Such a COA was obtained for Box Elder County at its new UAV test site with assistance from AggieAir personnel. Negotiations are underway to create a spinoff company that will market some AggieAir technology. New payloads are in development that will include a wider array of sensors. A new airframe is being designed that will provide much better capability in the field.

Work Plan FY15/FY16

Expand the AAFC business base through acquisition of more research contracts, develop and license a spinoff company to market AggieAir technology, and complete the development and deployment of new aircraft and payloads.

Informational Resources

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


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

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*
Business/Industry: *None*

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 transitions from 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 practice.

- **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. To deal with these issues, network analysis tools can identify alternative options, such as (1) where to locate water systems relative to source water for agricultural to urban water transfers, (2) whether to build or remove dams, (3) ways to protect ecosystem services, implement conservation measures, or diversify water supplies. 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 flows along particular links in the system, along with other system management scenarios. 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 the effects of link flow capacity on the nodes in a water resources network that are stable (their roles do not depend on the existence of particular nodes), topologically significant (when

removed or added to the network, these nodes cause other nodes to be unstable), and redundant (node pairs that have similar connections). The tool can alternatively examine the effects of other quantitative attributes that weight links such as average flow magnitude, minimum flow, etc.

- Within the lower Bear River water system, updated results show that the Cache Irrigation and Cache Urban service areas, as well as the South Cache Irrigation and South Cache Urban services areas, are still highly redundant. Further, the South Cache Irrigation and Cache Irrigation service areas remain promising candidates for agricultural to urban water transfers as they were in the analysis without link weighting.
- The most stable nodes are sources like the headwaters of the Bear, Blacksmith Fork, and Little Bear rivers while the most unstable nodes are junctions located far downstream in the network directly upstream of the Great Salt Lake Terminus and New Box Elder Irrigation service area.
- The most topologically significant nodes are Cutler Reservoir and the proposed diversion point on the Bear River to the Wasatch Front. These nodes have varying number of incoming and outgoing links (node degree) and flow capacities on the links and these results suggest that several factors beyond node degree and link density affect node topological significance. Additionally, sources located at more upstream locations in the river network are more topologically significant than sources located more downstream in the network even if the downstream source contributed more inflow.

Results:

- Both link weight and direction (e.g., downstream only, or bidirectional) affect node stability rankings. For example, considering only downstream flow direction instead of bi-directional flow affected the stability metric the most, causing nodes downstream to be more likely unstable. Together, the link direction and magnitude factors lead to more complex results that do not yield standard rules-of-thumb that can identify from visual inspection of the network which nodes will be most topologically significant.
- Revised the article on the RANK tool in response to peer reviewer comments received from the *ASCE-Journal of Water Resources Planning and Management* in Fall 2014.

Work Plan FY15/FY16

The only further work planned on the project is to complete the final revisions on the manuscript and submit it for publication to the *ASCE-Journal of Water Resources Planning and Management*.

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.

Research Faculty, Professional, and Support Staff

Research Faculty, Professional, and Support Staff

Utah Water Research Laboratory and Utah Center for Water Resources Research

Mac McKee, Director
William J. Doucette, Associate Director
Blake P. Tullis, Associate Director
Bethany Neilson, Assistant Director
David K. Stevens, Head of Environmental Engineering Division
Blake P. Tullis, Head of Water Engineering Division
R. Ivonne Harris, Publications Specialist
Tracy Brown, Senior Business Officer
Carri Richards, Public Relations Specialist
Jan S. Urroz, Administrative Supervisor

