MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2018

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

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Foreword

Again, this year, we have seen more of the same extreme climate events as recently recorded, along with their physical and monetary damage, and human suffering. Utah experienced the absolute driest and the second hottest year in the 123 years since 1895 when the State began keeping records. Once more, powerful hurricanes pummeled the southeast and gulf coast areas causing $ billions in damages, leaving tens of thousands homeless, without food, clean water, and power. In the West, Northwest and California, tinder-dry forests, brushy hillsides and grassland were burning out-of-control, polluting the air in smoke-filled valleys and causing significant loss of life and massive property damage. Clearly, these kinds of extreme events pose urgent new challenges in planning and managing how we use our water and land resources. The latest UN-IPCC international climate report makes clear that the next 20 years will be critical in our efforts to stem climate change and maintain a healthy, sustainable water and land resource environment that can meet the world's needs for food, fiber, energy, and economic growth.

The mission of the Utah Water Research Laboratory is to help the State meet its water, food, and energy resource needs now and in the future. The projects described in this report focus on cutting-edge research to find practical solutions to the most pressing water related problems facing Utah. To support our mission, the UWRL receives 2¼% of deposits made to the Mineral Lease (ML) Account, "to be used for activities… having as a purpose the development… of water resources in the State of Utah." With this basic support, UWRL is able to leverage significant funding from other public and private sources to enhance the scope and impact of our projects. This past FY we have nearly $4 million in project funding from other sources, thus providing additional opportunities for finding solutions to State water issues as well as contributing to economic growth. The UWRL also expands the benefits of its projects through collaborations and partnerships with local, state, and federal agencies. As one of the oldest, most respected and unique University-based water research facilities, UWRL's goals and mission remain the same: To provide data, tools, and solutions to better manage and use the limited water and land resources of the State. We look forward to many more decades of service to the Utah's citizens.

In compliance with House Bill 103 passed during the 1993 Legislature General Session, this report provides a brief description of the UWRL's 251 active research, training, and service projects this past fiscal year, along with an accounting of the ML funds for FY 2018, budgeted expenditures for FY 2019, and planned expenditures for 2020. The projects 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.

Events of this past year has shown that pressures on our water and environmental resources are continuing to increase, and the problems are becoming more complex. The UWRL brings together a world-class faculty whose work focuses on finding ways to provide for today's and tomorrow's water resource and environmental needs. We look forward with optimism to meeting this challenge. The UWRL is pleased to submit this year's report to 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.

We welcome any comments or questions that result from these reviews.

Mac McKee, UWRL Director

Foreword

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Introduction

History of the Utah Water Research Laboratory

The Utah legislature authorized the establishment of the UWRL at Utah State University in 1959 as an important component of the State of Utah's commitment to water resources research, assuring cutting-edge solutions to the State's water problems. Today, the UWRL continues its service as one of the oldest and most respected University based facilities performing research 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, and water, and particularly irrigation science and the engineering of water works, were of foremost importance as curricular and research components. During the next several decades, water resource education and research were mainly carried out by faculty and students in the relevant academic departments and by the Engineering and Ag Experiment Stations. In 1957, George Dewey Clyde, former Dean of Engineering at USU, was elected the 10th Governor of Utah, serving two terms until 1965. During his tenure, he strongly supported research on best practices for using and protecting Utah's precious water resources, including funding and breaking ground for construction of the Utah Water Research Laboratory in 1963. In the following year, 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 a world-class research 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, significantly upgrading facilities and equipment needed for water quality testing and research. In 2009, the UWRL completed a hydraulics modeling and testing laboratory in order to support expanded hydraulics research activities associated with releases from dams (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. This continued growth and productivity over the past 52 years have allowed the UWRL to have a greater state, national, and worldwide impact in water resources research and applications.

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 2018 of nearly $8 million makes it one of the largest institutes in the nation.

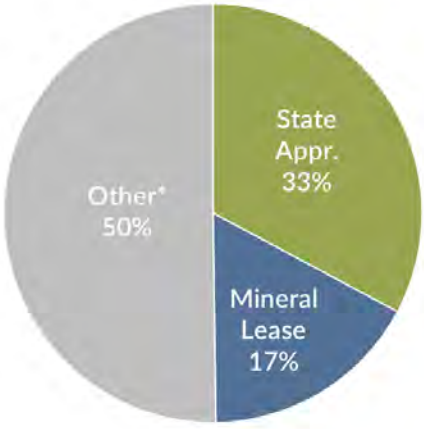
UWRL Financial/Academic Summary (FY/2018)

Number of Active Projects	251
Dollar Value of Active Projects	$7,719,954
Scholarly Publications in Peer-Reviewed Journals	102
Scholarly Presentations at Professional Conferences	126
Outreach Products (FY2018)	
Short Courses and Field Training	11
Degrees Granted	
PhD	4
MS	12
ME	4

In order to leverage the expertise of the UWRL, our faculty collaborate with colleagues from various USU departments, as well as faculty from other institutions and professionals from the private sector and government agencies in Utah and elsewhere. Several of our faculty members, including a 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 numerous state, national, and international engineering and science panels and committees.

Research Program Structure and Organization

The research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and most are 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 funds directly target problems facing the State of Utah. In FY 2018, MLF funding of just over $1.3 million accounted for 17% 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 2018 were nearly $ 8 million.



UWRL Funding

The UWRL's MLF-funded projects are organized into five major research program areas:

- Drinking Water and Wastewater Treatment
- Environmental Quality Management and Remediation
- Surface and Groundwater Quality and Quantity
- 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, Irrigation and Water Divisions)
- Electrical and Computer Engineering
- Mechanical and Aerospace Engineering
- Biological Engineering
- Computer Science

The overall 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 state funds and our 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 hydro-climatological 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 use by 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. Most of our projects also include an outreach component, so our staff is also engaged in public and professional service, technology and information transfer, and public education.

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. In order to train future water professionals, 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/2018

Graduate Students Supported (FY/18)	48
Undergraduate Students Supported (FY/18)	65

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 are 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 receives federal funds of $92,335 through the U.S. Geological Survey (USGS). This year, the base grant, in combination with ML funds, directly benefits the State of Utah in the following areas:

1. Understanding the water chemistry and flow factors that affect bloom forming behavior of Didymosphenia geminato in the Logan River drainage and using that information to determine the risks for specific stream reaches relative to ecosystem and ecological impacts.

2. Using sUAS technology to monitor the impact on wetland flow and consumptive water use due to invasive Tamarisk along the San Rafael River in Utah to assist state water managers in their eradication and stream restoration efforts.

3. Evaluating the effectiveness of the Water Strategy Advisory Team created by Utah's governor to assist with a 50-year water plan for Utah and assessing its value as a template for use in other states and jurisdictions.

In the future, the USGS 104 Program will continue 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 over many 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

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 change and environmental variability, the complex physical and biological processes that affect water quantity and quality, and the dynamic interaction of human activity in the 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 government 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 works with the following State agencies, many other statewide and regional 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 the national and international professional water and environmental organizations helps to bring recognition and external project funding to the state, and it provides opportunities to learn from other research and best practices worldwide. In return, this helps UWRL to identify current and future research needs that will affect our state, and further strengthens our research identification process to assure the relevancy of 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 2019 through FY 2020 for research projects in the five major **Program Areas.** UWRL administration and technology transfer expenditures account for approximately 26% of total MLF budgeted and planned expenditures.

Mineral Lease Fund Expenditures			
Research Program Area	**Actual FY/2018**	**Budgeted FY/2019**	**Planned FY/2020**
UWRL Administration	$340.017.08	$350,217.59	$360,724.12
Drinking Water and Wastewater Treatment	$163,127.25	$281,874.86	$290,981.10
Environmental Quality Management and Remediation	$215,884.09	$324,542.30	$343,528.57
Surface and Groundwater Quantity and Quality	$211,405.23	$294,341.18	$294,270.00
Water Education and Technology Transfer	$100,652.71	$184,626.48	$196,534.08
Water Resources Planning and Management	$279,911.72	$376,597.59	$326,162.13

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

Benefits to the State of Utah

ML funding is often used as leverage to acquire additional support from other sources, which allows us to perform even more research in the State. Every one of Utah's counties have benefited from one or more of the 251 UWRL projects conducted during the past year.

The following gives a general overview of some of the recent and current benefits produced by ML funded projects by Program Research Area. The Research Project Summaries section of the report describes specific State benefits from each research project.

Drinking Water and Wastewater Treatment

The program develops engineering approaches for the treatment and production of drinking water and the treatment and reclamation, recycling, and reuse of municipal and industrial wastewater, and evaluates the effectiveness of various seepage treatment options in Utah environments. Research in this area also investigates methods to develop renewable energy from waste streams

and creates new biological-based technologies for efficient, sustainable water treatment that utilize biosolids to produce methane gas for fuel, bioplastics, and other valuable bioproducts.

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 one of the largest field scale research programs of any academic institution in the nation. Varied research in this area includes bioreactor processing of environmental materials, and engineering scale-up of biologically based waste treatment. These developments encompass 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 and vehicle emissions.

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 projects in the groundwater research ranges from stochastic and numerical analysis of pollution transport of toxic contaminants in natural and engineered systems to the practical aspects of designing technologies to clean up and manage contaminated sites in Utah's aquifer systems. Other research focuses on surface/ground water interactions in streams, quantifying water losses in agriculture, and development of more accurate low-cost water quality sensors.

Water Education and Technology Transfer

Projects conducted by the UWRL in this program area, including many 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, and are often used to provide technical support to Utah's state and local agencies on water-related issues.

Water Resources Planning and Management

Research areas include water conservation, river basin planning, reservoir operating policies, habitat monitoring and restoration, urban water issues, land use, hydrologic modeling, and many others. This program area also addresses various institutional and legal aspects of water, such as water rights transfers, distributed water demand and supply modeling using geographical information systems, and cost allocation and determination of user fees for multiple purpose water resources projects. To be effective, water and environmental managers must have real-time access to relevant data. UWRL is a leader in developing cyberinfrastructure for water related data and interfacing data with user-driven

decision support systems for water and environmental planning and management. Another significant area of research focuses on the use of remote sensing technology and data to improve water, agricultural, and environmental resources management. This includes UWRL development of a unique unmanned aerial remote sensing system (AggieAir™). These small aircraft are programmed to fly over research sites, such as farm fields, wetlands, river and riparian environments collecting multispectral high-resolution imagery. These data are then analyzed and used for better irrigation of crops and for improved water and environmental management.

Outreach

The mission of the UWRL also involves outreach activities related to public service, information dissemination, technology transfer, and short courses. These activities provide benefit to Utah's state and local agencies, elected officials, citizens, and the nation. Additionally, our UWRL associated faculty, staff, and students provide various other outreach functions as described on 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. Recent specific panels include:

State of Utah Drinking Water Board

State of Utah Water Operators Certification Council

Salt Lake Valley 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

The Nutrient Criteria Development Core Advisory Team- 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

Logan City Renewable Energy and Conservation Advisory Board

Bear River Health Dept.'s Air Task Force

The Weber-Morgan Health Department Wastewater Advisory Committee

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 a feature article on different research projects, faculty, and students at the UWRL. The Utah On-Site Wastewater Treatment Training Program at the UWRL offers 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 driven by increased climatic variability and extreme climate driven events; 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 the 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 our State and Nation's ability to deal with these water challenges now and the future. As the UWRL looks forward to another year 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 outstanding reputation for water research and education.

Administration, Advisory Support, and Special Equipment

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

Project Name	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
Business Office	$150,074.25	$154,576.48	$159,213.77
Laboratory Infrastructure Support, Travel, and Special Request	$42,688.44	$43,969.09	$45,288.17
Publications Office	$64,404.60	$66,336.74	$68,326.84
UWRL Administration	$82,849.79	$85,335.28	$87,895.34
Total	**$340,017.08**	**$350,217.59**	**$360,724.12**

Administration and 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 Directors 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, ML 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 critical equipment items.

Administration of the MLF Program

The costs of administering the MLF program at the Utah Water Research Laboratory are conscientiously 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 critical water resources problems. MLF money spent on administration at the UWRL provides minimal salary support for the UWRL Director and Associate Directors and supports the administration of the USGS 104(b) program funding that comes to the state. FY 2017 administrative costs represented approximately 7% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL have generally fluctuated between $ 7 and $ 12 million, and at any point in time more than 200 active research contracts are administered at the UWRL. These projects require significant support from the UWRL Business Office in the form of accounting and financial oversight. Further, the UWRL Publications Office provides support for outreach activities (such as the production of presentations, maintenance of the UWRL and UCWRR web pages, etc.). MLF expenditures in FY 2018 on these support activities accounted for 16% of total MLF funding.

Advisory Support on Water Problems

The UWRL received many requests in FY 2018 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 identify and seek funding for new applied research in the state, and to provide expert advice relative to current water 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. The UWRL also maintains 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. ML funds are occasionally used to invest in state-of-the-art equipment to support these activities and provide long-term, sustainable capability to continue these efforts. The Project Reports sections describes any new equipment acquisition and their integration into research.

Research Project Summary Categories

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Summary by Research Projects

	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
UWRL Administration	$ 340,017.08	$ 350,217.59	$ 360,724.12
Drinking Water and Wastewater Treatment	$ 163,127.25	$ 281,874.86	$ 290,981.10
Environmental Quality Management and Remediation	$ 215,884.09	$ 324,542.30	$ 343,528.57
Surface and Groundwater Quantity, Quality	$ 211,405.23	$ 294,341.18	$ 294,270.00
Water Education and Technology Transfer	$ 100,652.71	$ 184,626.48	$ 196,534.08
Water Resources Planning and Management	$ 279,911.72	$ 376,597.59	$ 326,162.13
Totals	**$ 1,310,998.08**	**$ 1,812,200.00**	**$ 1,812,200.00**

Research Project Summary Categories

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 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	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
Biofiltration of Utah Municipal Drinking Water	$44,120.48	$45,444.09	$46,807.42
Biological Phosphorus and Nitrogen Removal from Lagoon Wastewater Using Rotating Algae Biofilm Bioreactors (RABR)	$30,226.53	$31,133.33	$32,067.33
Managing Drinking Water Quality in Park City, Utah	$40,115.33	$41,318.79	$42,558.35
Mitigation of Methane Emissions from Septic Systems	$18,425.87	$18,978.65	$19,548.00
Treatment of Wastewater Algae for Bioenergy and Animal Feed	$30,239.04	$30,000.00	$30,000.00
Designated Projects		$70,000.00	$70,000.00
Undesignated research projects in program area		$45,000.00	$50,000.00
Total	**$163,127.25**	**$281,874.86**	**$290,981.10**

Biofiltration of Utah Municipal Drinking Water

Principal Investigators:
David K. Stevens
Darwin L. Sorensen
Stetson Bassett (Student)

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

Project Description

- **Need and Purpose:**

  Biofiltration is a promising method for reducing the potential for unwanted disinfection byproducts and for minimizing regrowth of microorganisms in drinking water distribution systems. Because of the site-specific implementation of this technology, this project implemented biofiltration systems at two Utah water utilities to study the potential of biofiltration to reduce and modify the organic matter content of drinking water and develop preliminary information pertaining to the design and operation of such utilities. The primary objective was to assess and optimize biofiltration in Utah drinking water treatment plants at pilot scale and to answer the following questions: (1) Is biofiltration effective at reducing organic matter from source waters? (2) Can biofiltration reduce the potential for production of disinfection byproducts? 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?

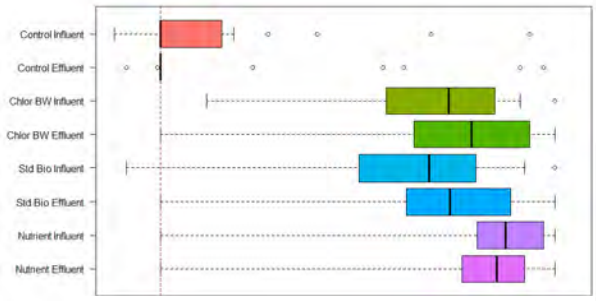
  A series of pilot-scale experiments at the Duchesne, UT, water treatment plant were completed in 2017 and a full-scale experiment at a Utah water treatment plant at Hurricane, UT was completed in 2018. The plants were chosen in consultation with project partners from the Utah Division of Drinking Water and the Utah Water Quality Alliance (operators of larger water treatment facilities in Utah). Operation and data collection at the Duchesne pilot-scale biofilters continued at the plants from April 2015 to April. 2016. Influent, intermediate, and effluent water triplicate samples were collected weekly 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 were collected during the study to assess the development of biological consortia through microbiological analyses.

  The Hurricane study at Washington County Water Conservancy District's Quail Creek water treatment plant was designed to evaluate operational practices by observing water quality and operational trends in a side-by-side full-scale biofiltration conversion. While the plant was in full production mode, three out of the twelve filters were operated as biofilters, and their performance was evaluated for one year. The plant operated in this configuration from July 2016 into 2018. The study analyzed four full-scale filters: one control that ran like the other eight plant filters (with pre-chlorination and chlorinated backwash water), and three that operated in biological mode. The influent to the three biofilters was de-chlorinated with thiosulfate: one had no pre-chlorination with chlorinated backwash, another had no pre-chlorination with non-chlorinated backwash), and the third had no pre-chlorination or non-chlorinated backwash and was supplemented with nutrients (i.e., nitrogen and phosphorus).

  The parameters used to determine filter performance were separated into four categories: organic carbon concentration (TOC/DOC, UVA/SUVA, CBXAs), biological activity (HPC, ATP, EPS), water quality (temperature, turbidity, pH, nutrients, DO, DBPs, Mn) and operational data (head loss, filter run length, wash time, wash rate, UFRV, EBCT).

- **Benefits to the State:**

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



Heterotrophic Plant Count, Summer

- **Geographic Areas:**
  Study Area: Duchesne, UT, Hurricane, UT (site of Washington County Quail Creek WTP).
  Areas Benefited: Statewide.

- **Accomplishments**:

  Findings: Samples collected from the Duchesne water treatment plant pilot system by CUWCD and USU personnel were analyzed on-site and also sent to the State lab in Salt Lake County and to the Utah Water Research Laboratory for further testing. These samples were assayed for a variety of chemical constituents. Findings confirmed that biofiltration at pilot scale reduced the amount of organic matter slightly relative to the control (no biofiltration), and significant levels of biological activity were observed in the pilot filters, as measured by ATP activity. Treated water quality showed no deterioration relative to drinking water standards in any of the pilot scale filters. The experimental conversion lasted one year, during which water quality and operational data were collected, resulting in a recommendation to convert all of the filters to biologically active, but without nutrient enhancement.

  Results: The plant performance in terms of the conventional measure of finished water quality (Total organic carbon) were unchanged, the biofilters showed clear signs of enhanced biological activity in the biofilters (Figure), and the primary goal of operating in biofiltration mode, reduction in disinfection by-product formation, as measured by total trihalomethanes (TTHM), was realized. In the control, the interquartile range of the TTHM concentrations was about 73–86 ug/L, while for the three treatments, especially the chlorinated backwash treatment, the TTHM concentrations were generally significantly lower (~45–70) for chlorinated backwash and nutrient addition, and 55–90 for the standard biofiltration. With further research to optimize operations in the biofiltration mode, additional improvement is expected.

Work Plan FY18/FY19

No further effort is immediately anticipated on this project.

Informational Resources

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

Bassett S., D. Stevens, E. Nieminski , M. Rau , M. Hoyt, and J.Crawford (2016). *Biofiltration of Utah Municipal Drinking Water Pilot Plant Testing of Biofiltration at the Central Utah WCD Treatment Plant in Duchesne, UT*. Final Report submitted to the U.S. Geological Survey, May, 2016.

Bassett. S., E.C. Nieminski, D.K. Stevens (2018). Evaluation of a Side-By-Side, Full-Scale Conversion to Biological Filtration. *J. AWWA*. Accepted for Publication.

Biological Phosphorus and Nitrogen Removal from Lagoon Wastewater Using Rotating Algae Biofilm Bioreactors (RABR)

Principle Investigators:
Ronald C. Sims
Charles Miller
Anna Doloman (PhD student)
Legor Pererva (PhD student)
Tyler Marlar (BS student)

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

Project Description

- **Need and Purpose:**
  In addition to the requirement to remove from effluent the total phosphorus concentration to 1 mg/L, Logan City recently also was required to remove nitrogen from wastewater in order to meet water quality criteria established by the State of Utah in 2015. The Rotating Algae Biofilm Reactor (RABR) was tested for phosphorus and nitrogen removal at the City Lagoons Wastewater Treatment Plant. The RABR technology treats wastewater to higher quality for both phosphorus and nitrogen removal during summer, and utilizes the biosolids produced to make valuable bioproducts.

- **Benefits to the State:**

  Implementing RABR microalgae wastewater treatment technology can boost economic growth through creation of new engineering jobs, new bioproducts, and services in Utah while decreasing the costs of wastewater treatment for cities and small communities. The RABR method for treating wastewater captures carbon dioxide, a greenhouse gas (GHG), in the form of microalgae, thereby providing "CO_2 credits" as part of a life cycle analysis of wastewater treatment impacts on the environment. Because the City does not currently have an anaerobic digester for biosolids treatment, the harvested microalgae can be disposed in the newly constructed Clarkston landfill and used to generate biogas that can be collected and used for power. The method developed is applicable to other wastewater systems in Utah that depend on lagoons or open ponds for treatment and to mechanical plants that treat lower volumes of highly concentrated nutrient streams.

- **Geographic Areas:**

  Study Area: The Salt Lake City area and Northern Utah, including the cities of Logan, Hyde Park, Smithfield, North Logan, River Heights, Providence, Nibley, and Utah State University.
  Areas Benefited: All areas of the state of Utah that must meet strict wastewater treatment plant nutrient limits, including mechanical plants and ponds or lagoons.

- **Accomplishments:**

  Findings: RABR-based microalgae can uptake phosphorus and nitrogen successfully into a harvestable biofilm that can be used as feedstock for both bioenergy production through anaerobic digestion and through application as a fertilizer for non-food vegetation. The "microalgae crop" can be applied to the

new Clarkston Landfill and fermented to produce biomethane as a source of heat and power. Another stream has a high protein content and omega fatty acids that can serve as feed for aquaculture,

Results: We successfully removed nutrients, including phosphorus and nitrogen, from Logan Lagoon wastewater using the RABR technology and generated biogas under anaerobic conditions using the microalgae. We developed and tested an improved method for processing the wet harvested algae to extract proteins and lipids for feed (Publication 2). These results demonstrated the success of mixed culture microalgae for treating municipal wastewater and producing valuable bioenergy and products utilizing all fractions of the algae biomass.

Figure 1. Rotating Algae Biofilm Reactor for laboratory testing of nutrient uptake from wastewater into microalgae biofilm

Work Plan FY18/FY19

This project was completed and the results are being used by Logan City and the Central Valley Water Reclamation Facility (CVWRF). No immediate research is planned for this topic.

Informational Resources

Contact:

Mr. Tom Holstron, Manager, Central Valley Water Reclamation Facility, Phone: (801) 973-9198, E-mail: holstromt@cvwrf.org
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, E-mail: rplaizier@westech-inc.com.

Publications from this project:

Doloman, A., Soboh, Y., Sims, R.C., and Miller, C.D. (2017). Microbial dynamics during anaerobic digestion of microalgal biomass in a USAB reactor. *International Journal of Microbiology* (Vol. 2017). https://doi.org/10.1155/2017/5291283.

Managing Drinking Water Quality in Park City, Utah

Principal Investigators:
Laurie S. McNeill
Joan E. McLean
David K. Stevens
William Kent, Tiana Hammer, and
Erin Andersen (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, 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. The 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 help Park City continue their proactive approach to improving water quality by assessing the causes of these adverse water quality events, evaluating monitoring techniques that can be used to predict future events, and recommending 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 monitoring strategy for 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: Thallium (Tl) is a rare heavy metal in drinking water, but its extreme toxicity makes its removal crucial for consumer health. Traditional treatment methods do not work for Tl in sources with high concentrations of ions like calcium (Ca) and potassium (K), as they are removed preferentially to Tl. A treatment method that specifically targets Tl must be applied. Pilot studies conducted in Park City concluded that pyrolusite, a manganese oxide ore, will remove Tl to very low concentration in the presence of competing ions, but because this method is not common, further study was required. We were able to characterize the association of Tl removed onto pyrolusite filter media, providing increased understanding of the stability of Tl removed from drinking water using this treatment technique. Carbonates are likely to sequester Tl on the pyrolusite surface, and dissolution of these carbonates was observed with minor changes in pH. Such dissolution could result in release of Tl from the pyrolusite media, so utilities should avoid the buildup of carbonates if possible, especially in water systems whose sources have variability in alkalinity or pH.

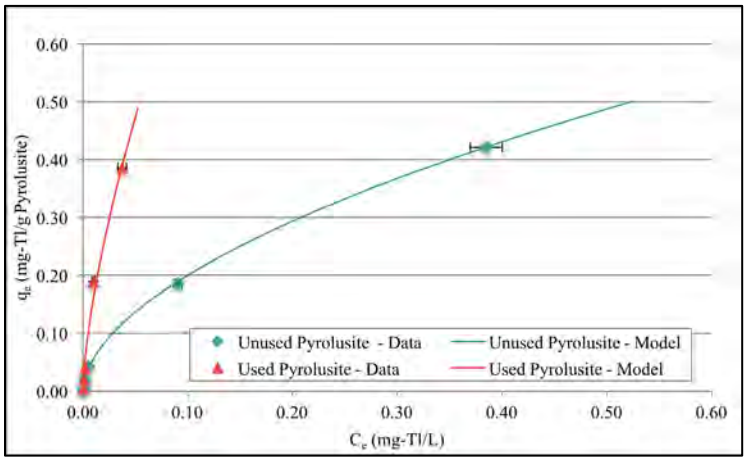


Figure 1: Average Tl removed onto the used and unused pyrolusite solid (qe (mg/g)) vs. equilibrium Tl concentration (Ce (mg-Tl/L)) with the applied Freundlich models. Error bars represent the standard deviations for measured Ce and calculated qe

Table 1: Summary of the Freundlich adsorption capacity (Kf (L/mg)N(mg/g)) and intensity (N) parameters. Larger Kf values indicate greater Tl sorption density for used pyrolusite collected by AggieAir™

Media	Water Quality	Kf	N
Unused Pyrolusite (no carbonates)	A	0.715	0.553
	B	0.557	0.533
	C	0.496	0.442
Used Pyrolusite (with carbonates)	A	3.560	0.673
	B	2.250	0.616
	C	2.304	0.621

Work Plan FY18/FY19

The project has been completed.

Informational Resources

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

Publications: A report is available from the Water Research Foundation: www.waterrf.org/Pages/Projects.aspx?PID=4509.

Mitigation of Methane Emissions from Septic Systems

Principal Investigators:
Judith L. Sims
Charles Miller
Ronald C. Sims
Katelyn Ellis (student)
Jace Parkinson (student)

Partners/Collaborators:
- *None*

Project Description

- **Need and Purpose:**

Concerns about 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.

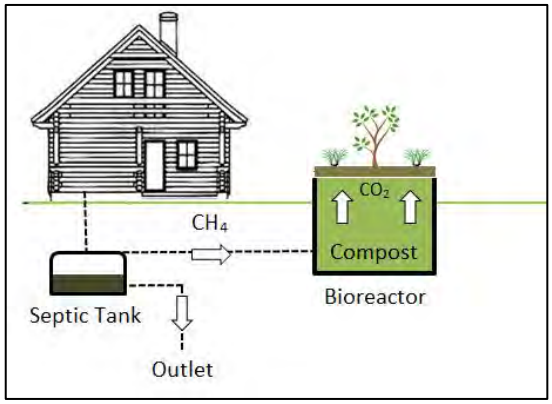


Figure 1. A schematic showing the process of mitigating methane at a local residence.

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 a method to mitigate the impacts of methane produced in septic tanks that collects the methane and treats it in a compost biofilter system. The methane is converted to carbon dioxide, which can be used by plants growing on the compost (Figure 1).

- **Benefits to the State:**

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: Of three methanotroph bacteria species being considered for use in mitigation of methane in septic systems, Methylomicrobium alcaliphilum was selected because of its robustness and fast growth rate. M. alcaliphilum cultures were observed to become visibility turbid in as little as 2 days (Figure 2), much faster than the 25–30 days required by cultures of another potential methanogen, M. hirsute (Figure 3), to become visibily turbid. Additionally, M. alcaliphilum naturally secretes a valuable biproduct used in cosmetics called ectoine, which, in its refined form, has a value reported to be upwards of $450/lb.

  Results: An experimental growth curve was developed by monitoring bacterial growth of triplicate samples of *M. alcaliphilum* for a period of 48 hours using light spectroscopy. Data collected confirmed the fast growth of the bacteria and showed peak growth to occur between 0–20 hours of inoculation and feeding (Figure 4).

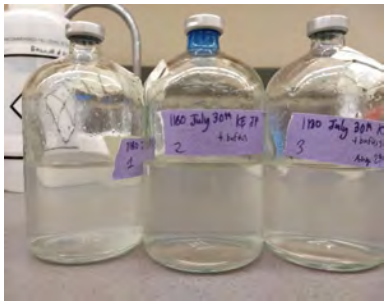


Figure 2. Growth of M. alcaliphilum

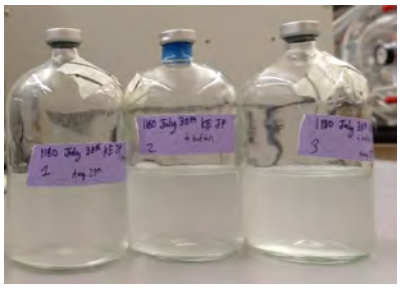


Figure 3. Growth of M. hirsute

Work Plan FY18/FY19

July 2018 – December 2018:

- Perform gas chromatography analysis to confirm laboratory samples of *M. alcaliphilum* are reducing methane levels.
- Design batch operated bench scale bioreactors containing compost inoculated with bacteria.
- Perform gas chromatography analysis to confirm methane introduced into batch-operated bioreactors is reduced or eliminated.

January 2019 – June 2019:

- Evaluate methane mitigation using continuous-flow, bench-scale bioreactors containing compost inoculated with bacteria using gas chromatography analysis to confirm methane reduction in continuous flow bioreactors.
- Develop methods and laboratory design for ectoine extraction.

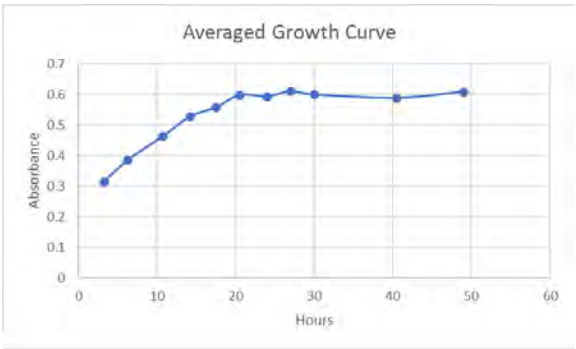


Figure 4. Growth curve for methanotroph M. alcaliphilum

Informational Resources

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

Poster Presentations:

Hodges, Alan; Hancock, Celeste; Sims, Ronald, and Sims, Judith. (2016). *Reduction of Greenhouse Gas Emissions from Septic Tanks via Compost Biofiltration*. Annual Conference, Institute of Biological Engineering, Greenville, SC, April 7–9.

Parkinson, Jace C, and Ellis Katelyn A. (2018). Mitigation of Methane Emissions from Septic Tanks via Compost Biofiltration. *Utah State University Student Research Symposium*, Logan, UT, April 12.

Treatment of Wastewater Algae for Bioenergy and Animal Feed

Principal Investigators:
Ronald C. Sims
Charles Miller
Anna Doloman (PhD student)
Jason Peterson (MS student)
Tyler Marlar (BS student)

Partners/Collaborators:
- ***Local:*** *Allen Young, USU Caine Dairy Personnel*
- ***Business/Industry:*** *Jon Richins, WesTech_Inc, SLC*

Project Description

- **Need and Purpose:**

  This project is assisting the USU Caine Dairy Center, which currently cannot apply water from the waste treatment lagoons to the land because of the high concentrations of nutrients. Therefore, this project is evaluating the use of microalgae cultivated as a biofilm to take up nutrients from dairy wastewater and the transformation of the algae into animal feed and bioenergy. Algae cultivated from dairy wastewater represents a promising substrate for bioenergy production that can be used as a source of combined heat and power (CHP) for the dairy industry. Algae was cultivated on dairy wastewater at the USU Caine Dairy in the form of a biofilm utilizing a rotating algae biofilm reactor (RABR) that could be alternately exposed to the wastewater and then to the sunlight. While algae do not normally grow in turbid and colored wastewater due to lack of light penetration, this approach treats the turbid and colored wastewater with microalgae. The harvested microalgae are then used to produce both animal feed and bioenergy in the form of methane.

- **Benefits to the State:**

  Both animal feed and alternative energy sources based on local treatment system wastewaters provide a path from waste to valuable biofuels and result in greater energy independence and a positive economic impact for rural communities in Utah. Utilizing microalgae that are cultivated as a biofilm in turbid and colored wastewater to remediate the nutrients provides an important path to producing bioenergy from wastewater treatment products in the State.

- **Geographic Areas:**

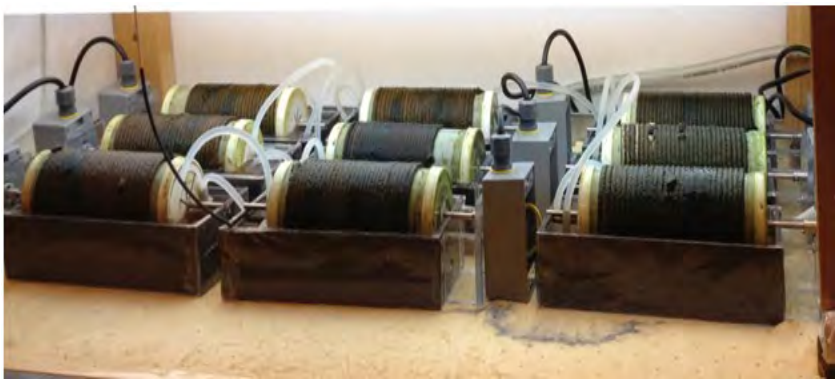
  Study Area: Areas in rural Utah treating animal waste in open ponds and lagoons. Such wastes may be derived from dairy, cattle, swine, poultry, and aquaculture (fish) industries.
  Areas Benefited: All areas of the State of Utah, especially rural agricultural communities where wastes can be utilized as sources of nutrients to grow algae, which can then be transformed into feed as a source of protein and omega fatty acids and also bioenergy for heat and power. Animal waste managers often face a challenge in dealing with nonpoint source runoff. Farm and industrial use of the rotating algae biofilm reactor (RABR) technology provides a way to both treat the waste and recover feed and bioenergy for their use.

- **Accomplishments:**

  Findings: Bioeneergy in the form of biomethane was produced from harvested microalgae using anaerobic digestion). Dairy wastewater that was supplemented with microalgae from the RABR showed increased biomethane production using biomethane potential (BMP) tests. The results were described in a thesis by Mr. Jason Peterson (Reference 1).

Algal lipid-protein (ALP) was extracted from microalgae cultivated on the rotating algae biofilm reactor (RABR). Optimal process conditions were developed to maximize the ALP production. The procedure recovered crude protein and fatty acids. This process of cultivating microalgae on dairy wastewater and then extracting the protein-lipid portion provide a sustainable closed-loop between wastewater remediation of agricultural wastewater and production of animal nutrition.

Results: Treatment of dairy wastewater was successful using the novel bioreactor (RABR), in which the nutrients are taken up into microalgae grown as a biofilm. The waste-cultivated microalgae were used as a feedstock for anaerobic reactors to generate bioenergy and also to produce valuable protein and lipid feed.



Dairy wastewater treated with a rotating algae biofilm reactor (RABR) for nutrient removal and source of animal feed

Work Plan FY18/FY19

This project was successfully completed. No more research is planned at this time.

Informational Resources

Contact: Dr. Allen Young, Caine Dairy Center, Utah State University, Phone: (435) 797-3763, E-mail: allen.young@usu.edu.
Dr. Ronald C Sims, Phone: (435) 797-3156, E-mail: ron.sims@usu.edu.

Publications:

Peterson, Jason (2017). "Anaerobic digestion of wastewater: effects of inoculants and nutrient management on biomethane production and treatment." Utah State University, Logan, UT. (Spring). All Graduate Thesis and Dissertations. 5699.

Marlar,T., M. Hansen, A. Sathish, and R. C. Sims (2018). Lipid-Protein extraction from wastewater cultivated algae for animal feed: optimization and characterization. *International Journal of Innovative Research in Scientific Engineering and Technology*, (IJIRSET), Vo. 1 (1), May.

Environmental Quality Management and Remediation

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

Project Name	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
Cache Valley's Pollutant Profiles and Application to Additional Areas in Utah	$36,581.94	$37,679.40	$38,809.78
Contaminant Mobility and Fate in Corn Grown with Reclaimed Water and a Biochar Soil Amendment	$45,957.27	$47,335.99	$48,756.07
Field and Laboratory Methods to Quantify Nitrogen Cycling in Receiving Waters below Water Reclamation Facilities	$11,013.95	$11,344.37	$11,684.70
Impact of Metals and Metal Ions on Soils and Plants	$44,270.64	$45,598.76	$46,966.72
Logan City Renewable Energy and Conservation Advisory Board	$2,000.00	$2,060.00	$2,121.80
Organosilicon Adjuvants in Pollen: Initial Results from a 2018 Field Survey	$10,613.39	$10,000.00	$33,000.00
Real-Time Polymerase Chain Reaction (RT-PCR) Instrumentation	$11,013.96	$11,344.38	$11,684.71
Using Duckweed as a Treatment Technology for Nutrients and Pharmaceutical Contaminants in Municipal Wastewater Systems	$17,850.99	$6,500.00	$6,695.00
Vehicle Cold Start, Hot Start, and On-Road Emissions	$36,581.95	$37,679.40	$38,809.79
Designated Projects		$65,000.00	$55,000.00
Undesignated Projects		$50,000.00	$50,000.00
Total	**$215,884.09**	**$324,542.30**	**$343,528.57**

Cache Valley's Pollutant Profiles and Application to Additional Areas in Utah

Principal Investigators:
Randal S. Martin
Ian Hammond (M.S. student)

Partners/Collaborators:

- ***Local:*** *Utah State University*
- ***State:*** *Utah Division of Air Quality (UDAQ), Air Monitoring Center (AMC), University of Utah, Weber State University*
- ***Business/Industry:*** *Brigham Young University*

Project Description:

- **Need and Purpose:**

  The more densely populated areas in Utah, including most of the Wasatch Front in Cache Valley are known to violate winter-time standards for $PM_{2.5}$ (Particulate Matter), which is a serious, well-known threat to human health. These regions in Utah have been categorized by the USEPA as $PM_{2.5}$ "non-attainment" areas since 2009, and neither the Cache Valley nor the Wasatch Front reached their attainment dates of Dec. 2015. Consequently, the Cache Valley needed to modify its State Implement Plan (SIP) and applied for an extended target date of Dec. 2017. In Oct. 2108, the USEPA declared that the Cache Valley airshed had indeed obtained this new target date, but official "attainment" status has not yet been codified and will not be until a maintenance plan is approved. Owing to similar missed target dates and an incomplete SIP, the Wasatch Front airsheds have been declared "serious' non-attainment areas, and more stringent controls and remediation scenarios will have to be explored and implemented. An ad hoc study conducted in the winter of 2015–2016 by UDAQ, USU, the U of U, and Weber State University provided some detailed insight into the particularities of local $PM_{2.5}$ formation. That study provided impetus for a much larger 2017 Utah Winter Fine Particulate Study (UWFPS) involving the aforementioned Utah universities, along with the USEPA, NOAA, USDA, and some non-Utah universities. The 2017 Utah Winter Fine Particulate Study (2017 UWFPS) ran through the winter of 2017 and the data analysis and results continued through much of 2018.