Utah Water Research Laboratory Faculty

Mac McKee, PhD, Director UWRL/UCWRR; Professor, CEE/UWRL
Craig Adams, PhD, Professor, CEE/UWRL
Niel Allen, PhD, Associate Professor, CEE/UWRL
Steven L. Barfuss, MS, Research Associate Professor, CEE/UWRL
Anthony Castronova, PhD, Research Assistant Professor, CEE/UWRL
William J. Doucette, PhD, Associate Director, UWRL/UCWRR; Professor, CEE/UWRL
R. Ryan Dupont, PhD, Professor, CEE/UWRL
Ardeshir Ebtehaj, PhD, Assistant Professor, CEE/UWRL
Thomas B. Hardy, PhD, Research Professor, CEE/UWRL
Jeffery S. Horsburgh, PhD, Assistant Professor, CEE/UWRL
Michael C. Johnson, PhD, Research Associate Professor, CEE/UWRL
Jagath J. Kaluarachchi, PhD, Professor, CEE/UWRL; Interim Department Head, BE; Associate Dean, College of Engineering
Randal S. Martin, PhD, Research Associate Professor, CEE/UWRL
Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
Joan E. McLean, MS, Research Associate Professor, CEE/UWRL
Laurie S. McNeill, PhD, Professor, CEE/UWRL
Christopher Neale, PhD, Professor, CEE/UWRL
Bethany T. Neilson, PhD, Associate Professor, CEE/UWRL
Richard C. Peralta, PhD, Professor, CEE/UWRL
William J. Rahmeyer, PhD, Professor, CEE/UWRL
David E. Rosenberg, Ph.D., Associate Professor, CEE/UWRL
Judith L. Sims, MS, Research Associate Professor, BE/UWRL
Ronald C. Sims, PhD, Professor, BE/UWRL
Darwin L. Sorensen, PhD, Research Professor, BE/CEE/UWRL
David K. Stevens, PhD, Professor, Head of Environmental Engineering Division, CEE/UWRL
David G. Tarboton, PhD, Professor, CEE/UWRL
Blake P. Tullis, PhD, Associate Director, UWRL/UCWRR; Professor, CEE/UWRL; Head of Water Engineering Division, CEE/UWRL
Gilberto E. Urroz, PhD, Associate Professor, CEE/UWRL
Wynn Walker, PhD, Professor Emeritus, CEE/UWRL
Anhong Zhou, PhD, Associate Professor, BE/UWRL

Research Faculty, Professional, and Support Staff

Utah Water Research Laboratory Staff

Abigail Bride, BA, Staff Assistant III
Marianne Brown, Staff Assistant I
Tracy Brown, MS, Senior Business Officer
Mark Cannon, BS, Research Engineer
Andrea Carroll, Accounting Technician
Peg Cashell, MS, Soil Scientist
Christopher Coffin, MS, Research Engineer I
Cal Coopmans, PhD, Postdoctoral Fellow II
Pabitra Dash, PhD, Software Engineer
Leila Esfahani, PhD, Postdoctoral Fellow
Thomas Fisher, MS, Research Engineer I
Maria Gates, BS, Business Officer III
Ian Gowing, BS, Research Engineer
Jessica Griffiths, BS, Staff Assistant I
Tessa Guy, BS, Research Assistant I
R. Ivonne Harris, MS, Publications Specialist
Nathan Hoffer, MS Research Engineer I
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
Stephanie Reeder, BS, Programmer/Analyst
Carri Richards, BS, Public Relations Specialist
Daniel Robinson, Aviation Technician
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, BS, Research Engineer

Research Faculty, Professional, and Support Staff

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
A. Bruce Bishop, PhD, Professor Emeritus, CEE/UWRL
David S. Bowles, PhD, Professor Emeritus, CEE/UWRL
Duane G. Chadwick, MS, Professor Emeritus, EE/UWRL
William J. Grenney, PhD, Professor Emeritus, CEE/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 Emeritus, 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