- **Benefits to the State:**

  Understanding the composition of $PM_{2.5}$ and its temporal changes will contribute to improved modeling of the current $PM_{2.5}$ behavior and to understanding the effectiveness of implementing remediation proposals and strategies. This project and other studies have shown that gas-phase NH_3 is an integral part of the $PM_{2.5}$ formation process, which was much of the focus of the USU investigators. Knowing the abundance and distribution of NH_3 along the Wasatch Front and in Cache Valley can give local scientists, modelers, and regulators the understanding needed to improve air quality to benefit the affected populations. The quantification of ground level NH_3 was the prime assignment of the USU team.

- **Geographic Areas:**

  Study Areas: During the winter of 2017, arrayed networks of NH_3 samplers were deployed along the Wasatch Front (American Fork to Brigham City, 11 sites) and in Cache Valley (25 sites). USU ran a real-time NH_3 monitor that was co-located with an EPA research trailer in Logan. Additionally, in June 2107, the USU

team was presented with the opportunity to examine NH_3 and other amine concentrations in and around a fur production facility. To our knowledge, this has never been studied before.

Areas Benefited: The studies directly examined areas along the Wasatch Front and the Cache Valley. However, the methodologies employed by this project are directly applicable to other state and national regions with air pollutant issues.

- **Accomplishments:**

Findings: A diverse team of university scientists, engineers, and agency personnel, formed an intra- and interstate group that worked cooperatively to successfully complete this year's work. Aside from its scientific findings, this study presented a major opportunity to develop collaborative air pollutant studies among the major Utah academic institutions.

Results: The figures below shows the average NH_3 concentrations observed across the Wasatch Front (Brigham City to American Fork) and Cache Valley during the UWFPS. The Wasatch Front had an average NH_3 concentration of 31 ppb, with slightly higher concentrations observed toward the south (Figure 1). This is different from the 2016 study, which found lower concentrations and little gradients. However, the 2017 grid extended much farther to the south. In Cache Valley, the average observed NH_3 was 78 ppb as compared to the 65 ppb of the 2016. The concentration gradients (Figure 2) were very similar to the previous studies, with higher gradients near larger agricultural facilities.

Figure 1. NH_3 concentration along Wasatch Front

Additionally, the analyses of the amine samples collected from the fur production facility were completed in mid-2018. These first-of-their-kind results suggest that such facilities cannot be discounted in their contributions to local atmospheric amine concentrations. An overall project interim report was submitted to UDAQ in October 2017, and the final report was submitted to Utah's Division of Air Quality (UDAQ) in April 2018, was made available to the public shortly thereafter, and is available at https://deq.utah.gov/division-air-quality. Separate manuscripts are in preparation.

Work Plan FY18/FY19

Some of the work initiated under the 2017 UWFPS data will continue. Specifically, UDAQ funding will allow us to better quantify the ammonia (NH_3) and hydrochloric acid (HCl) distributions and likely contribution to local $PM_{2.5}$ at 40 sites arrayed from Brigham City (Box Elder County) to Mona (Juab County)—roughly 4x the sites from the previous study. Results from these studies will provide better understanding of source apportionment and photochemical mechanisms.

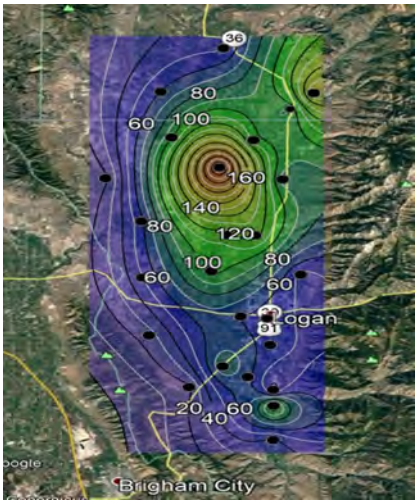


Figure 2. NH_3 gradients in Cache

Informational Resources

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

Contaminant Mobility and Fate in Corn Grown with Reclaimed Water and a Biochar Soil Amendment

Principal Investigators:
William J. Doucette
Jeff Flashinski, Graduate Research Assistant

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

Project Description:

- **Need and Purpose:**

Reclaimed water is increasingly used in arid and semi-arid regions for non-potable purposes (irrigation, industrial processes, toilet flushing, groundwater recharge, etc.). When used for irrigation, any contaminants in the reclaimed water, such as pharmaceuticals and personal care products (PPCPs) and other compounds, can accumulate in exposed crops.

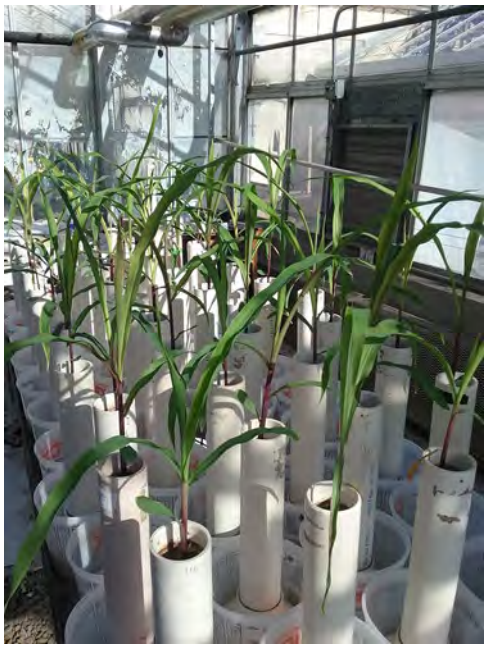


Figure. 1. Corn grown in columns containing, sand, soil, or soil amended with biochars.

Biochar is biological material (often a plant material) that has partly or fully undergone pyrolysis (decomposition at high temperatures with no oxygen). Biochar is a potentially cost-effective soil amendment and contaminant sorbent that could reduce plant exposure to the contaminants in reclaimed water.

The main objective of this study is to investigate the impact of wood biochar on the crop bioavailability of selected PPCPs often found in reclaimed water and biomass production. A secondary objective is to quantify the contaminant sorption-desorption characteristics in the amended soils and to determine if there is a relationship between sorption-desorption behavior and plant bioavailability. Development of sorption-desorption and plant bioavailability relationships could help determine the quantity and type of biochar needed as an effective soil amendment. PPCPs were selected as target contaminants because of their widespread occurrence in reclaimed water and their potential impact on animals feeding on the irrigated crops (Ferrari et al., 2003). Target PPCPs were selected for this study based on chemical properties, widespread use, frequent detection in WWTP effluent, and potential risk to the environment. The target PPCPs represent a range of therapeutic uses including antibiotics linked to antibiotic resistance in bacteria (sulfamethoxazole (SMZ) and triclosan (TRI)), an anticonvulsant that prevents seizures and relieves nerve pain (carbamazepine), an antidepressant (fluoxetine (FLX)), and an antihyperlipidemic (gemfibrozil (GBZ)). Atrazine (ATZ) was also selected because it is an herbicide commonly used on corn and has been used in a number of sorption studies with biochar. Pinyon Juniper– and Lodgepole Pine–derived biochars were chosen because they were produced from tree species that often require removal due to insect infestations. Corn was used as the test plant because of its commercial value and because it has been grown with reclaimed water in the past.

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Areas: 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:**

  Findings: Corn plants were grown in PVC columns filled with sandy loam soil, sand, biochar-amended soil, or perlite amended soil under greenhouse conditions (Fig. 1). Treated plants were watered with reclaimed wastewater spiked with the target compounds, whereas the control plants received no spike. All treatments were conducted in triplicate, along with 2 additional plants used to determine growth rates, resulting in a total of 50 plants. At 28 days, the corn leaves, stems and roots were collected and dried in a desiccator.

  Dried plant tissue samples were placed into centrifuge tubes and extracted with methanol using a vortex shaker. The combined extract was cleaned up prior to analysis and chromatographic separation.

  Results: One concern associated with amending soils with biochars to reduce contaminant uptake is the potential for also reducing nutrient uptake. However, initial results showed that biochar amendments did not negatively impact growth. Biochar was also observed to reduce the uptake of target compounds. (Fig. 2). Leaf concentrations of the target compounds were highest in sand followed by soil then biochar amended soil. Leaf concentrations varied with compound with carbamazepine > fluoxetine > atrazine > triclosan > sulfamethoxazole.

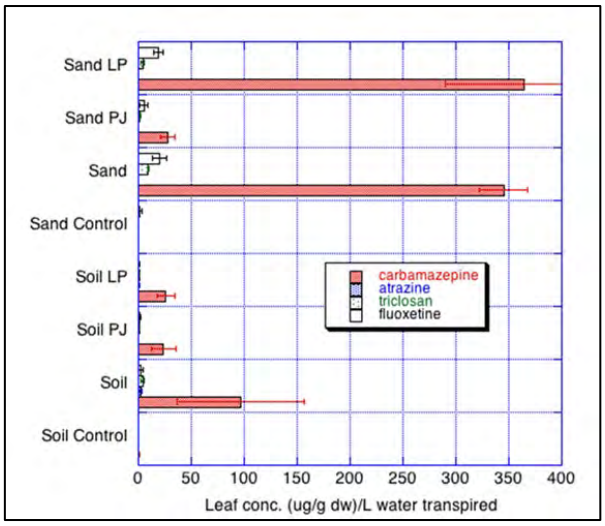


Figure. 2. Leaf concentrations of target compounds vs. plant growth media.

Work Plan FY17/FY18

We will continue plant uptake and sorption studies. Once the studies are completed, the impact of biochar on contaminant uptake will be evaluated along with its relationship to PPCP sorption/desorption behavior.

Informational Resources

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

Field and Laboratory Methods to Quantify Nitrogen Cycling in Receiving Waters below Water Reclamation Facilities

Investigators:
R. Ryan Dupont
Darwin L. Sorensen
Chelsea Stewardson, Jared Richins, and Makenzie Beltran (Graduate Students)

Partners/Collaborators:
State: *Nicholas von Stackelberg, Environmental Scientist, and Jodi Gardberg, Section Manager, Standards and Technical Services Section, Division of Water Quality, Utah Department of Environmental Quality*

Project Description

- **Need and Purpose:**

  Nitrogen discharge from treatments plants reduces oxygen levels needed in streams to maintain a healthy ecosystem due to nitrification in which ammonia-nitrogen (NH_4^+-N) is oxidized to nitrate-nitrogen (NO_3^--N), depleting the oxygen in the stream. In 2011, the US EPA launched a "Working Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions." The Utah Division of Water Quality (UDWQ) established a nutrient reduction program (http://www.nutrients.utah.gov/) and is drafting rules to implement the state's nutrient control strategy. Many Utah wastewater treatment facilities may need to demonstrate that their effluents will not lead to impairment of receiving waters.

  Relatively high amounts of peat-like decomposing plant material can generate high sediment oxygen demand and lead to significant sediment denitrification. In addition, nitrogen fixation and assimilation in growing plant material and potential nitrification of cycled ammonia (Figure A) would be expected in streams exposed to treatment plant effluent. This project tested each component of the nitrogen cycle using in-stream chambers and laboratory measurements to determine their impact on observed oxygen depletion. Findings from Silver Creek, East Canyon Creek, Box Elder Creek, and the Jordan River aided in formulating recommendations to UDWQ regarding field and laboratory testing, field chamber modifications, modeling, and monitoring for accurately determine impacts of nitrogen discharge to Utah streams.

- **Benefits to the State:**

  Regulating nitrogen loading to Utah streams will require a more complete understanding of in-stream processing of nitrogen from wastewater treatment plants. Validated methods for improved detection of significant nitrogen transformation processes and measurement of nitrogen transformation rates will help set water quality standards and guide in stream nutrient transformation modeling and the design and operation of Utah's wastewater treatment plants.

- **Geographic Areas:**

  Study Area: Park City, Summit Co., UT; Brigham City, Box Elder Co., UT; Salt Lake City, 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 were conducted at three field sites above and below treated wastewater effluent discharge points between August 2014 and June 2017 over a wide range of seasonal

conditions. Chambers were designed so that isotope (^{15}N) dilution and pairing methods could be used to track the transport and transformation of nitrogen through the system. Based on the results of the first Silver Creek sampling campaign, sampling procedures and the field chamber design (Figures B and C) were modified to improve the sensitivity and reliability of nitrogen transformation rates within the water, plant, and sediment compartments. A collection of laboratory methods (non-isotope enriched N measurements, chemical inhibition methods, long-term BOD methods) were also established and tested at all four field sites to evaluate their ability to replicate field determined N transformation rates at lower cost to wastewater treatment plants than the in situ field chambers.

Results: Chamber design and sampling improvements made to increase mass recovery during sampling and to optimize study data were successful in generating a more robust data set when implemented at East Canyon Creek (Figure C) located near Silver Creek in Summit County, in Box Elder Creek. ANNAMOX and DNRA were also detected at the East Canyon field site using the revised chamber design and field protocol, but at two orders of magnitude lower than other N transformation rates.

The following conclusions were generated from the study:

1. Lab-based method results indicated that both sediment and water are needed in lab reactors to generate nitrogen transformation rates representative of in situ chamber results.
2. Many of the field and laboratory measurements of nitrification, denitrification, and ammonification rates were found to be within the range of literature and modeling values.
3. However, a number of field-based measurements of ammonification rates were found to be significantly above reported literature and modeling values, while a number of field-based nitrification measurements were significantly below modeling values. This suggests currently calibrated models likely underestimate ammonification and overestimate nitrification, especially at sites with high sediment organic carbon content like the Box Elder Creek and Jordan River sites monitored in this study.
4. It is particularly important to generate site and location-specific ammonification and nitrification rates using field and laboratory methods validated in this study to improve model predictions of wastewater treatment plant impacts to Utah streams.

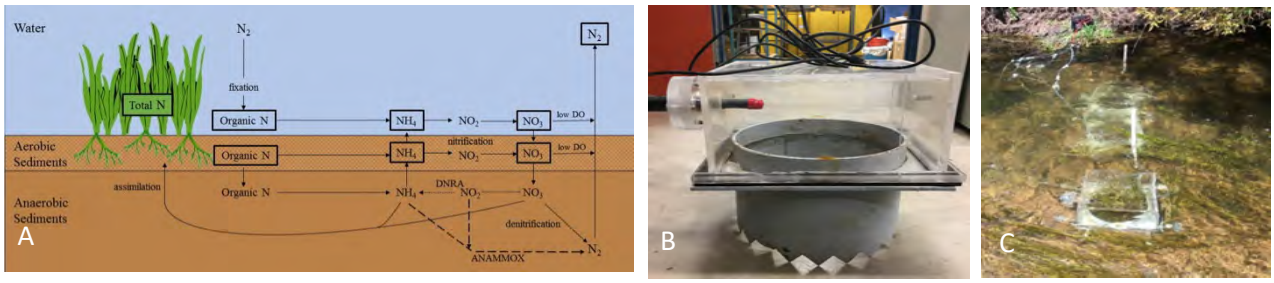


Figure A. Nitrogen cycle within water, plant, and sediment compartments in streams. Figure B. Modified in situ benthic chambers developed in response to findings from the Silver Creek Field Study. C. Field-deployed modified In-situ benthic chambers at East Canyon Creek, Summit County

Work Plan FY18/FY19

This project is complete.

Informational Resources

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

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)
Joshua Hortin (Graduate student/staff)
Jessica Cooper (Undergraduate student)

Partners/Collaborators:
None

Project Description

- **Need and Purpose:**

  Copper oxide nanoparticles (CuO NPs) are used in agriculture as an antifungal or antimicrobial, a fertilizer, or a drought resistance treatment. However, application of CuO NPs in or near soils for any purpose may have unintended consequences to plant and microbial life as the NPs dissolve, transform, or move. Plants need copper (Cu) as a micronutrient, but elevated levels of bioavailable Cu are highly toxic to plants and their associated bacteria. Soils are exceedingly complex and many properties influence the behavior of Cu in the soil. Plant roots and bacteria add to the complexity as they exude chemicals (exudates), which frequently bind to Cu in solution promoting dissolution of the CuO NPs (Fig. 1). This project investigates the bioavailability and toxicity of CuO NPs on wheat and looks at how properties of Utah's agricultural soils and root or microbial exudates specifically influence the bioavailability of CuO NPs to wheat plants.

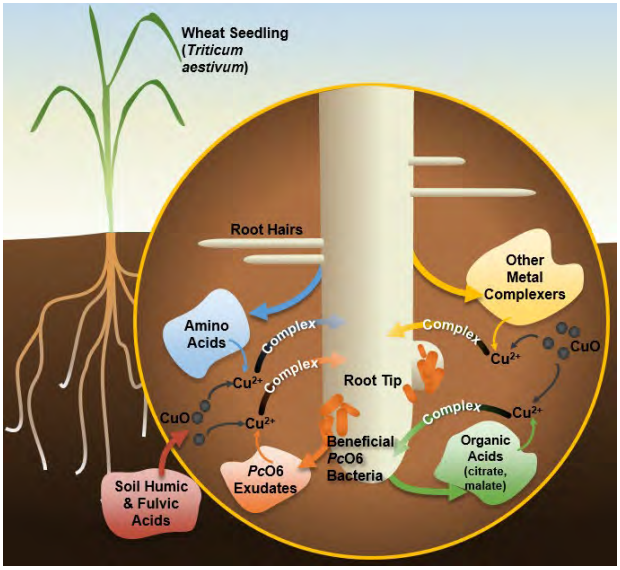


*Figure 1. Diagram of the some of the potential interactions between CuO NPs, root exudates, root bacteria (Pc*O6*) and wheat root.*

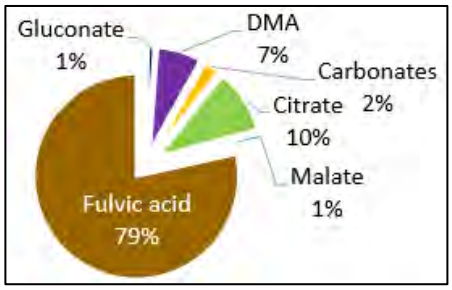


Figure 2. Distribution of dissolved Cu bonds in the rooting zone of wheat in a sand and soil pore water matrix (determined by dissolved Cu measurement and geochemical modeling). The soil pore water originates from a conventionally-farmed wheat field. Results show 79% of the dissolved Cu is associated with fulvic acid.

- **Benefits to the State:**

  Although the research focuses on CuO NPs, it is also relevant to metal pollution and other NPs in general. Results directly benefit Utah counties by protecting environmental quality and human health related to metal exposure. CuO NPs may benefit counties with agricultural operations as more research is conducted on the pesticidal and drought resistance-stimulating properties of the NPs, particularly as drought and opportunistic pathogens increase in frequency.

- **Geographic Areas:**
  Study Areas: Counties with abandoned and active mining operations, counties with industrial operations, and counties with agricultural operations—all counties in Utah.
  Areas Benefited: All counties in Utah.

- **Accomplishments:**

Findings: Citrate and fulvic acid have protective effects on wheat from Cu toxicity. Drought conditions exacerbate root exudate production, which may alter Cu uptake by wheat.

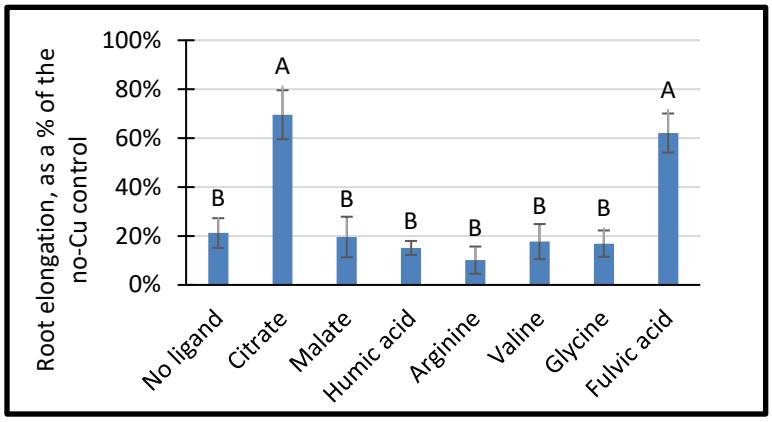


Figure 3. The effect of various root exudate or soil compounds on the toxicity of Cu to wheat seedlings, as measured by the length of the root compared to the no-Cu control root length (%). Citrate and fulvic acid decreased plant uptake resulting in better root growth.