Appendix: 50-Year Anniversary Publications

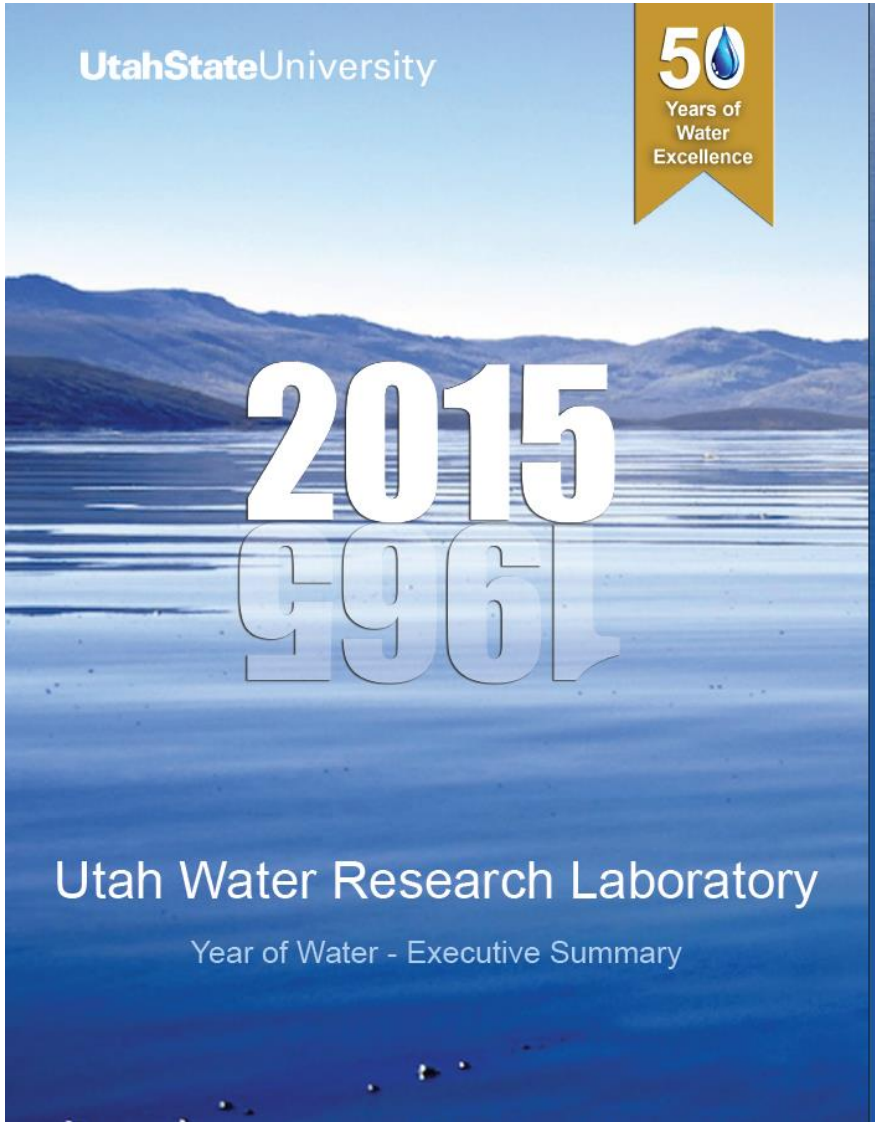
Appendix: 50-Year Anniversary Publications