Results: Findings from the previous year under MLF support indicated that soil pore waters partially protected wheat seedlings from the adverse effects of CuO NPs. The pore water was extracted from soils in Cache Valley under different agricultural practices that affect the type and concentration of organic matter. Fulvic acid (a component of soil organic matter) and citrate (a root exudate) complexed Cu in solution driving dissolution of the CuO NPs (Fig. 2), but this did not result in an increase in Cu concentration in the plant. Therefore in additional experiments, wheat seedlings were exposed to solutions of individual chemicals comprising soil pore water (as controls) with and without Cu, to determine which of these soil chemicals shielded the wheat seedlings from Cu toxicity. Citrate and fulvic acid appeared to protect wheat seedlings from Cu toxicity (Fig. 3), while malate, humic acid, arginine, valine, and glycine did not compared to the Cu-only (no ligand) treatment. These results indicate that soils with more fulvic acid may be protective of plants to metal contaminated soils. Further, abiotic stressors such as drought alter the root exudate patterns (Table 1), which will in turn alter how the root exudates interact with CuO NPs and how Cu gets taken into the plant.

Work Plan FY18/FY19

Table 1. Effect of water stress on wheat root exudates (mg/L)

	Malate	Citrate
No stress	2.2	1.3
Water stress	35	2.7

Work during the FY18/FY19 will continue and address: (1) How do wheat root exudates from differing water stress conditions change the solubility and bioavailability of CuO NPs? (2) Do CuO NPs, ZnO NPs, or SiO_2 NPs reduce stress experienced by wheat under drought? These questions will be answered through (1) collection of wheat root exudates under normal and water stress conditions, followed by CuO NP solubility studies and wheat root elongation studies, and (2) greenhouse pot studies utilizing wheat under water stress in Utah agricultural soil with CuO, ZnO, or SiO_2 NPs followed by plant morphology, leaf respiration, and tissue metabolite measurements to determine significant differences.

Informational Resources

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

Publications:

McManus, P., Hortin, J., Anderson, A.J., Jacobson, A.R., Britt, D.W., Stewart, J., and McLean, J.E. (2018). Rhizosphere interactions between copper oxide nanoparticles and wheat root exudates in a sand matrix: Influences on copper bioavailability and uptake. *Environmental Toxicology and Chemistry* doi:10.1002/etc.4226.

Hortin, J. (2017). *Behavior of copper oxide nanoparticles in soil pore waters as influenced by soil characteristics, bacteria, and wheat roots*. MS Thesis. Utah State University, Logan, Utah. All Graduate Theses and Dissertations 6895.

Logan City Renewable Energy and Conservation Advisory Board

Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***Local:*** *Emily Malik, Logan City Environmental Department; Herm Olsen, Jeannie Simmonds, Logan City Council*

Project Description

- **Need and Purpose:**

  The mission of the Logan City Renewable Energy and Conservation Advisory Board (RECAB) is to provide advice and technical assistance related to the conservation and efficient use of resources, to assist in transitioning the City of Logan toward a fully renewable energy portfolio that is secure, diverse, and cost-effective and promotes security of the environment.
  RECAB's goals include:

  (1) Reduction of residential energy consumption (per capita) over the next 10 years.
  (2) Improved energy efficiency of commercial and public customers.
  (3) Implementation of demand-side management (DSM) programs with residential, commercial and public customers.
  (4) Identify and research potential sources of renewable energy for Logan City.
  (5) Identify and promote green building standards.
  (6) Identify and promote alternative forms of public transportation.
  (7) Promote public education on issues of energy supply security, energy cost security, and environmental security.
  (8) Reduce carbon emissions and assist with Logan City's carbon emission study.

- **Benefits to the State:**

  The RECAB purpose is to provide Logan City with technical expertise and experience regarding the potential of new renewable energy sources, carbon emission estimates, and public education. The PI attends monthly meetings of the Logan RECAB, provides comments and input on renewable energy and waste management issues that arise, and has responded to special requests from RECAB regarding technical issues related to alternative renewable energy sources. Recent examples of special project requests during the reporting period include (1) an in-depth analysis of the renewable energy potential of landfill methane gas recovery and power generation at the soon to close municipal landfill and (2) additional evaluation of the potential for energy use reduction at the planned mechanical wastewater treatment plant through process modification and installation of anaerobic digesters for secondary treatment load reduction and energy production.

- **Geographic Areas:**

  Study Area: Logan City and Cache County.
  Areas Benefited: Logan City and Cache County.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled Logan RECAB meetings throughout FY17–18 and provided review and comment on all RECAB items relevant to his area of expertise. Topics have included the following:

1. Analysis and presentation on landfill gas recovery from the existing Logan landfill
2. Process modifications for energy reduction at the planned mechanical wastewater treatment plant
3. Input regarding the optimal beneficial use of decommissioned wastewater treatment plant lagoons
4. Input on the long-term renewable energy Road Map for Logan City that was passed by the Logan City Council in 2018.

Work Plan FY18/FY19

Involvement of the PI with the Logan RECAB will continue, as will his response to special project requests as they arise, to support Logan City RECAB's mission and goals.

Figure 1. Solar array installed at the Logan City Wastewater Treatment Lagoons

Informational Resources

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

Website: http://www.loganutah.org/government/departments/light_and_power/energy_conservation_solar/recab.php.

Organosilicon Adjuvants in Pollen: Initial Results from a 2018 Field Survey

Principal Investigator:
William J. Doucette
Autumn Slade, Graduate Student

Partners/Collaborators:
- ***Local:*** *Diana Cox-Foster, USDA/ARS Pollinator Research Lab, Logan Utah*

Project Description

- **Need and Purpose:**

  Trisiloxane surfactant (TSS) adjuvants are used to improve the wetting, spreading, rainfastness, and plant penetration of active ingredient(s) in pesticide products. They are assumed to be biologically inert and are not required to be EPA registered. TSS adjuvants are mixtures of oligomers consisting of a hydrophobic trisiloxane backbone with hydrophilic side chains composed of ethylene oxide (EO) units. Most TSS adjuvants list the ingredients as a proprietary blend or a polyether and trisiloxane mixture. TSS adjuvants contain either hydroxy, acetoxy, or methoxy side chain end groups (Figure 1). TSS adjuvants have been found in pollen, beeswax, and honey[4] and have been shown to impair honey bee learning[5] and interact synergistically with viral infections in bee larvae.

  This project aims to determine the frequency of TSS detection and concentration in pollen samples collected by bee keepers and look for potential relationships between TSS and pesticide levels in pollens.

- **Benefits to the State:**

  Bees are key pollinating insects, and understanding the potential role of adjuvants, previously thought to be biologically inert, on bee health and colony collapse disorder is critical in managing this agriculturally vital species.

- **Geographic Areas:**

  Study Area: United States.
  Areas Benefited: All of Utah.

- **Accomplishments**: Pollen Collection.

  Three blank pre-weighed 50 mL centrifuge tubes with caps were sent to beekeepers along with two commercial pollen samples (one clean and one spiked with TSS standards). Beekeepers collected pollen from traps (Figure 2) and sent it back to the UWRL via USPS. Most of the pollen samples (88) were collected in California during February and March 2018. Additional samples were collected from Wisconsin (9) and Kentucky (2). Almonds were the main crop associated with the pollen collected.

- **Findings:** Hydroxy-capped TSS were found in 43% of the samples, with concentrations in the low ng/g levels. Based on sum of all hydroxy oligomers. n = 6–8 were the most commonly found. 15% of samples had high concentrations of an acetoxy capped TSS-like compound. RT match, but quant. and qual ion ratios did not match the standards. No methoxy-capped TSS were found above the LOQs. Freshly spiked pollen recoveries were 56–65%. Spikes mailed to the field and back had much lower recoveries (8–37%). Additional studies are being conducted to determine the cause of the losses. A preliminary screening analysis for over 65 pesticides was performed on each sample using LCMS-QQQ. Nine compounds were

tentatively identified: azoxystrobin, Cyprodinil, Chlorpyrifos, diflubenzuron, diuron, fenpyroximate, flubendiamide, Methoxyfenozide, and Phoxim.

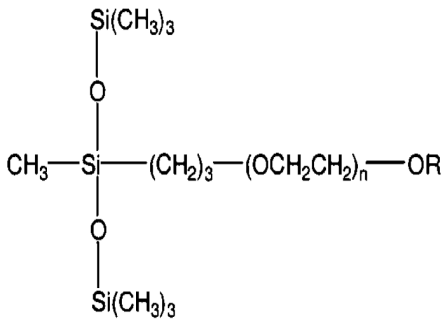


Figure 1. Generalized Structure of TSS

Figure 2. Bee collecting pollen and pollen trap on hive. Photo from https://cosmeticsandskin.com/faf/pollen.php

Work Plan FY18/FY19

We plan to (1) investigate the correlation between TSS and pesticide levels in pollen and confirm and identify additional pesticides by GCMS, (2) feed bees the pollen found to contain TSS to test whether bee behavior is impacted, and (3) determine TSS concentrations within various plant tissues including pollen.

Informational Resources

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

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

Investigators:
R. Ryan Dupont
Joan E. McLean

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 community and function and has become a standard technique for engineering applications 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 research 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, and represents preliminary analyses preceding advanced, high-throughput DNA sequencing, primarily 454 pyrosequencing, that has taken place at sequencing facilities on the USU campus. This instrumentation has been 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 tools are being used to explore the make-up of impacted microbial communities and their interactions in natural systems, and the response of microbial communities to engineered modifications to improve contaminated environments.

- **Benefits to the State:**

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

  1. Provide quantitative analysis of specific organism numbers and/or gene copies 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. Analyze the community composition and function associated with biofilms accumulating within the potable water distribution system in Park City.
  4. Evaluate the presence and abundance of arsenic reducing bacteria in soil and groundwater surrounding the Logan City Landfill, and also active in storm water retention areas, in order to isolate the impact of the landfill's storm water treatment systems on groundwater quality impairment.

Environmental Quality Management and Remediation

- **Geographic Areas:**

  Study Area: Utah counties 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 these molecular tools for use on samples from natural, contaminated, or engineered sites.

- **Accomplishments**:

  Findings: Two separate studies have recently been completed using this equipment to explore microbial community complexity and composition. This provides insights into optimizing the remediation of contaminated soil and groundwater sites. These quantitative molecular tools are also useful in studies that (1) evaluate the presence, abundance, and expression of *Dehalococcoides mccartyi (Dhc)* and functional genes associated with TCE transformation in soil and groundwater contamination; and (2) evaluate the presence and abundance of arsenic-reducing bacteria in soil and groundwater surrounding the Logan City Landfill.

  Results: Figure 1 summarizes the findings from the TCE transformation study, which indicate an unexpectedly high diversity of *Dhc* strains that exhibit wider genetic and metabolic diversity than previously reported. Perhaps more importantly, It shows their specific composition, rather than total abundance, that is critical for complete TCE dehalogenation. Figure 2 shows PCR amplification of the arrA gene involved in arsenic reduction using an arrA PCR primer designed at the UWRL for arsenate reductase diversity assessment and quantification in environmental samples.

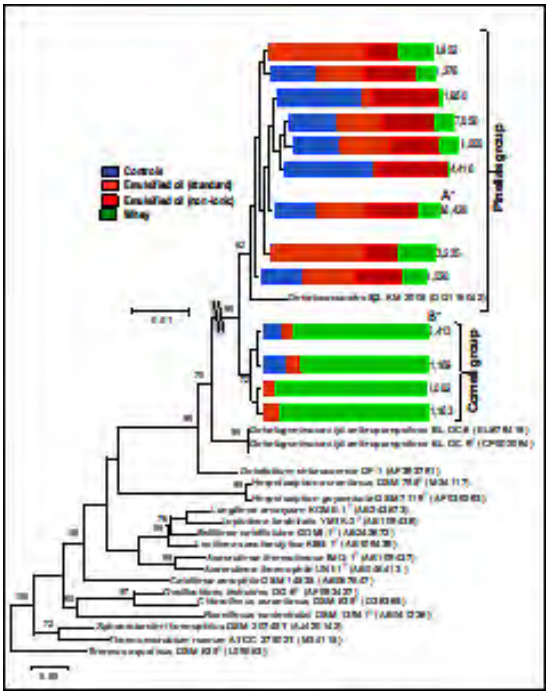


Figure 1. Maximum likelihood phylogenetic tree based on the Dhc 16S gene sequences from four different TCE biostimulation treatments

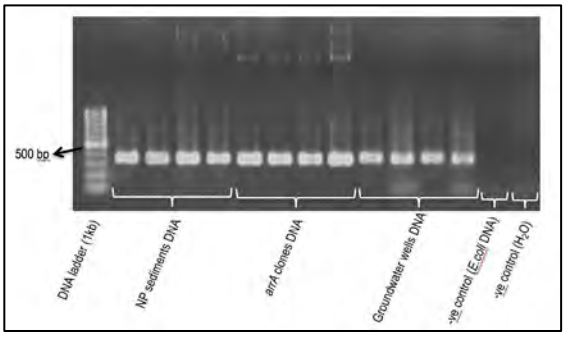


Figure 2. PCR amplification of ArrA gene using the newly developed PCR primers from arrA gene clones, soil and groundwater samples

Work Plan FY18/FY19

We will continue to identify and analyze arsenic reducing microorganisms isolated from shallow and deep groundwater samples collected throughout Cache Valley and northern Utah. The analyses will be added to earlier findings of the uniqueness and diversity of arsenic-reducing species endemic to this region. This will create a bigger picture and better understanding regarding the use of bioremediation for treating contaminated soils and water. Additional QPCR work will continue in the detection and quantitation of pathogenic organisms associated with reclaimed wastewater from three wastewater treatment plants in Cache Valley.

Informational Resources

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

Environmental Quality Management and Remediation

Using Duckweed as a Treatment Technology for Nutrients and Pharmaceutical Contaminants in Municipal Wastewater Systems

Principal Investigators:
R. Ryan Dupont
Leila Ahmadi (Post-Doc)
Kwame Duodu Cristal (Graduate student)
Carolina Collins (Undergraduate student)

Partners/Collaborators:

- ***Local:*** *Scott Wells, City Manager, Wellsville City; Issa Hamud, Director, Environmental Department, Logan City; Kevin Maughn, Manager, Hyrum City Wastewater Treatment Plant*

Project Description

- **Need and Purpose:**

Figure 1. Bank view of duckweed covering the Wellsville lagoons, May, 2017

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 effects on aquatic ecosystems. Conventional wastewater treatment systems are not effective in removing these contaminants. 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 removing nutrients and PCPP contaminants from municipal wastewater, especially in communities like Wellsville City and Logan City that currently have lagoon wastewater treatment systems. In addition, this work quantifies the energy recovery potential of harvested duckweed biomass using anaerobic digestion, and also determines the fate of PCPPs exposed to anaerobic digestion and the growth of heterotrophic algae on the digester supernatant.

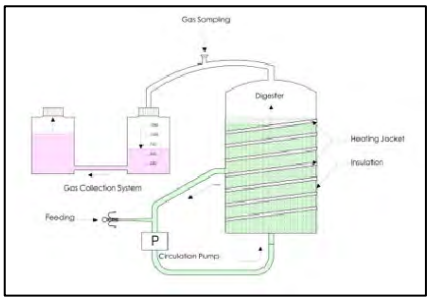


Figure 2. Schematic of the batch-fed anaerobic digesters

- **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 effective, low-cost treatment methods to remove nutrients and 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 requiring low-cost, sustainable nutrient management systems for water quality improvements.

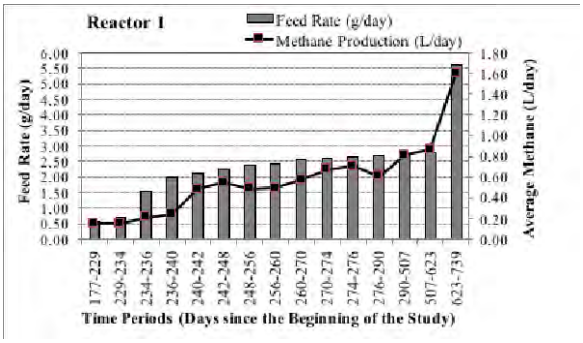


Figure 3. Reactor 1 gas production as a function of time and duckweed feed rate

- **Accomplishments**:
Findings: Studies at the Wellsville lagoons (Fig. 1) showed significant duckweed growth rates, high nutrient concentrations accumulated in the duckweed biomass, and high PCPP removal rates. This

demonstrates that a duckweed-based wastewater treatment system can be feasibly implemented. However, the effectiveness of the system is dependent, on efficient cost-effective harvesting, stabilization, and processing of the biomass. Freshly grown duckweed and field-harvested biomass are used as feedstock for lab-scale anaerobic digesters (Fig. 2) that stabilize harvested biomass and generate methane (Fig.3). We are evaluating the digester methane production and reactor stability and exploring the use of digester effluent to grow heterotrophic algae for use in producing valuable biofuels. We have also developed methods to extract and analyze PCPPs from duckweed biomass and anaerobic digester effluent so we can predict PCPP concentrations in treatment plant effluent.

Results: More than 250,000 lbs. of dried duckweed material could be harvest annually from the 56-acre Wellsville lagoons, and approximately 2,500 lbs. of phosphorus would be removed from the treated effluent. Our laboratory studies showed significant removal rates for pharmaceutical compounds, such as Acetaminophin (56-99%), Sulfamethxazole (45-86%), Fluoxetine (82-93%), Carbamazepine (0-38%), and Progesterone (82-98%). These values are comparable to more expensive physical/chemical treatment systems. Bi-weekly harvesting of duckweed biomass provides sufficient P removal for Wellsville to meet its 2017 permit limits. The Duckweed technology is clearly a feasible low-cost alternative to much more expensive advanced biological/chemical treatment processes. In addition, it produces a potentially valuable end product in the form of harvested duckweed biomass.

Influent and effluent concentrations of 12 PCPPs of common interest relative to public health and environmental safety were quantified in the Wellsville and Logan lagoon systems. Fig. 4a shows the influent and effluent concentrations for the Wellsville lagoons. Fig. 4b shows relative effluent PCPP concentrations for the two lagoon systems as compared to effluent from the Hyrum mechanical biomembrane plant. Removal of most PCPPs was between 50 and 99.9% in the lagoon systems. This is consistent with laboratory results, and is comparable to the more complex and expensive mechanical biomembrane reactor system utilized at the Hyrum Wastewater Treatment Plant.

Work Plan FY18/FY19

We will (1) monitor wastewater- and duckweed-associated PPCP concentrations along the Wellsville Lagoon system flow path to evaluate PPCP uptake and transformation in duckweed under field conditions, (2) conduct laboratory anaerobic digester and aerobic composting studies to evaluate PCPP transformation in duckweed biomass solids handling systems to quantify their fate during anaerobic digestion and composting, (3) develop guidelines and recommendations for duckweed harvesting and stabilization to maximize PPCP degradation and minimize the risk of duckweed biomass processing and reuse.

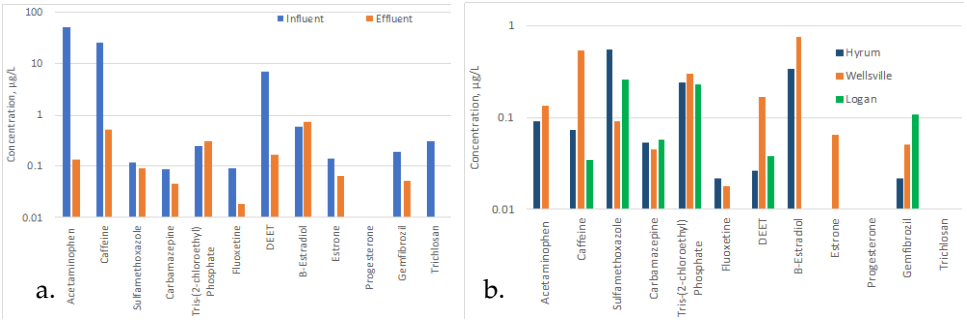


Figure 4. a. Influent and effluent PCPP concentrations at the Wellsville lagoon system. b. Effluent PCPP concentrations at the Logan and Wellsville lagoons compared to effluent from the Hyrum biomembrane plant.

Informational Resources

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

Website: http://duckweedresearch.blogspot.com/2012/05/duckweed-research-presentations-and.html.

Vehicle Cold Start, Hot Start, and On-Road Emissions

Principal Investigators:
Dr. Randal S. Martin
Joe Thomas, UDAQ/NCST
Nancy Daher, UDAQ

Partners/Collaborators:

- ***Local:*** *The City of Logan, USU,*
- ***State:*** *Utah Division of Air Quality (UDAQ) & Air Monitoring (AMC), 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 $PM_{2.5}$ (Particulate Matter) and O_3 (Ozone) air pollution health issues in the Cache Valley and along the Wasatch Front, especially during the wintertime conditions of northern Utah. Strategies to limit exposure include staying indoors, and automotive anti-idling programs. A related issue is the effect of hot vs. cold vehicle engine starts, as well as real-life on-road emissions under Utah conditions. Additionally, through other, local (state) ambient studies, it has become apparent the current air pollutant emission inventories underestimate available ambient ammonia (NH_3), a key component of our local/regional $PM_{2.5}$ (ammonium nitrate). State-wide photochemical modeling attempts must be artificially enriched to adequately predict observed ambient concentrations. Literature searches have shown little available data on raw NH_3 emissions from mobile sources, although it is often inferred that the mobile sector may be a significant source of these underestimations. This project combines Mineral Lease funds and funds from the Utah State Division of Air Quality (UDAQ) to expand the overall scope of the research.

- **Benefits to the State:**

  Ultimately, accurately assessing the NH_3 and other pollutant emissions from sources relevant to the fleets and conditions of the Cache Valley and Wasatch Front will help to identify the significance of these sources, particularly under wintertime conditions. This will also facilitate the development of information that can be provided to the general public through local and statewide outreach programs, for both gasoline and diesel engine types.

- **Geographic Areas:**

  Study Area: We plan to conduct the setup for the majority of the automobile emissions testing at the Utah Water Research Laboratory and at Weber State University's National Center for Automotive Science and Technology.
  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. The results will also be of use to UDAQ in planning future mitigation strategies. Air quality research partnerships have also been established among UDAQ/AMC, USU/UWRL, WSU and U of U.

- **Accomplishments:**

  Findings: Data collection has not yet begun. However, a large (2-yr) project scope was negotiated with the Utah division of Air Quality and funds were secured to start the cooperative study beginning in October of 2018. Additional but separate funds were secured through the Utah State Legislature and UDAQ to purchase several new instruments to quantify laboratory and on-road tailpipe emissions. The two main instruments are (1) an ECM miniPEMs—a Portable Emissions Monitoring system that measures

on-road emissions of oxides of nitrogen (NO_x) and ammonia (NH_3) (approximately $15k) and (2) a Piccaro G2013 cavity ring-down real-time NH_3 monitor (approximately $80k). Because the G2013 was desired for use in both direct emission (high-concentration) and ambient (low-concentration) measurements, significant negotiation and development with the supplier took place. Further, the G2013 is considered "the gold standard" for real-time, gaseous NH_3 concentrations, and the ECM system is an, as of yet, unproven technology; therefore, side-by-side comparisons are planned. Both of these instruments, were obtained early in the fall of 2018 and laboratory characterizations have begun.

Results:

The project planning, funding solicitation, and instrument selection took considerable effort and time; as such, no numerical results are yet available. As shown in Figure 1, laboratory characterization of the Picarro G2013 has begun at USU's UWRL and will continue until actual tailpipe measurements are begun in early 2019. As a point of interest, and to demonstrate the instrument's sensitivity, careful examination of the spikes toward the end of the graphical traces on the computer screen reveals that, simply from the operator walking in the lab to take this picture, the background NH_3 (top row) increased from 7 ppb to 13 ppb, water vapor increased from 0.57% to 0.62%, and carbon dioxide (CO2) increased from 445 ppm to 540 ppm.

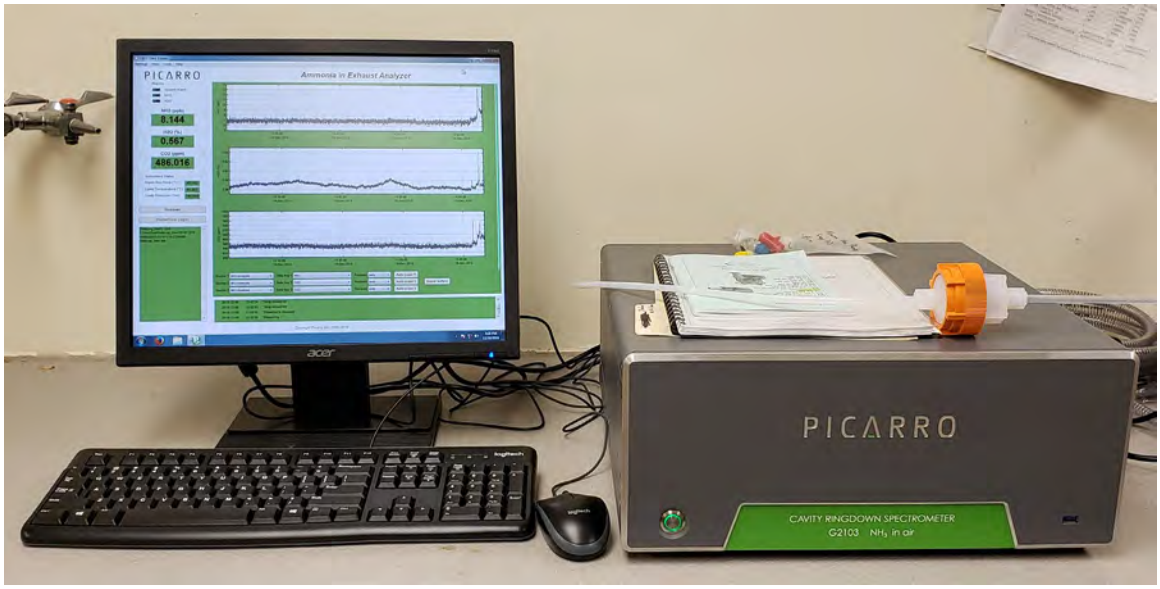


Figure 1. Newly purchased Picarro G2013 caivity ring down (CRD) real-time ammonia analyzer in Dr. Martin's laboratory at the Utah Water Research Laboratory

Work Plan FY18/FY19

Characterization and calibration of the equipment will continue through fall 2018, and laboratory measurements of test vehicles (both gasoline and diesel) will begin during winter 2019 and continue through much of the next year. After successful, or modified as need, laboratory dynamometer testing, an appropriate on-road segment will be identified and tailpipe testing will begin.

Informational Resources

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

Surface and Groundwater Quality and Quantity

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

Project Name	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
Improving Representation of Environmental Objectives to Inform Integrated Water Management Strategies in Utah	$3,946.00	$10,000.00	$12,000.00
"Lab-on-a-Chip"—Miniaturized Salinity Sensor Arrays for Water Quality Monitoring	$795.27	$0.00	$0.00
Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies	$44,020.56	$45,341.18	$20,000.00
Quantification of Groundwater Influences in High Gradient Utah Streams and Rivers	$74,841.63	$50,000.00	$51,500.00
Release of Arsenic from Aquifer Solids Under Anaerobic Conditions	$65,678.91	$15,000.00	$15,450.00
Source Water Protection from Potential Phosphorus Mining Impacts in the Uintah Basin	$17,039.74	$36,000.00	$37,080.00
Understanding the Variability of Groundwater Recharge and Mountainous Stream Discharge in Karst Environments	$5,083.12	$8,000.00	$8,240.00
Designated Projects		$60,000.00	$60,000.00
Undesignated Projects		$70,000.00	$90,000.00
Total	**$211,405.23**	**$294,341.18**	**$294,270.00**

Improving Representation of Environmental Objectives to Inform Integrated Water Management Strategies in Utah

Principal Investigators:
Belize Lane
Bethany Neilson

Partners/Collaborators:
- ***Local****: City of Nibley, UT*
- ***Federal****: Trout Unlimited*

Project Description:

- **Need and Purpose:**

  As one of the driest and fastest growing states, Utah's limited water resources are under increasing pressure and uncertainty in meeting both human and environmental needs in the future. For example, in dry summers, irrigation diversions dewater lowland river reaches, which can negatively affect native trout populations that then take years to recover. To address these and other issues, water resources managers need a better understanding of the ecological consequences of flow alteration. Hence, this project examines how aquatic biota respond to changes in streamflow as a basis for developing predictive tools to inform better water management decisions. How aquatic biota respond to changes in streamflow is fundamental to predicting ecological consequences of flow alteration.

- **Benefits to the State:**

  The overall benefit of this research is improved coupled human–environmental water management in northern Utah, particularly in lowland agricultural regions downstream from mountain canyons. Currently, we are monitoring trends in streamflow, groundwater exchange, water temperature, and macroinvertebrate drift over the summer low flow period. These data are being used to improve our understanding of flow–ecology relationships. This in turn will allow us to more accurately assess tradeoffs between water uses and propose solutions that benefit both farmers and fish.

- **Geographic Areas:**

  Study Areas: Lower Blacksmith Fork River, Nibley, UT.
  Areas Benefited: This research will directly benefit the City of Nibley. The information gained and methods developed will be applicable to all of Utah's many lowland streams and rivers.

- **Accomplishments:**

  Findings: Based on discharge, water temperature, and groundwater exchange patterns recorded along the study reach in the lower Blacksmith Fork River, we are developing a set of minimum water quantity and quality requirements to maintain a fishery through hot dry summers.
  Figure 1 below illustrates the river instrumentation deployed between the Nibley Blacksmith Fork and College Ward Irrigation canals over the 2018 summer. These include temperature sensors, trap cameras, macroinvertebrate samples, and pressure transducers. The Utah Water Research Laboratory's AggieAir™ UAVs were used to collect aerial and thermal imagery to assess spatial patterns of water temperature.

  Results: The information gained in this field-intensive project will quantify limiting streamflow and temperature conditions and locations for native and recreational trout fisheries in the Blacksmith Fork River. These thresholds will help us determine the water flow needed in the river to maintain fish through the hot summer months, particularly in dry years.

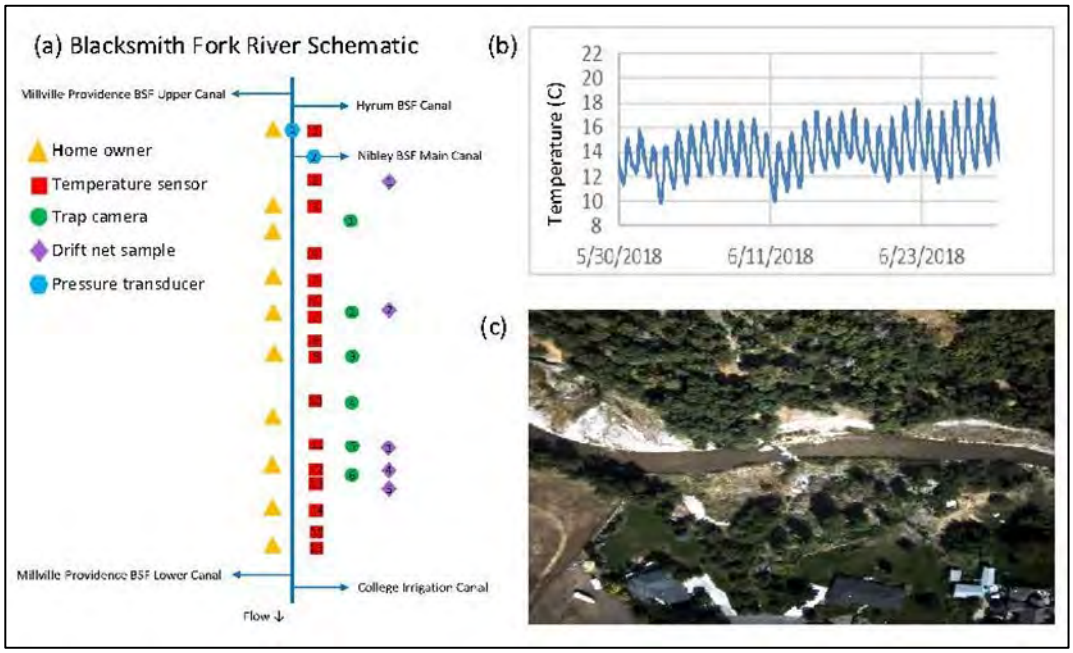


Figure 1. (a) Schematic of river instrumentation, (b) example water temperature time series used to identify limiting temperature conditions for fish, and (c) aerial imagery collected by AggieAir™

Work Plan FY18/FY19

The physical river parameters monitored in Summer 2018 will be monitored again in Summer 2019 to compare outcomes in different antecedent climate conditions, since Winter 2017/2018 was very dry. Further, we are working with Trout Unlimited and the City of Nibley to implement a proposed solution to keep minimum instream flows in the Blacksmith Fork River based on the outcomes of this research project.

Informational Resources

Contact: Dr. Belize Lane, Phone: (650) 520-4584, E-mail: belize.lane@usu.edu.

Representative Publication:

Alger, M., Neilson, B.T., and Lane, B.A. (2018).Dewatering gradients in an arid agricultural stream with groundwater exchange. *Journal of Hydrology*. In Prep.

"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 involved with irrigated agriculture in the Upper Colorado River, especially in drainages such as the Price and San Rafael Rivers in Utah. However, substantial uncertainty exists 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) producing ion sensor arrays that can measure salt loading in critical Utah rivers, (2) making available a portable detector for measuring the most significant ions contributing to salinity from sources in Utah and other states, and (3) helping water managers improve the timing and efficiency of water quality monitoring to track 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 focused on developing a smartphone app and testing our device for detection of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water samples. The calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions are two major ions contributing to the salinity problem in Utah. We also compared results from commercial kits and commercial software with our Android smartphone device for testing various water samples from fountain water, tap water, drinking water, and the Logan River. These results show that our paper-based smartphone App works favorably in detecting concentrations of both ions in the range needed to meet the water quality monitoring.

  Results:
  1) We developed an Android app that can be used with a smartphone device to continuously monitor Ca^{2+} and Mg^{2+} ions in water samples by quantifying the colorimetric changes (Fig. 1).
  2) The Android app shows a linear response for Ca^{2+} ions in a range of concentration from 10–1000 ppm, and the simulation shows the distribution of concentration and flow rate (Fig. 2).

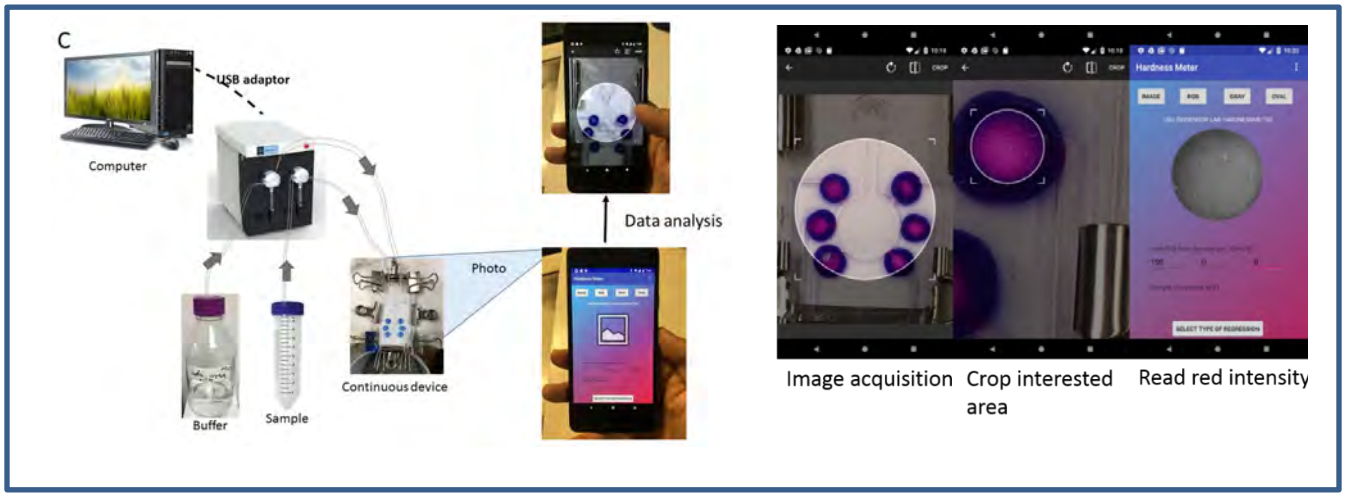


Figure 1. Android smartphone paper-based colorimetric continuous monitoring of Ca^{2+} and Mg^{2+} ion water sample. (Left) integrated monitoring system; (Middle) image acquisition; (Right) examples of Android App screenshots

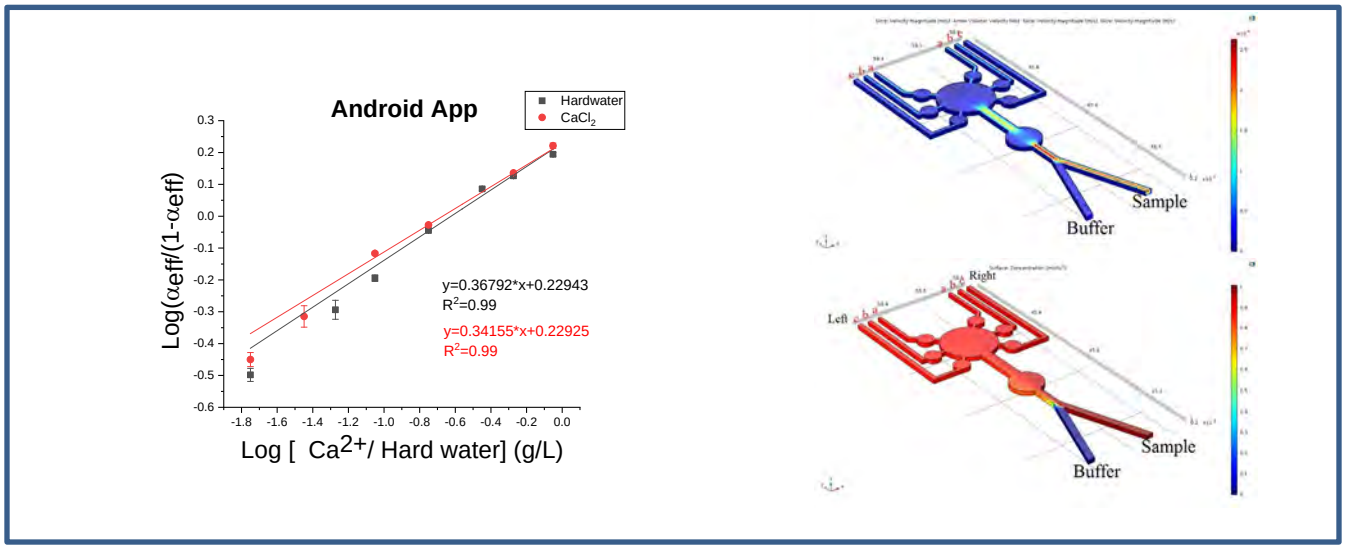


Figure 2. (Left) Android app used for testing Ca^{2+} ion detection in hard water samples (black) and $CaCl_2$ solution (red). (Right) COMSOL simulation of fluidic flow analysis of velocity field (top) and surface concentration distribution (bottom)

Work Plan FY18/FY19

No further work is planned at this time, due to lack of funding.

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., A. Zhou (2018). Smartphone colorimetric detection of calcium and magnesium in water samples using a flow injection system. Manuscript in preparation.

Optimizing Storm Water BMP Performance through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont, Joan McLean
Trixie Rife (PhD student)
Rosa Fernandez and Kaisa Petersen (MS students)
Avery Holyoak (Undergrad student)

Partners/Collaborators:

- ***Local:*** *Bill Young, Logan City Public Works Department. Salt Lake City Public Utilities, Salt Lake County Public Works.*

Project Description

- **Need and Purpose:**

  The EPA National Pollutant Discharge Elimination System (NPDES) water pollution control program mandates municipalities across Utah to 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. Objectives of this work are to: (1) minimize discharge volumes and pollutant loadings from urbanized areas flowing into receiving water bodies, and (2) address increased flooding and decreased water quality from urban and rural non-point storm water sources.