50-Year Anniversary Publications

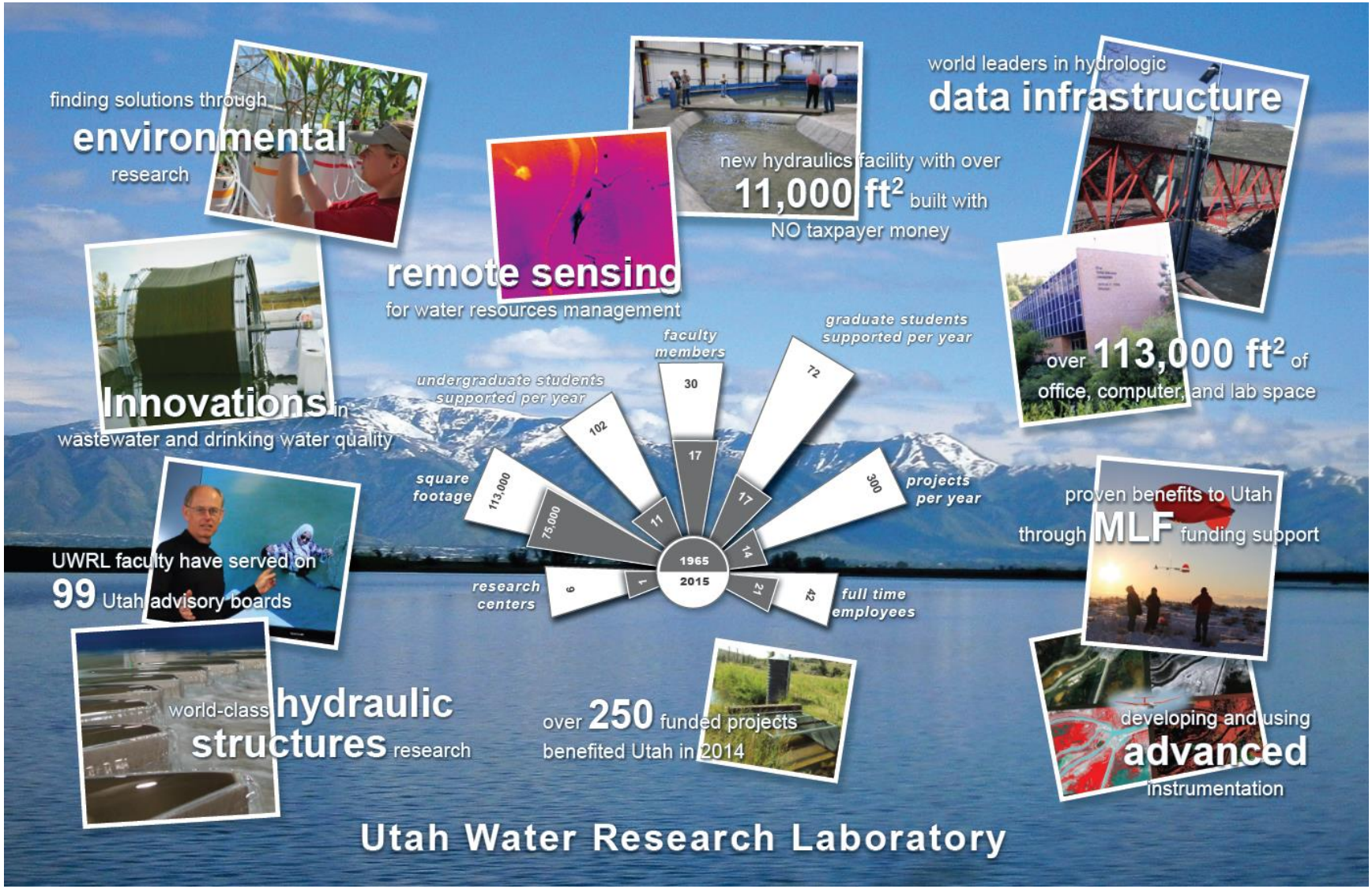
The two publications included in this appendix were created as part of the 50th anniversary of the dedication of the UWRL building. They represent a concise overview of some of the progress and accomplishments of the Utah Water Research Laboratory over the past 50 years.

- 2015 Year of Water Executive Summary
- Powering 50 Years of Water Research: A Brief History of Water Resources Management

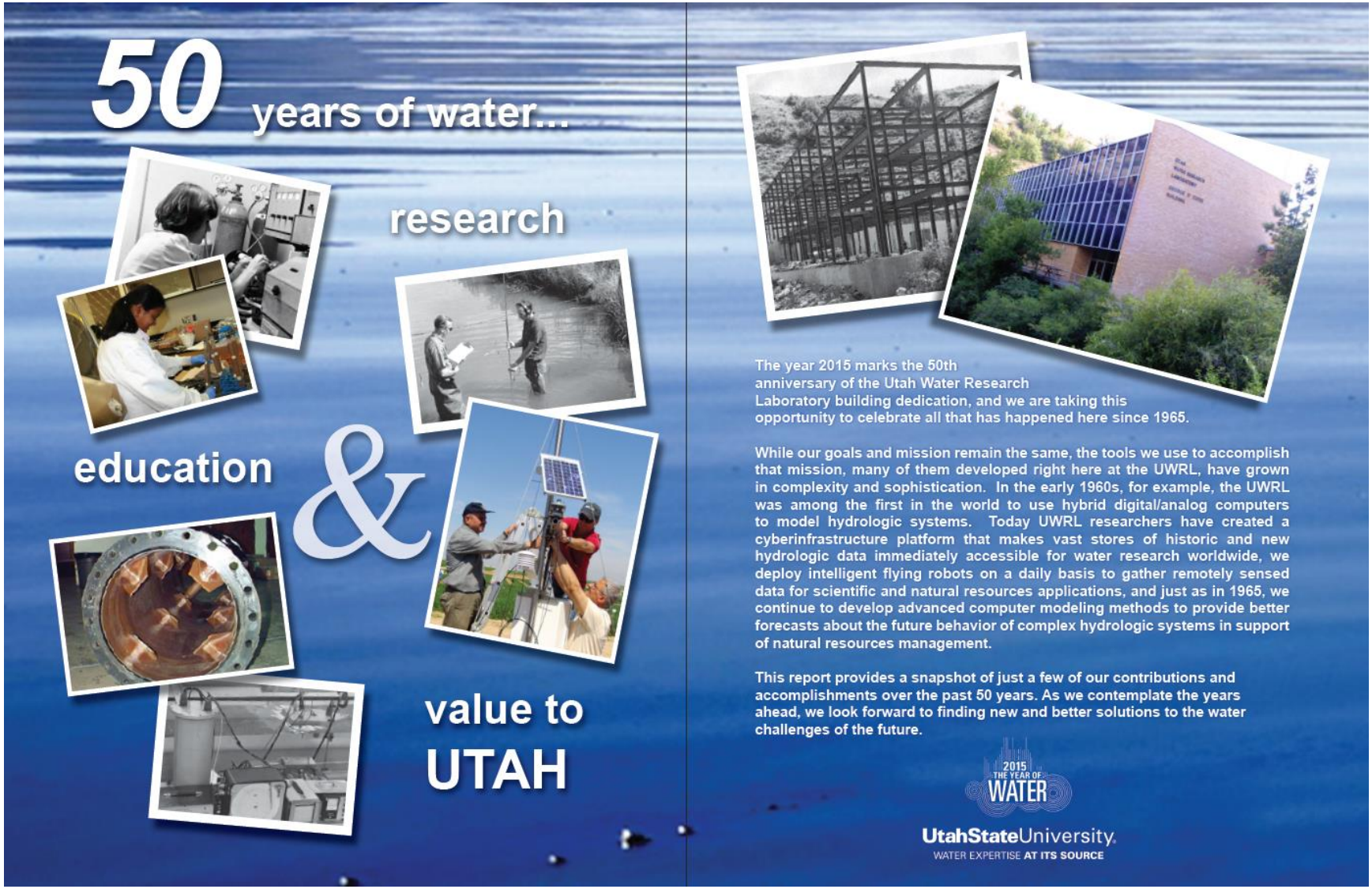
2015 Year of Water Executive Summary (front cover and inside front cover of tri-fold brochure)