  Utah municipalities are beginning to address storm water quality and quantity issues. To do this effectively, these municipalities need locally generated, quantitative research to accurately characterize the effectiveness of vegetated storm water management systems. This study measured biomass production and water quality improvement in a controlled greenhouse environment and was validated by findings at a field demonstration study site at the Green Meadows subdivision in Logan, Utah. Water and pollutant uptake for seven plant species were quantified in the laboratory under simulated (frequency and duration) rainfall events. The field demonstration site used three of these plant species, as well as naturally propagated plant species and non-vegetated control plots. Plant growth was quantified and contaminant (nutrients and metals) removal was measured in response to periodic plant harvesting. To evaluate the effectiveness of storm water BMPs for storms under real environmental conditions, studies are underway to evaluate green infrastructure performance in capturing and treating storm water and storing it via groundwater recharge at additional sites in Logan (Fig. 1), and one in Salt Lake City (Fig. 2).

- **Benefits to the State:**

  This study is identifying storm water nutrient and metal removal effectiveness of local plant species that Utah municipalities can use to optimize storm water BMP systems. These data are specific to Utah's climate and geologic conditions. Logan City officials intend to utilize this information in the upcoming TMDL regulations for reductions in nutrient loading (particularly of phosphorous) for discharges into Cutler Reservoir. In addition, these quantitative results will prove critical to Utah municipalities and counties that are responsible for meeting new MS4 storm water management permit requirement by the State and U.S. EPA.

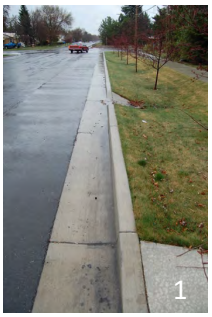
- **Geographic Areas:**

  Study Area: Field demonstration sites in Logan: Green Meadows Subdivision detention basin, 600 S and 1600 W; curb cut/bio-swale, 300 E between 900 and 1000 N; parking lot vegetative strip, Early Education Building, USU campus; roof drain/dry well, Engineering Building, USU campus; Green roof on Early Education Building, USU campus. Field demonstration site in Salt Lake City: SLC Public Utilities Complex bioretention system.

Areas Benefited: All counties in Utah would potentially benefit.

- **Accomplishments**:

Findings: Evidence of species differences in nutrient and metal concentrations accumulated in the harvestable, above-ground biomass at both greenhouse and field-scale suggests that sedges are optimal plants to improve the water quality of storm water in arid northern Utah. Plant biomass reached steady-state levels of growth within 3 years of planting. Results indicated that, while twice per year harvesting increased nutrient removal from the system, single seasonal harvesting showed identical metal uptake. Total containment of storm water generated at the demonstration site continues to result in 100% pollutant removal from surface water discharge.



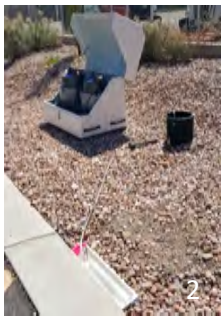


Figure 1: Stormwater BMP site, 300 E Logan
Figure 2: Sample collection at a stormwater BMP site, Salt Lake City Public Utilities building

Results: New studies are investigating the effectiveness of other green infrastructure systems, such as modification to conventional curb and gutter utilizing curb cuts, and creating bio-swales that completely eliminate storm water discharge into the collection system for storms up to 2 inches in depth (24-hr, 25-year storm in Logan, UT). Data collected at the SLC Public Utilities site (Fig. 2) showed no overflow and complete retention of all parking lot runoff at the site over the 12-month study period. Soil pore water lysimeters and soil samples used to monitor nutrient and metal uptake by grasses in the 300 E bio-swale, (Fig. 3a) and sampling wells below the filtration layer at the SLC Public Utilities site (Fig. 3b) indicated pollution from these BMPs infiltrating the underlying groundwater. While these pollutant concentrations were low, groundwater quality remains a concern, especially at the Public Utilities site.

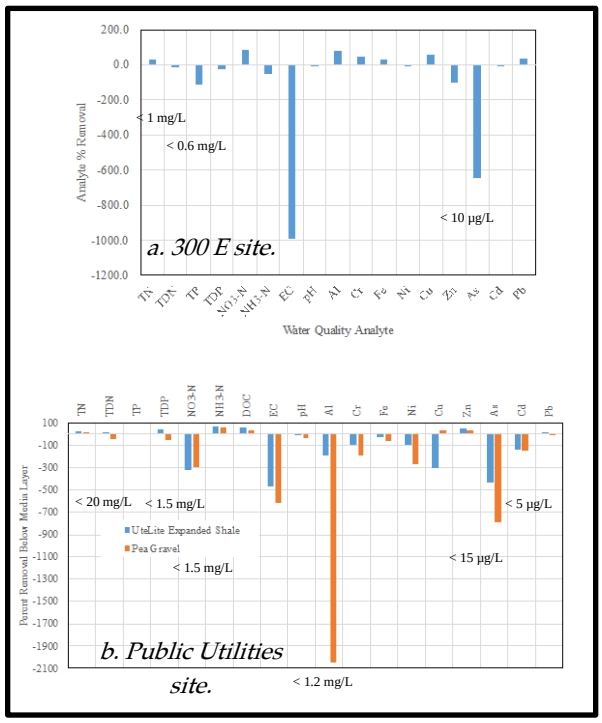


Figure 3: Stormwater BMP site pollutant removal performance 2016-2017 sampling season. (a) 300 E Bioswale 20 in depth, Logan. (b) SLC Public Utilities Bioretention System sampling wells below filtration media, Salt Lake City

Work Plan FY18/FY19

We will continue to collect data and report data from the green infrastructure study at the three sites in Logan and the Salt Lake City site during FY18, specifically groundwater infiltrate concentrations. A final field-scale vegetation study will be conducted at the Green Meadows site to specifically focus on quantifying pollutant loading rates to groundwater measured below the soil rooting zone to determine if groundwater protection can be mitigated by plant selection in stormwater BMPs.

Informational Resources

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

Quantification of Groundwater Influences in High Gradient Utah Streams and Rivers

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:**
  Characterizing groundwater gains and losses in stream and river systems is critical because of their effect on in-stream water quantity and quality. Some modeling approaches indirectly estimate the influence of groundwater sources and sinks on heat and solute transport in rivers. A wide range of data-centric methods is also used to estimate groundwater exchanges. Recent groundwater exchange studies in northern Utah have focused efforts on smaller scale reaches using a wide variety of data types, but there is also a need for a broader, variable scale investigation of groundwater gains and losses along fast flowing high-gradient streams and river systems.

- **Benefits to the State:**

  This research analyzes existing flow and chemical data collected throughout two northern Utah streams. The study aims to quantify groundwater influences in pristine mountainous and human–impacted urban portions of each watershed. Detailed flow data were gathered in 2014–2015 at small spatial scales during different flow conditions in the Logan River (five sampling events) and Red Butte Creek (four sampling events). These data are available along the main-stem as well as tributary inflows and diversions. For two sampling events in each watershed, chemical data were also gathered at all discharge locations. These chemical and flow data can be used to determine the role of groundwater on surface water throughout each watershed. Time series data from a subset of locations in each watershed may also provide fundamental information regarding the temporal variability of exchanges. The results of this research will contribute to better management of local water quantity and quality.

- **Geographic Areas:**

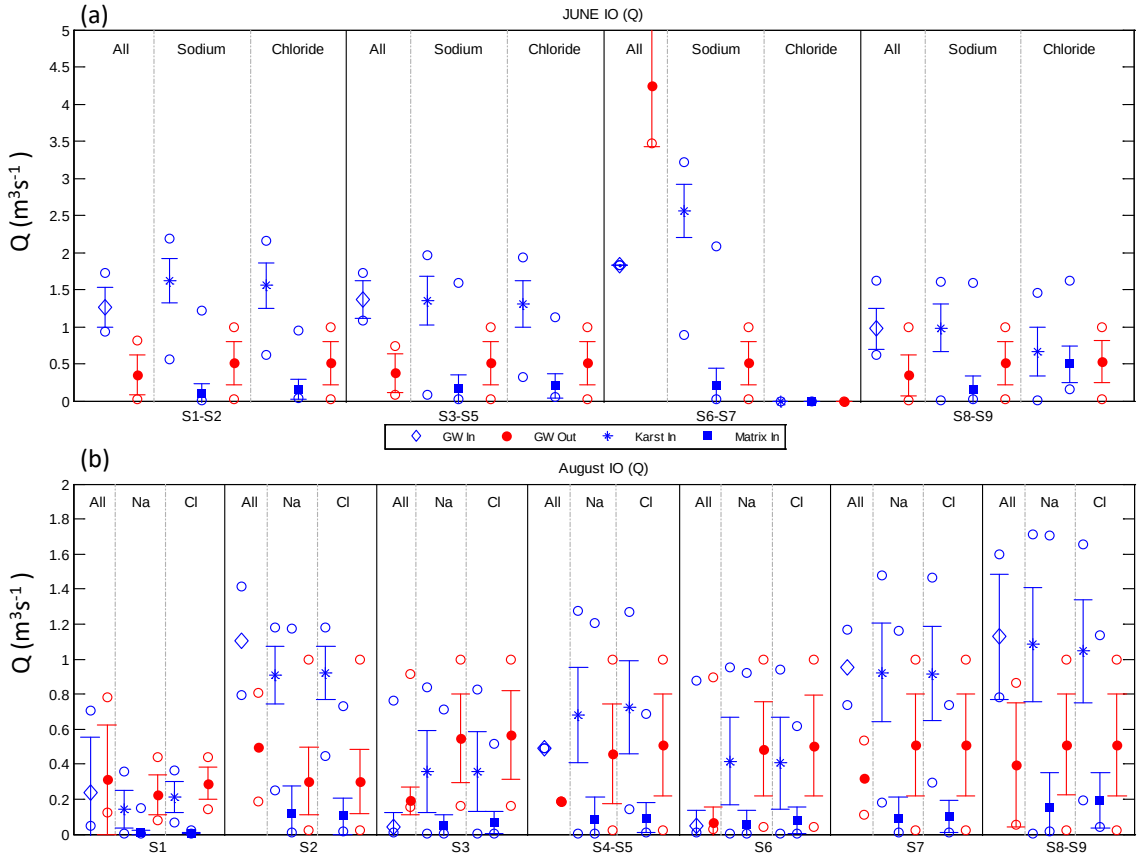
  Study Areas: Logan River, Logan, UT and Red Butte Creek, Salt Lake City, UT.
  Areas Benefited: This research will directly benefit the most populated portions of Utah, but the information gained and methods developed should be applicable to the entire state of Utah.

- **Accomplishments:**

  Findings: Based on flow and mass balances, we have developed a series of assumptions and equations that allow for the quantification of karst and matrix groundwater in gaining, losing, and simultaneously gaining/losing reaches. The figure below the change in flow within a reach (S1, S2, etc.) due to total groundwater gains, groundwater gains from karst features, groundwater gains from matrix or slower moving groundwater, or losses to groundwater calculated from a combination of flow and mass balances using conservative ions (see Neilson et al. 2018).

  Results: This unique approach and data set provides a simple method for understanding complicated groundwater interactions in karst mountain watersheds as shown within the Logan River watershed (Neilson et al. 2018). An undergraduate (BS) and two graduate (1 PhD and 1 MS) students have assisted

on this project, and we have joined with collaborators at the University of Utah, with a focus on Red Butte Creek. Eleven conference and seminar presentations about these findings have also been given.



Work Plan FY18/FY19

We are in the process of proposal development for NSF and the Logan River Observatory is being established in part based on these data.

Informational Resources

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

Representative Publications: where **=Post-Doctoral Researcher, ** = Graduate Student, *** = Undergraduate Student*

Neilson, B.T., H. Tennant***, T.L. Stout**, Miller, M., Gabor, R.S., Y. Jameel, M. Millington, A. Gelderloos, G.J. Bowen, and P.D. Brooks (2018). Stream-centric methods for determining groundwater contributions in karst mountain watersheds. *Water Resources Research*. 54. https://doi.org/ 10.1029/2018WR022664.

Gabor+, R.S., S.J. Hall, Y. Jameel, M.L. Barnes**, T.L. Stout**, H. Tennant***, M. Millington, A. Gelderloos, D. Eiriksson, B.T. Neilson, G.J. Bowen, and P.D. Brooks (2017). Persistent urban impacts on surface water quality mediated by stormwater recharge. *Environmental Science and Technology*. 51 (17)9477–9487, doi:10.1021/acs.est.7b00271.

Release of Arsenic from Aquifer Solids under Anaerobic Conditions

Principal Investigators:
Joan E. McLean
R. Ryan Dupont
Kaisa Forsyth and Jeremy Jensen (MS students)

Partners/Collaborators:

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

Project Description:

- Need and Purpose:

  Arsenic is one of the most frequently detected contaminants in private wells used for household drinking water and public water supplies in the U.S., and local geology is often the source. Geologic formations throughout Utah contain arsenic. Many of these formations are stable and pose no threat to humans or the environment, while others respond to altering hydrologic conditions by leaching arsenic into the groundwater. Our research on aquifers in Cache Valley, UT has emphasized the importance of not only oxidation-reduction controlled dissolution from iron containing minerals, but also the role of dissolution and precipitation of carbonate minerals affecting arsenic solubility. Carbonate minerals are common in the geology of the semi-arid west and contribute significantly to arsenic biogeochemistry in soils and groundwater in this region. This year we have been evaluating the effect of wetting and drying cycles on the solubility of arsenic because these cycles control oxidation-reduction and dissolution-precipitation reactions. We are presently studying these cycles in (1) seasonal raising and lowering of the water table in the center of Cache Valley and (2) laboratory column studies.

- **Benefits to the State:**

  All counties in Utah will benefit from an improved understanding of the biogeochemistry governing the behavior of arsenic in surface and subsurface environments as they are exposed to wetting-drying and oxidizing-reducing conditions that can lead to groundwater contamination.

Figure 1. Field sampling and analysis of groundwater in Cache Valley UT

- **Geographic Areas:**

  Study Areas: Cache County.
  Areas Benefited: In addition to the specific areas above, this project will contribute to protect groundwater resources throughout the state. Arsenic in groundwater is a worldwide problem.

- **Accomplishments:**

  Findings: Wetting and drying cycles in groundwater aquifers basins in Cache Valley alter the system's biogeochemistry, resulting in solubilization of arsenic.
  Results: Groundwater sample collection is complete (Fig 1), and analysis of data is ongoing. Two years of collection has revealed potential effects from wet and dry years (Fig 2), with seasonal and annual changes in groundwater arsenic concentration. A laboratory column experiment has begun to replicate the effects of groundwater fluctuation on the specific carbonate-rich soil layer (Fig 3). This allows for control of factors such as time, biological interaction, redox state, and soil moisture. Carbonate-rich soil layers were

separated from core samples and placed in columns subject to different biological treatments and alternating wet/dry cycles. Data from one wet/dry cycle has been collected and is currently being analyzed.

Preliminary results illustrate that biologically active systems (biotic) are driven by oxidation-reduction reactions (Fig 4). When biological processes are removed by poisoning the microbes, redox processes are removed, but As(V) undergoes dissolution/precipitation processes presumably associated with carbonate chemistry.

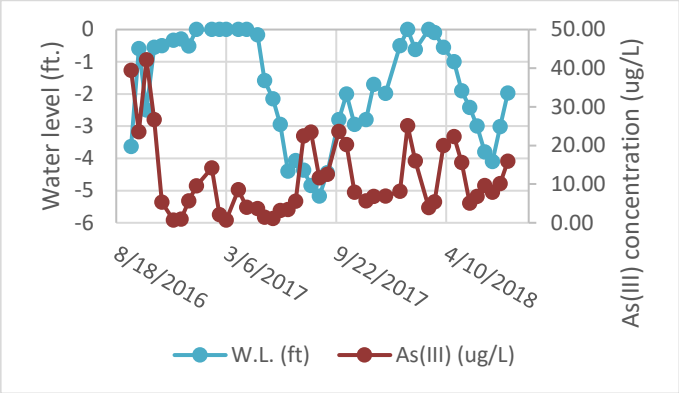


Figure 2 As(III) in groundwater responds to changes in the water table elevation that vary annually and seasonally

Work Plan FY18/FY19

Columns from the controlled laboratory experiment will be subjected to two more wet/dry cycles. These data will be used to determine the effects of multiple cycles of groundwater levels on the release and precipitation of As in the carbonate-rich soil layer. Additionally, the effects of biological interaction on As speciation in the carbonate layer will be studied.

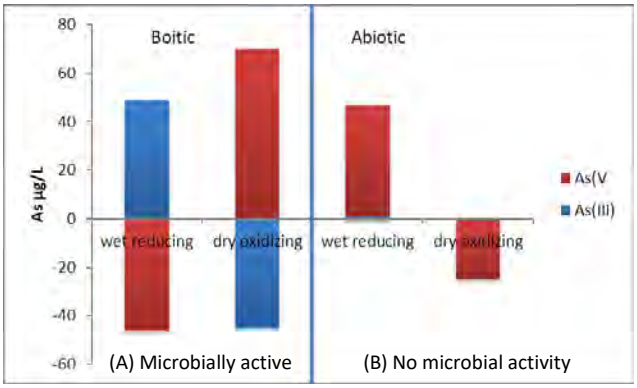


Figure 4. Column study preliminary results. For system (A), As(V) concentration in solution decreased with a corresponding increase in solution phase As(III) under wet conditions, while As(V) concentration increases with a corresponding decrease in As(III) in dry oxidizing. These reactions are evidence that microbially driven redox processes are driving dissolution of As. For system (B), As(V) concentration increases in solution under wet conditions and decrease with drying, showing dissolution/precipitation reactions that are not microbailly driven

Figure 3. Constructed columns containing soil and groundwater from the site in Cache Valley. Columns are incubated under microbial active conditions non biological controls (poisoned) to observe the role of oxidation-reduction reaction and dissolution of carbonate on arsenic solubility

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 E. McLean
Ahmed Bitar (graduate student)

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

Project Description

- Need and Purpose:

  Source water protection for drinking water systems remains a significant public policy concern in the State of Utah. A proposed phosphate mine in the Uintah Basin, Utah, near the city of Vernal on Ashley Creek, may threaten the 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. These include 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; data incorporated into a database system to produce data summaries and reports; and public meetings with stakeholders.

- **Geographic Areas:**

  Study Area: All project related work is being 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 2017. Additional land use, topography, weather and other data have been collected. Although, in the main, the data are suitable for the source water protection zone determination, additional information, mainly in the form of metadata, were obtained for the purpose of rounding out the assumptions required for the APEX modeling effort.

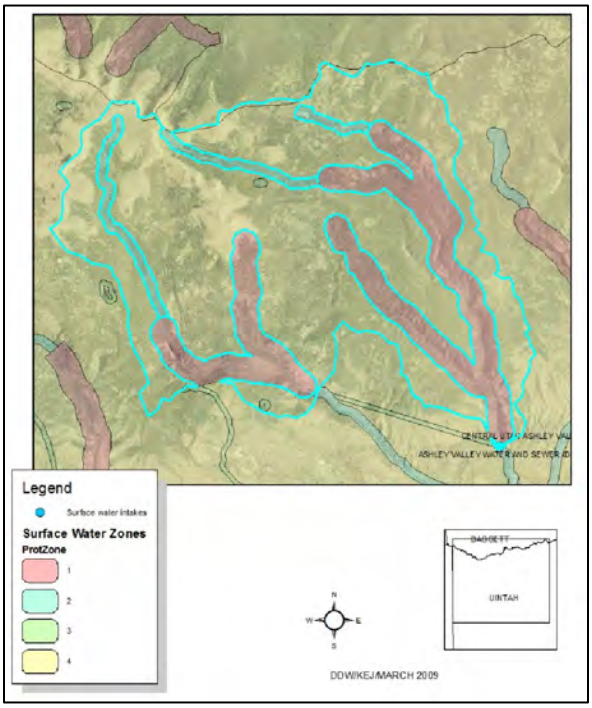
  Delineate/Assess Source Water Protection Zones—A Source Water Protection plan was developed by the Central Utah Water Conservancy District for Ashley Springs based on land use in effect in 2009. The Zone 1 protection area (the most critical) is shown shaded in red on the map below, extending 1/2 mile 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.

  Ahmed Bitar, completed his ME degree.

Work Plan FY 18-19

- Complete and deploy the model for the effect of P mining on Ashley Spring. Apply SWAT/ APEX rainfall/runoff/contaminant transport model to the source protection zone.
- Complete development of 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.
- Complete analysis of hydrologic, geological, and water quality data, following source protection protocols to add this fifth source and determine suitable plan changes.
- Recommend a source water protection zone.