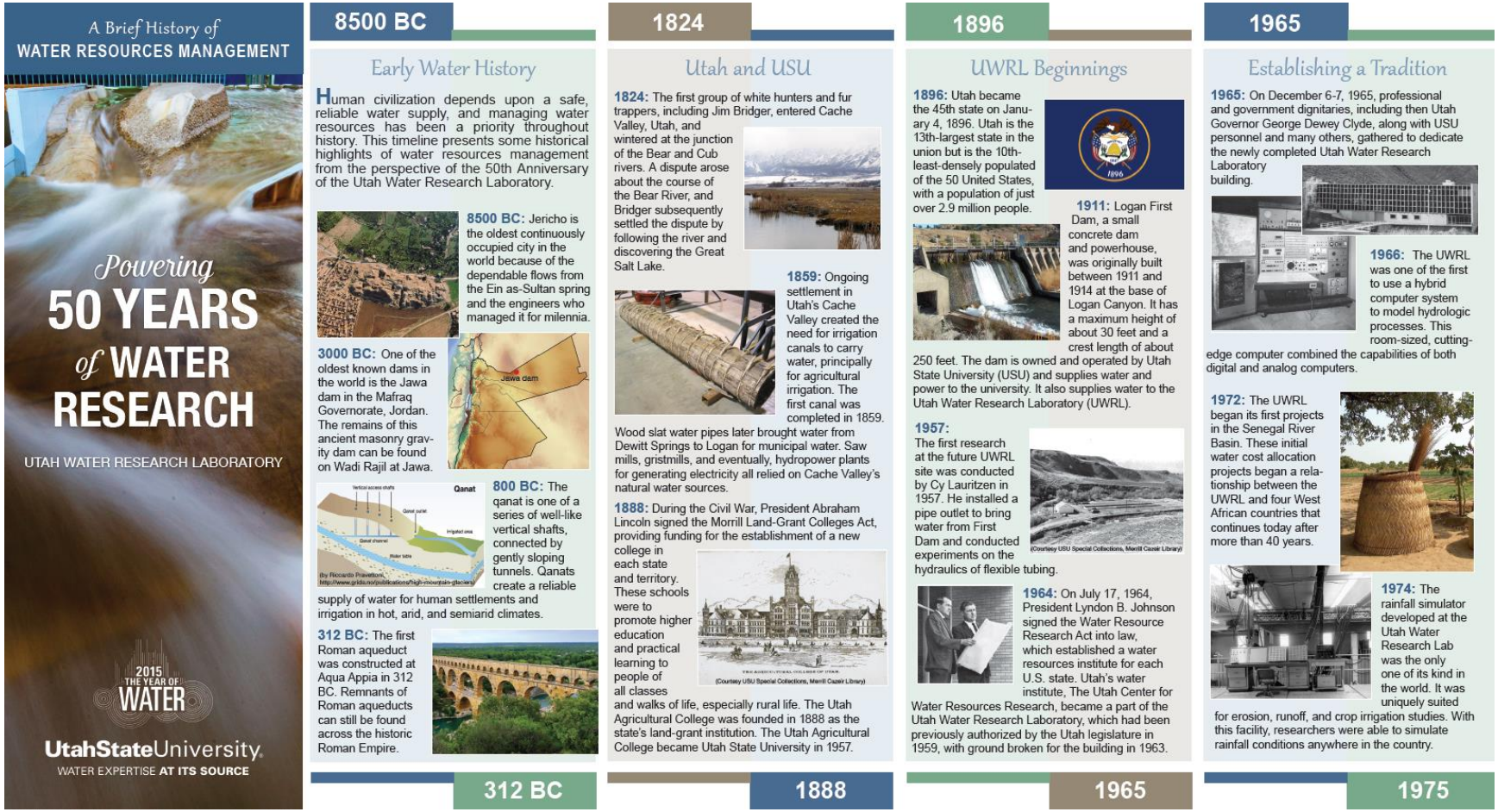
2015 Year of Water Executive Summary (center of tri-fold brochure)



2015 Year of Water Executive Summary (inside fold and back cover of tri-fold brochure)

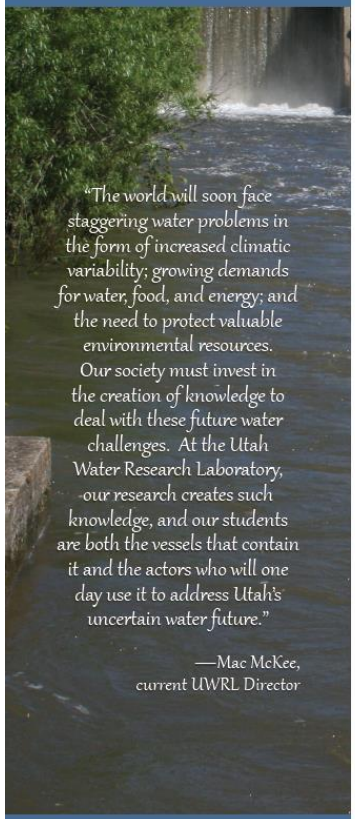


Powering 50 Years of Water Research: A Brief History of Water Resources Management (p.1)



Powering 50 Years of Water Research: A Brief History of Water Resources Management (p2)

Utah Water Research Laboratory



"The world will soon face staggering water problems in the form of increased climatic variability; growing demands for water, food, and energy; and the need to protect valuable environmental resources. Our society must invest in the creation of knowledge to deal with these future water challenges. At the Utah Water Research Laboratory, our research creates such knowledge, and our students are both the vessels that contain it and the actors who will one day use it to address Utah's uncertain water future."

—Mac McKee,
current UWRL Director

uwrl.usu.edu

1975

Expanding Our Capabilities

1978: The State of Utah commissioned the UWRL to review the safety of Utah's non-federal dams. The project revealed that the capacity of many of Utah's dam spillways did not meet current design requirements. This initial work led to development of expertise in both dam risk assessment and hydraulic modeling of spillways for dam rehabilitation starting in the late 70s.