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

Informational Resources

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

Understanding the Variability of Groundwater Recharge and Mountainous Stream Discharge in Karst Environments

Principal Investigators:
Tianfang Xu
Bethany Neilson
Conor Tyson, Jason L. Manley (students)

Partners/Collaborators:
- ***Local**: Dennis L. Newell (USU), City of Logan, Cache Valley Water District, James P. McNamara (Boise State University*

Project Description:

- **Need and Purpose:**

  Snow recharged karst aquifers are the primary source of municipal and agricultural water supply in many mountainous areas including northern Utah. Logan City uses karst springs and wells for drinking water. Groundwater discharge into the Logan River is the primary resource for irrigation water demand. Variability in climate is projected to result in shifting patterns of snow and rain, thus creating uncertainty in water resources sustainability. Effective water resources management and planning needs to consider the impact of these changes on karst mountain watersheds, and develop tools for predicting watershed response to shifts in temperature and precipitation patterns.

- **Benefits to the State:**

  The overall focus of this research is to develop a simulation model that can synthesize existing data and provide a quantitative assessment of water resource sustainability. The proposed data collection efforts in this study complement the climatic, hydrologic, and chemical data collected in previous research. These data will be synthesized with long-term historical observations of snow and discharge using a hybrid model that comprises a physically-based snow accumulation and melt model (UEB) and a machine learning model of the karst groundwater system. The hybrid model will be applied to the Logan River watershed to quantify the historical effects of snow-rain distribution and timing on (1) karst aquifer recharge and (2) the inter-annual and intra-annual variability of karst discharge. The results will lay the foundation for assessing the resiliency of water resources in northern Utah. The outcomes of this study will be the basis for a follow-on proposal for longer-term external funding needed to deliver more information to support local water resources management decisions.

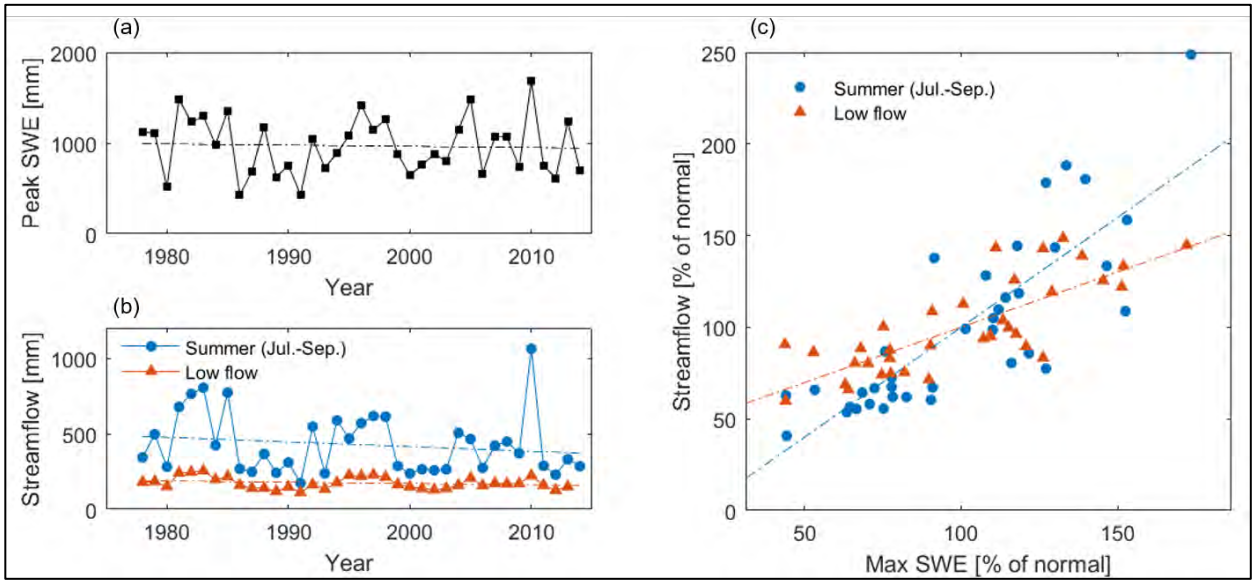
- **Geographic Areas:**

  Study Areas: Logan River, Logan, UT.
  Areas Benefited: This research will directly benefit Cache Valley, a populated portion of Utah. The information gained and methods developed should be applicable to the entire state of Utah.

- **Accomplishments:**

  Findings: We found through exploratory data analyses that (1) Logan River discharge exhibits high interannual variability mainly due to the fast response and short resident time of the karst groundwater system, (2) summer and winter streamflow of the Logan River is closely related to several climate factors (e.g., maximum snow water equivalence (SWE), spring temperature, and day of year corresponding to maximum SWE), and (3) groundwater recharge varies due to the spatial pattern of snow melt, which is a function of elevation and topography.

Results: As shown in the figure below, long time discharge records of the Logan River exhibit high interannual variability. This can be largely explained by the interannual variability of snow water equivalent (SWE) records at a nearby SNOTEL station. A strong positive linear correlation (r=0.82) exists between annual summer streamflow (averaged over July to September) and the peak SWE each year. This illustrates the sensitivity of the discharge during the highest demand times in summer to the maximum winter snow accumulation (slope=1.2). The following year winter when snow is accumulating is also positively correlated with that winter low flow period but is less sensitive (r=0.78, slope = 0.60). A similar correlation exists with the days of the year that SWE peaks and that snow melts out, suggesting a link between summer and winter streamflow and timing of aquifer recharge.



Work Plan FY18/FY19

We will continue to develop the hybrid models and will maintain the gaging stations along the canyon portion of the Logan River and at the mouth of the three tributaries as part of this project. We are in the process of proposal development for NSF.

Informational Resources

Contact: Dr. Tianfang Xu, Phone: (435) 797 4146, E-mail: tianfang.xu@usu.edu.

Representative Publication:

Neilson, B.T., Tennant, H., Stout, T.L., Miller, M., Gabor, R.S., Jameel, Y., Millington, M., Gelderloos, A., Bowen, G. and Brooks, P. (2018). Stream-centric methods for determining groundwater contributions in karst mountain watersheds. *Water Resources Research*.

Water Education and Technology Transfer

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

Project Name	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
Education Program for Homeowners and Other Users of Septic Systems in Utah	$15,434.09	$15,897.11	$16,374.03
Manuals for On-Site Wastewater Treatment Best Practices	$15,434.09	$15,897.11	$16,374.03
Salt Lake Valley Solid Waste Management Council	$2,000.00	$2,060.00	$2,121.80
State of Utah Drinking Water Board	$2,000.00	$2,060.00	$2,121.80
State of Utah Operators Certification Commission	$2,000.00	$2,060.00	$2,121.80
USU Stars! Gear Up Summer Engineering Camp	$17,482.27	$18,006.74	$18,546.94
Utah On-Site Wastewater Treatment Training Program	$46,302.26	$47,691.33	$49,122.06
Designated Projects		$40,000.00	$50,000.00
Undesignated Projects		$40,954.19	$39,751.62
Total	**$100,652.71**	**$184,626.48**	**$196,534.08**

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

Principal Investigators:
Judith L. Sims
Shay Larsen

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. Many brochures and flyers 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:**

  Utah watersheds would benefit by protection from the harmful effects of excessive organic materials, nitrogen, phosphorus, suspended solids, and pathogens that may occur in runoff of wastewater that surfaces from failing on-site systems. Proper management of septic systems used by homeowners can reduce the flow of contaminants (especially pathogens and nitrogen) carried by subsurface movement of wastewater from failing, overloaded, or improperly maintained systems into ground water and into the watershed's streams and rivers.

- **Geographic Areas:**

  Study Area: Statewide
  Areas Benefited: Areas in Utah where water bodies or ground water would be adversely affected by poorly maintained or managed septic systems. In addition, educational materials developed in this project will be made available to all thirteen Utah local health departments for dissemination to homeowners and other septic system users.

- **Accomplishments:**

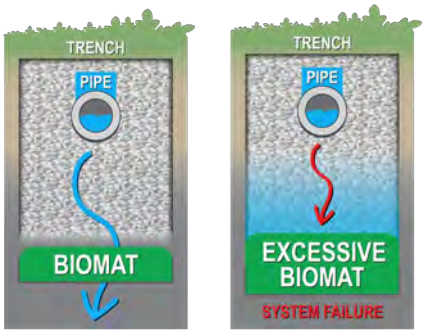
  Findings: We have investigated approaches to educational programs using social marketing techniques. Social marketing is the use of marketing principles to influence human behavior in order to improve health or benefit society. Social marketing includes: (1) focusing on a key issue, (2) developing a 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 define topics that are essential for homeowners to know regarding the use (and abuse) and maintenance of their septic systems

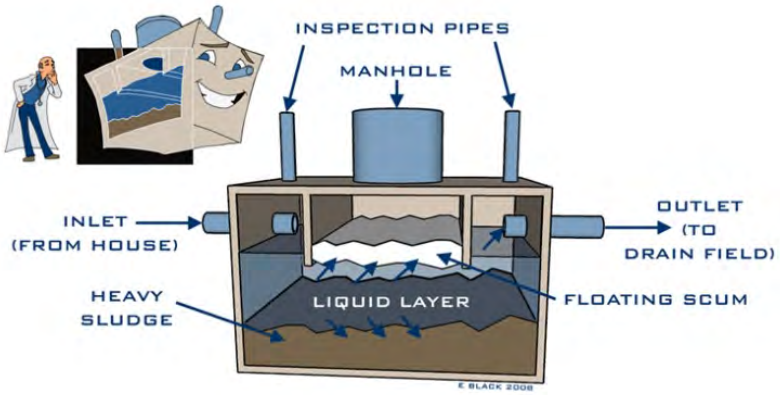
Results: Based on our investigations, we identified the following topics as essential for our educational program:

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 FY17/FY18 we finalized documents and presentations associated with the topics identified as being critical and distributed them to stakeholders.





Work Plan FY18/FY19

The project has been completed.

Informational Resources

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

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:**

  The best practice manuals developed for various aspects of on-site wastewater treatment methods and technologies 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*). The 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) into ground water and then by ground water inflow to the watershed's 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 from on-site systems into water bodies.

- **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, current Utah Training Program educational materials and tools, U.S. Environmental Protection Agency guidance materials, and educational materials developed by the Consortium of Institutes for Decentralized Wastewater Treatment. The manuals developed through this project focus on Utah regulations, practices, and needs.

Results: During FY17/FY18, we continued and finalized the development of design worksheets, recording sheets for site and soil information, installation and inspection checklists, and operation & maintenance checklists. These worksheets and forms were prepared specifically to address Utah guidelines and practices.
We provided the manuals to stakeholders, including local Utah health department, Utah Division of Water Quality staff, and participants in on-site professional certification workshops.

Work Plan FY18/FY19

The project has been completed.

Informational Resources

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

Salt Lake Valley Solid Waste Management Council

Investigators:
R. Ryan Dupont

Partners/Collaborators:
- ***Local:*** *Scot Baird, Salt Lake County Public Works; 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; Mark Hooyer, 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, composting, and other sustainability practices, 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 food waste composting proposals, investigation of the impact on the SLVSWMF carbon and energy footprint of expanding green waste recycling on a county-wide basis, implementing food waste composting in Salt Lake City, and an analysis of the connection between curbside green waste collection and water quality impacts to the Jordan River from urban stormwater from Salt Lake City.

- **Geographic Areas:**
  Study Area: Salt Lake City, West Valley City, and Salt Lake County.

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

Figure 1. Flare at landfill gas recovery system at the Salt Lake Valley Solid Waste Management Facility

Accomplishments:

Findings/Results: The PI attended all regularly scheduled SLVSWMF Council meetings throughout FY16–17 and provided review and comment on all Council items relevant to his area of expertise. He was heavily involved in analyzing and developing 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 Count. He was also involved in composting system and shredder analyses, gas collection system updates, green waste collection/stormwater impacts, and cost of services analyses.

Work Plan FY18/FY19

Involvement of the PI with the SLVSWMF Council ended at the beginning of FY17 after 28 years of service to the Council. He remains available to respond to special project requests, as they arise, to support the SLVSWMF's mission and goals.

Informational Resources

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

Website: http://www.slvlandfill.slco.org/.

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, 2017 to June 30, 2018, 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 previewing projects and making recommendations to the full board concerning action or tabling of proposals. The Finance Committee holds teleconference meetings 6–7 times per year, and the PI participated in each of them.

Work Plan FY18-/FY19

Continued involvement on the Board through 2019.

Informational Resources

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

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

State of Utah Operators Certification Commission

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. The Board created the Water Treatment Operators Certification Commission in 1984 and Dr. Stevens has been a member of that commission since 1987.

- **Benefits to the State:**

  Membership on the Operators Certification Commission provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by managing training for water treatment plant operators. This includes setting policy, administering examinations, and making decisions on appeals. The PI attends yearly meetings of the Commission held in Salt Lake City and provides comments and inputs policies and procedures regarding the certification of water treatment and distribution system operators in accordance with 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 scheduled Operators Certification Commission meetings July 1, 2017 to June 30, 2018, and provided review and comment on all Commission items relevant to his area of expertise. The PI also serves on the Drinking Water Board and its Finance Committee, reviewing projects and making recommendation to the full board concerning action on proposals.

Work Plan FY18/FY19

Involvement on the Board will continue through 2019.

Informational Resources

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

Website: http://www.deq.utah.gov/Certification/certification/drinkingwater/certsysoperator.htm.

USU Stars! Gear Up Summer Engineering Camp

Investigators:
R. Ryan Dupont
Randy S. Martin
Alfonso Torres-Rua
Patrick Strong
Cal Coopmans

Partners/Collaborators:

- ***Local:*** *Aggie Air; Nancy Mesner, College of Natural Resources, USU; Kurt Becker, Engineering Education, USU; Max Longhurst, School of Teacher Education and Leadership, USU*

Project Description

- **Need and Purpose:**

  The USU Stars! Gear Up Project is a summer camp designed to improve high school graduation rates and enhance college-readiness for Utah students, focusing specifically on underrepresented student populations (women and minority students) in STEM fields. This program encourages middle/high school students to pursue post-secondary STEM education by offering pre-college experiences focused on specific areas of engineering practice.

- **Benefits to the State:**

  The Gear Up program is addressing future workforce development needs in science and engineering, as well as needs in STEM diversity and educational equity across historically underserved populations in the state. Students and teachers throughout Utah are invited to participate in a range of engineering educational experiences during a week-long summer workshop on the USU campus to familiarize both cohorts with science and engineering research and practice, and ways in which engineering principles can be incorporated into science learning standards for middle and high school curricula.

- **Geographic Areas:**

  Study Area: Logan City and Cache County.
  Areas Benefited: Teachers and students from Logan, North Davis, Gunnison, Manti, North Sanpete, Cottonwood, and Salt Lake City.

Figure 1. Student poster presentation session at the culmination of the Engineering Camp

- **Accomplishments:**

  Findings/Results: Sixty students and eight teachers from school districts across the State attended a week-long summer engineering workshop focused on the science and practice of water and environmental data collection, including remote submersible drone water sampling, high-frequency water quality sampling using a river sensor network, and air quality and water resources data collection using aerial drones. Finally, each student group generated a poster highlighting the science and engineering principles they discovered during the week.

  Module 1: Underwater Remotely Operated Vehicles (ROVs). Using low cost materials and relatively low-tech tools, students constructed an underwater robot that demonstrated the basic principles of buoyancy, motor resistance, and remote water quality sampling and analysis. This module provided students and teachers experience with the construction of an underwater ROV outfitted for remote temperature data logging, video logging of the subsurface, and remote sample collection for DO and pH measurements to compare water quality conditions at depths throughout a local recreational reservoir and river.

Module 2: Data Collection and Analysis from a River Sensor Network. Continuous monitoring of different types of river properties (flow, temperature) and water quality conditions (pH, turbidity, dissolved solids) is now possible through innovations in sensors and information networks. Students used water quality monitoring data from a network established on the Logan River to learn how continuous data are collected, how they can be accessed, how they can be analyzed to understand the dynamics of a river, and how those dynamics can affect the quantity, quality, and ecology of a river. The students and teachers visited a water quality monitoring station, learned about the sensors, collected and measured by hand some sensor parameters and river velocity to verify their validity and developed and tested hypotheses about river dynamics using sensor data available from the network.

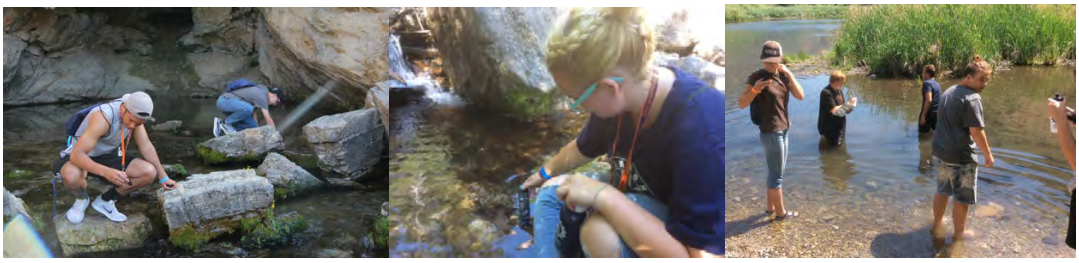


Figure 2. Students making water quality measurements throughout Logan Canyon

Module 3: Air Quality Measurements and Exposure Assessment. The Water Cycle includes the movement of water as vapor from rivers and lakes into the atmosphere. Many pollutants are also released into the atmosphere and result in human exposure and risk. Students and teachers learned how to assemble a low-cost, lightweight air quality monitor based on an Arduino-type microcomputer to monitor barometric pressure (altitude), temperature, and relative humidity, as well as new generation air quality sensors for particulate matter. The assembled unit, fixed to a small, quad-copter drone, was used to monitor the vertical profile of the parameters at several USU campus locations. By examining the vertical gradients of these parameters, the students and teachers gained insight into atmospheric mixing properties, water transport through the environment, and pollutant source strength, dispersion, deposition, and potential exposure.

Module 4: Water Resources Monitoring with Drones. AggieAir, a research program at the Utah Water Research Laboratory at USU, has 10+ years of experience designing drones that help scientists remotely collect and process large quantities of environmental data so that water and other natural resources can be used more efficiently. Students and teachers learned about advanced drone components and how they work. They explored different types of sensors and how they are used to monitor water (soil water content, plant and soil evapotranspiration) via remote sensing. Students and teachers participated in a drone data-collection mission, and then learned how raw data from these drone sensors can be turned into useful scientific information.

Work Plan FY18/FY19

Building on successes in 2018, planning has begun for the 2019 USU Stars! Gear Up Summer Engineering Camp. New teachers and students from different locations around the State will gain STEM-related college-preparedness experience designed to strengthen Utah's technology future.

Informational Resources

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

Utah On-Site Wastewater Treatment Training Program

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

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 they 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 a manner that will effectively 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.

  Because Level 1, Level 2, and Level 3 certifications expire after 3 years, workshops are also provided for renewal of certifications.

  Results: During FY17/FY18, two Level 1 workshops, two Level 2 workshops, two Level 3 workshops, two Level 1 & 2 recertification, and two Level 3 recertification workshops were taught at various locations around the State of Utah, including Richfield, Hurricane, and Logan.

Work Plan FY18/FY19

We will continue to provide workshops in support of the mandatory State of Utah certification program for on-site wastewater professionals (through FY 2019–20). Fall workshops in 2018 will be held in Ogden, Vernal, and Logan. Spring 2019 workshops will be held in Logan and other locations yet to be determined.

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., Cashell, M., Cowan, B., and Jex, R. (2017, 2087). *Course Manuals for Levels 1, 2, and 3 Original Certification and Recertification Workshops*. Utah Water Research Laboratory, Utah State University, Logan, UT.