1980: Significant growth in environmental engineering research opportunities led to the need for additional lab space and personnel. To meet those emerging needs, the UWRL added several new faculty and an 11,000 sq. ft. environmental quality laboratory facility, which was dedicated in August 1980.

1982: In official ceremonies, the UWRL building was formally named after former Utah Governor George Dewey Clyde who, during his tenure, was instrumental in making the Utah Water Research Laboratory a reality.

1984: Using satellite data, computers, and skis, UWRL scientists modeled snow-pack levels within northern Utah snow basins to generate more accurate runoff forecasts. Later UWRL experts extended this early work to develop the Utah Energy Balance snowmelt model still used today as part of continuing glacier melt and streamflow forecasting research.

1985

Extending our Reach

1987: The US EPA had identified many Utah sites requiring long-term hazardous waste cleanup. In 1987, UWRL environmental engineers began bioremediation efforts in conjunction with Hill Air Force Base (HAFB) that have continued for more than 25 years. Remediation efforts have included phytoremediation studies and long-term soil column studies that have enhanced the knowledge base regarding the reaction mechanisms involved in bioremediation. UWRL researchers continue to address a wide range of environmental challenges throughout the State of Utah.

1991: December 1991 marked the completion of a 5-year project in India with Harza International, funded by USAID to develop a training program to teach Indian engineers, economists, and water scientists the concepts of integrated river basin planning and management. UWRL experts provided intensive training to more than 200 engineers from across India, who then returned to their home states to work on river basin planning.

1993: The UWRL continued to expand environmental research with national Superfund projects in Utah and Montana as part of the EPA Bioremediation Field Initiative established in 1990. Soil and groundwater at the Libby, Montana Superfund site were contaminated by chemicals used at a wood preserving facility formerly operated at the site. In a three-year project ending in 1993, UWRL researchers helped to carry out and compare several different biological treatment processes in the soil and groundwater at the site.

1995

Research for a New Century

1995: In a unique collaboration, UWRL researchers joined with several other universities in the Colorado River Basin states to study the effects of a severe sustained drought on the arid southwestern US. This work established the UWRL as a leader in hydrologic modeling and paved the way for further advances in hydrologic modeling at the UWRL.

2001: The Tom Miller dam study in Texas was one of many dams and spillways along the Lower Colorado River modeled at the UWRL during this decade. UWRL engineers have built and analyzed at least 125 physical large-scale models of dams, spillways, and other hydraulic structures to date, providing cost-effective solutions that improve design and reduce risk. In addition, the UWRL has tested thousands of valves and flow meters and developed valuable design improvements for a variety of hydraulic structures. A significant investment in labyrinth weir research in 2008 has enabled UWRL faculty to become leading experts in the world in this field.

2004: Increasing levels of phosphorus and other pollutants lead to impairment of streams and other water bodies. While assisting Utah leaders to establish Total Maximum Daily Load targets for these constituents, UWRL researchers also investigated the effectiveness of implemented Best Management Practices. This was impossible to determine, however, based only on traditional random point measurements. Thus began an intensive research program to gather real-time water quality data and investigate correlated surrogate measurements to assess water quality and learn about the behavior of these constituents as they move through the watershed.

2005

Looking to the Future

2006: AggieAir is an autonomous unmanned aerial vehicle developed at the UWRL to meet emerging needs for inexpensive, high-resolution data, both spatially and temporally, in a wide range of scientific applications. This technology is the next generation of field equipment for precision agriculture, wetlands management, riparian/instream flow habitat, endangered species and climate change monitoring, etc.

2011: Computer modeling of hydrologic systems has led to a new scientific era in which high-resolution spatial and temporal datasets are enabling new kinds of synthetic research. The UWRL is at the cutting-edge in creating the cyberinfrastructure that is making hydrologic data readily available world-wide via the internet, allowing researchers and decision makers to access, integrate and analyze large data sets and perform the data-intensive research that will lead to water-related scientific breakthroughs in the future.

50 Years of Water Excellence

2015: December 7, 2015 marks 50 years since our original UWRL building dedication. Some of today's water challenges and those in the future are not so different from those from earlier times, but our knowledge and experience have increased dramatically in finding solutions to those problems. We look forward to building on the inspiring work of water engineers past and present as we face new and emerging challenges in the years to come.

1985 1995 2005 2015