Water Resources Planning and Management

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

Project Name	FY2018 Actual Expenditures	FY2019 Budgeted Expenditures	FY2020 Planned Expenditures
Advancing the Capability for Hydrologic Modeling	$19,857.18	$20,452.90	$21,066.48
Allocating Scarce Water for Utah Wetland Riverine, and Riparian Areas with Ecological Uncertainties	$15,671.10	$16,141.23	$16,625.47
Birds Nest Aquifer Saline Injection Simulation, Optimization, and Economic Impact	$2,007.16	$2,600.00	$0.00
Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management	$4,217.63	$5,000.00	$5,000.00
Feasibility of Integrating UAS Multispectral and Thermal-Infrared Data at Very Fine Pixel Resolutions with the Energy Balance Models	$64,205.29	$66,131.45	$0.00
High Frequency Data and Cyberinfrastructure Tools for High Resolution Modeling in Snowmelt Dominated Watersheds	$23,564.14	$10,000.00	$10,000.00
High Resolution Remote Sensing of Crop Yields from Fields using Deficit Irrigation for Water Conservation	$5,000.00	$5,000.00	$5,150.00
Hydraulic and Thermal Characteristics of Habitats and Wetlands in the Lower San Rafael River, Utah	$1,650.35	$0.00	$0.00
Impacts of Climate Variability on Cattle and Hay Production in the Upper Colorado River Basin	$4,000.00	$0.00	$0.00
Mapping Subsurface Tile Drainage Systems with Unmanned Aerial Vehicles (UAVs)	$4,689.74	$8,000.00	$8,000.00
Metering Non-Residential Water Users to Identify Conservation Opportunities	$44,535.88	$40,000.00	$20,000.00
OpenET Upper Colorado River Basin	$585.00	$5,000.00	$5,150.00
Organizing and Synthesizing Water Management Data to Support Modeling	$17,739.82	$18,272.01	$18,820.18
UAV Remote Sensing Service Center	$5,811.30	$20,000.00	$20,000.00
Water Management in the Event of Recurring Long-Term Historical Droughts	$66,377.13	$45,000.00	$46,350.00
Designated Projects		$65,000.00	$70,000.00
Undesignated Projects		$50,000.00	$80,000.00
Total	**$279,911.72**	**$376,597.59**	**$326,162.13**

Advancing the Capability for Hydrologic Modeling

Investigators:
David G. Tarboton
Irene Garousi-Nejad (graduate student)
Tian Gan (graduate student)
Tseganeh Gichamo (graduate student)
Prasanna Dahal (graduate student)

Partners/Collaborators:
Michelle Stokes, Colorado Basin River Forecast Center
Gerald Day, RTI, Ft Collins

Project Description

- **Need and Purpose:**
  Hydrologic modeling capability is needed to provide better quantification of the availability of water and the potential for flooding. This research is focused on advancing the capability for hydrologic prediction by developing models that take advantage of new information and process understanding enabled by new technology. We want to improve quantification of the amount of water available to ensure sufficient water resources in times of shortage. We want to be able to better forecast, plan for, and mitigate the effects of floods. Both droughts and floods are prevalent in Utah, the Colorado River Basin, and the Western US, where much of our water originates as snowmelt. There is thus a focus on improving the modeling of snowmelt as it relates to water supply and flooding.

- **Benefits to the State:**

  Water is a critical resource in Utah. This research will provide an improved ability to predict water supply in the future as a result of land use and climate changes. It will also advance our understanding of the impacts of water resources development activities around the Great Salt Lake. Planning for potential growth and development in the state requires information on water availability, as well as on the effects of growth on our water resources. This work is improving our capability to model snowmelt, the 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 area served by the National Weather Service (NWS) Colorado Basin River Forecast Center (CBRFC) in Salt Lake City, which includes the Colorado River and Great Salt Lake Basins. The snowmelt studies are using focus watersheds for the within this area, including the Logan River, Animas, Upper Green, and Dolores watersheds within the Colorado River Basin. A stretch of the Bear River below Cutler Reservoir is the focus of a flood study.
  Areas Benefited: Watersheds throughout Utah benefit from improved water supply forecasts. All counties in the state stand to benefit from a better quantification of available water and the risk and potential for flooding.

- **Accomplishments:**

  Findings

  (1) Graduate student Tian Gan is investigating physical based energy balance snowmelt model capability and has found that the Utah Energy Balance (UEB) model can account for sublimation losses and the variability of snowmelt based on vegetation.

(2) Graduate student Tseganeh Gichamo has developed a novel approach based on a statistical technique referred to as an Ensemble Kalman Filter, to use information on snow accumulation and melt measured at SNOTEL stations to adjust gridded snow accumulation and melt across a watershed and improve water supply forecasts.

(3) Graduate student Prasanna Dahal implemented a web application to demonstrate prototype capability to provide researchers with easy to use access to complete web based hydrologic modeling functionality.

(4) Graduate student Irene Garousi-Nejad, working with the National Water Model (NWM), a new hydrologic model based on the WRF-Hydro modeling framework being used by the National Water Center to provide streamflow forecasts across the US, has shown that improved terrain analysis methods can improve the accuracy with which flood inundation can be mapped.

Results: The improvements in snowmelt modeling in findings (1) and (2) above have been implemented using the UWRL Utah Energy Balance (UEB) Snowmelt model, a physically based model that offers the potential to improve upon the temperature index approach currently used for operational water supply forecasting by the NWS CBRFC. Current methods use a temperature index model to drive the SAC-SMA soil moisture accounting model for water supply forecasts. Ongoing work, in collaboration with RTI (Research Triangle Institute Fort Collins Office) and the CBRFC is evaluating the use of this capability in the CBRFC water supply forecasting. Results indicate that use of the UEB with updating based on SNOTEL observations allows water supply forecasts to be updated as more measurements are obtained, reducing their uncertainty as the season progresses. The web application modeling work (3) has been reported in a MS thesis. Improvements in flood inundation mapping capability with the NWM (4) have been demonstrated for a reach of the Bear River where there was a snowmelt flood in 2017 and we were able to, in a retrospective analysis, compare modeled inundation, as well as potentially improved modeled inundation, with satellite observations.

Work Plan FY18/FY19

In the coming year, we will continue the work to improve the UEB snowmelt model and integrate it with hydrologic models used for streamflow and water supply forecasting in the Great Salt Lake Basin and Colorado River Basin. We will also continue work on improving snow related aspects of the National Water Model. This will include evaluation of UEB within the WRF-Hydro modeling framework and advances to the height above the nearest drainage terrain analysis methods for flood inundation.

Informational Resources

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

Publication:

Dahal, P., (2018), "Advancing the Implementation of Hydrologic Models as Web-based Applications." M.Sc. Thesis, Civil and Environmental Engineering, Utah State University, Logan, UT. https://digitalcommons.usu.edu/etd/6932, 104 pp.

Allocating Scarce Water for Utah Wetland, Riverine, and Riparian Areas with Ecological Uncertainties

Investigators:
David E. Rosenberg
Karin M. Kettenring
Belize Lane
Ayman Alafifi, Todd Brown (Students)

Partners/Collaborators:

- ***Local:*** *Joan Degiorgio, The Nature Conservancy; Bryan Dixon, Bear River Land Conservancy; Bob Fotheringham, Cache County, Jim DeRito, Trout Unlimited*
- ***State:*** *Paul Thompson, Utah Division of Wildlife Resources*
- ***Federal:*** *Bob Barrett, Howard Browers, U.S. Fish and Wildlife Service*
- ***Business/Commercial:*** *Eve Davies, PacifiCorp; Con Baldwin, PacifiCorp*

Project Description

- **Need and Purpose:**

  Wetlands, flood plains, and aquatic areas provide critical bird, wildlife, and fish habitat and a variety of social and economic services including water purification, storm water retention, and recreation for hunters. These areas need water, but in Utah and the western U.S., water is often scarce and not available to flood and maintain wetland, floodplain, and aquatic area habitats and functions. Scarce water is a challenge as managers make decisions on how to best allocate limited water to and within these areas to improve ecosystem functions and services. Uncertainties about water availability, bird and fish populations, and native plant species responses also complicate water allocation decisions. In addition to water, there is also need to manage native and invasive vegetation.

  Work this year explored the effects of uncertain hydrologic, management, and ecological factors on water and vegetation management to improve aquatic, floodplain, and impounded wetland habitats within the lower Bear River basin. This work used a previously developed Watershed Area of Suitable Habitat (WASH) model for the basin.

- **Benefits to the State:**

  The project benefits Utah in several ways: (1) helping Utah environmental managers allocate scarce water to important aquatic, floodplain, and impounded wetland areas across a watershed, (2) showing how to synergistically manage water and vegetation, and (3) quantifying the effects of uncertainties in hydrologic and ecological factors on recommended management. Work helps managers to protect the State's rivers and critical fish, floodplain vegetation, and wildlife. Finally, the project is integrating systems modeling, ecology, and stakeholder input and showcases a new Utah-based approach to environmental management.

- **Geographic Areas:**

  Study Area: Bear River basin, Box Elder County, Utah and Cache County, Utah.
  Areas Benefited: Wetland, riparian, and riverine areas throughout Utah.

- **Accomplishments:**

  Findings and Results:
  - A new Monte-Carlo simulation method linked to semi-supervised clustering was developed to show the effects of a large number of uncertain hydrologic, management, and ecosystem factors on water and vegetation manage to improve habitat.

- Suitable habitat area is most sensitive to water depth, which is used to represent suitable habitat for target fish species like Bonneville cutthroat trout and brown trout (Figure 1).
- Rich tradeoffs exist between aquatic, floodplain, and wetland habitat area objectives, and they change when managing for different target fish and floodplain vegetation species (Figure 2). These tradeoffs are not apparent when solving a deterministic version of the model that only uses average parameter values.
- Management for different target species also implies different reservoir release strategies (Figure 3).
- Ayman Alafifi completed his Ph.D. dissertation.
- Publication submitted to the *Journal of Water Resources Planning and Management.*
- One Bear River Fellow continues to write an article to describe the 16 Fellows' experiences conducting undergraduate environmental and ecological research.
- A two-page fact sheet was developed that discusses existing and potential legislative tools to promote instream flows and implement project findings.

Work Plan FY18/FY19

- Continue to distribute results to interested parties.
- Extend interactive WASHmap to work for other systems models and watersheds.

Informational Resources

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

Website: Ayman Alafifi's Ph.D. dissertation.
Website: Interactive map of WASH Model Results.
Website: http://bearriverfellows.usu.edu/.

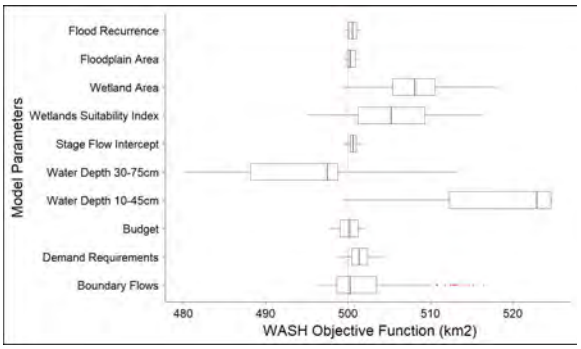


Figure 1. Sensitivity of suitable habitat area (WASH Objective function) to hydrologic, management, and ecological factors.

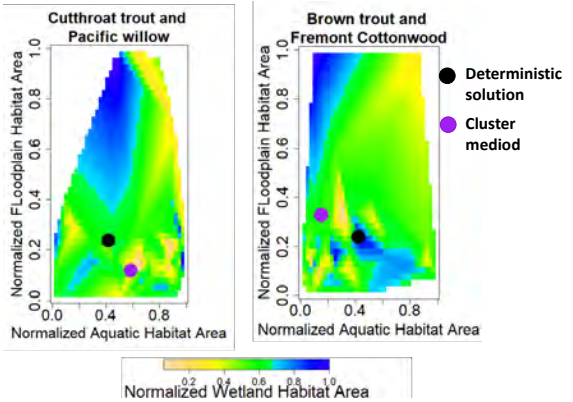


Figure 2. Tradeoffs in aquatic, floodplain, and wetland habitat area for different target fish and floodplain vegetation species. Deterministic solution uses average parameter values, colored traces show solution closest to cluster center (medioid).

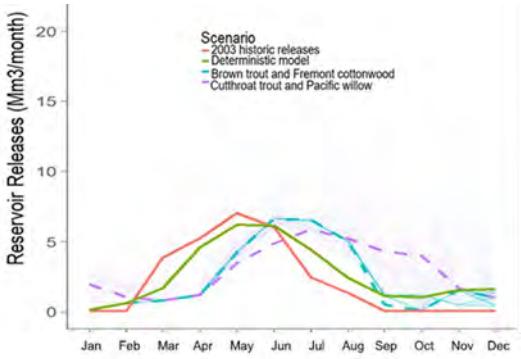


Figure 3. Model-recommended Hyrum reservoir releases to manage for uncertainties in target fish and floodplain vegetation species. Dashed traces show cluster medioid, grey traces show other cluster members.

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

Principal Investigators:
Richard C. Peralta
Rick Lyons (graduate student)

Partners/Collaborators:
- ***Local**: 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, UT, petroleum production. Oil and gas production also produce saline water. From 2001 to 2011, natural gas, crude oil, and saline water production increased 208%, 160%, and 86%, respectively. An additional 25,000 proposed petroleum wells would produce a huge saline water volume requiring disposal. For environmental reasons, the preferred Uintah basin disposal method is subsurface injection. Gas producers propose to increase saline water injection into the Birds Nest Aquifer (BNA), which exists within the oil shale horizon. This aquifer has veins of solid hydrocarbon Gilsonite 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 its water concentration exceeds 10,000 mg/L total dissolved solids (TDS). Southeastern aquifer water has less than 10,000 mg/L TDS and is protected from injection. The Utah Geological Survey (UGS) and US Bureau of Land Management (BLM) have identified possible negative injection consequences. Horizontally flowing injectate could harm existing groundwater supply wells, increase fresh water spring discharge, and cause saline springs that might contaminate surface waters. Injection mounding could economically harm Gilsonite mining. Water could also flow downward through Gilsonite veins and reach fractures in fracked oil-shale strata, flooding future petroleum-harvesting activities. The physical setting is complex. Guidance is needed, but no appropriate study area groundwater flow and contaminant transport models exist. Predicting injection impacts in the aquifer and in anticipated fractures resulting from lower stratum fracking, require two appropriately discretized calibrated flow models. Then a calibrated transport model is needed to predict salinity concentrations at target locations and times. To address the range of expressed agency concerns, the employed flow and transport models must represent the BNA and associated higher and lower strata. Porous media flow simulation can represent BNA flow. Flow through vertical fractures caused by hydro-fracking requires fracture-flow modeling.

- **Benefits to the State:**

  The project will provide critically needed guidance for Utah energy-development decisions that have large economic, environmental, social, and political ramifications. To the Utah Division of Oil, Gas, and Mining (UDOGM), of the Utah Geological Survey (UGS), we will provide optimal safe saline injection strategies for collaboratively formed management scenarios. Each strategy is a spatial/temporal distribution of injected saline water developed via a simulation-optimization (S-O) model that couples simulation models with mathematical optimization algorithms. By simulation, we will also project the 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, or domestic well impacts. Collaborator interaction will help assure practical utility of project results. Results will aid the sustainable, safe development of Uintah Basin water and energy resources.

- **Geographic Areas:**

  Study Areas: Utah's Uintah Basin.
  Areas Benefited: The project provides Uintah Basin strategies for safely disposing of saline water resulting from oil and gas production. Developed method are applicable worldwide.

- **Accomplishments:**

  Findings/Results: Using additional interpreted data and target heads improved calibration of the Lower Birds Nest aquifer model (LBNM). Initially, we tried to replicate the Holmes and Kimball (1987) groundwater flow simulation model developed for part of the LBN aquifer. We reviewed all available source data, well logs, journal papers, and reports. We used additional target calibration head values from the Final Environmental Baseline Report of the White River (VTN, 1977). Our calibrated LBNM model more closely matches observed head values than the original model.

  To represent the entire Bird's Nest aquifer, we extended the LBNM horizontally and added two model layers (Upper Birds Nest Aquifer and inter-burden). This Birds Nest aquifer model (BNM) has 41 rows and 97 columns, uniform 804.7 m x 804.7 m cells, aquifer layer top and bottom elevations from UGS Special Study 147 (2013), aquifer parameters adjusted from those of Holmes & Kimball (1987). Preliminary steady-state calibration results are reasonable.

  To give the LBNM model transient simulation ability, we must provide aquifer storativity values. To obtain these we are searching well-logs, neutron-porosity logs, and density-porosity logs. We are interpreting findings, and compiling the results. We will interpolate or extrapolate to estimate values for areas where field data are sparse. Then we will calibrate the BNM for transient flow.

  Using FLOPY and Python enabled us to use new heuristic optimizers in calibration.

  For MODFLOW modeling, we began using FLOPY, an open-source, USGS-backed, Python library. This has sped progress and allowed use of new optimization algorithms for calibration.

  We calibrated the Birds Nest three-layer model using four different optimization algorithms. We tested these algorithms on our study to (a) obtain the model most representative of the physical system, (b) test the usability of various optimizers for use later in this study, and (c) compare novel optimizers against standard optimizers for simplicity and accuracy in calibration.

Work Plan FY18/FY19

- Complete Well Log Study
- Run Transient BN model with Injection
- Complete combined model of Uinta Basin Model and LBNM.
- Perform preliminary simulation-optimization of saline water into an aquifer.

Informational Resources

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

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

Principal Investigators:
Calvin Coopmans
Mac McKee

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 (sUAS) called AggieAir can provide low-cost, multispectral aerial imagery and other scientific data quickly and frequently. Because the AggieAir platform is not dependent on a runway for takeoff and landing, it can be launched almost anywhere. Some examples of AggieAir applications include agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, and fish and wildlife tracking.

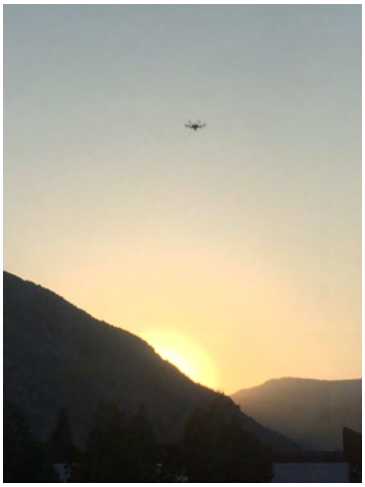


Figure 1: AggieAir scientific aerial payload flying aboard the AggieAir DJI Matrice 600 craft during a thermal inspection mission over Utah State University

- **Benefits to the State:**

  The data produced by AggieAir have the potential to save water in Utah as farmers and scientists use it as a low-cost way to map crop soil moisture for more efficient irrigation or canal operators use it to manage water resources more effectively. This data can also help wetland managers to manage invasive plant species that, if left unchecked, can crowd out 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 for AggieAir is to create a business within the state of Utah to market this technology.

- **Geographic Areas:**
  Study Area: Most test flights took place at our test site near Cache Junction, UT, with official approval from the FAA (FAA Form 7711-1 2013-WSA-63). Over the past year, AggieAir has also flown at sites across Utah and California.
  Areas Benefited: All counties in the state could benefit.

- **Accomplishments**:

  Findings: The AggieAir systems (avionics, payload, and operations) have been upgraded to a new level of reliability and performance. The avionics (the electronics and software that control the aircraft and the missions) have been significantly updated with custom-designed hardware that is engineered to perform in the field scenarios that AggieAir encounters, is repeatable, and can be maintained with maintenance protocols. AggieAir's new airborne platform, BluJay, has been updated to these new hardware and software standards, and has been undergoing field trials with the goal of being field-ready for the 2019 field season. BluJay, which is nearing field readiness, can fly up to 200 minutes with its scientific payload and can map up to an impressive 20000 acres with upgraded scientific clarity. The existing AggieAir

Minion platform continues to provide reliable results, and the AggieAir hangar has simply grown with the addition of new BluJay aircraft.

Smaller upgrades to payload hardware and software (AggieCap3) have been performed, as well, to allow for new sensors such as shortwave IR (SWIR) camera support. In addition, a new datalogging system that allows for full reconstruction of all system states (mission performance data) in post-flight analysis has been implemented. The AggieAir payload system has the ability to fly and collect data via other aircraft, such as the DJI Matrice 600 pro. This has allowed AggieAir to fly a greater variety of missions, such as a 3D and thermal inspection of the Utah State University campus for USU facilities (Fig. 1), resulting in the thermal map seen in Fig 2.

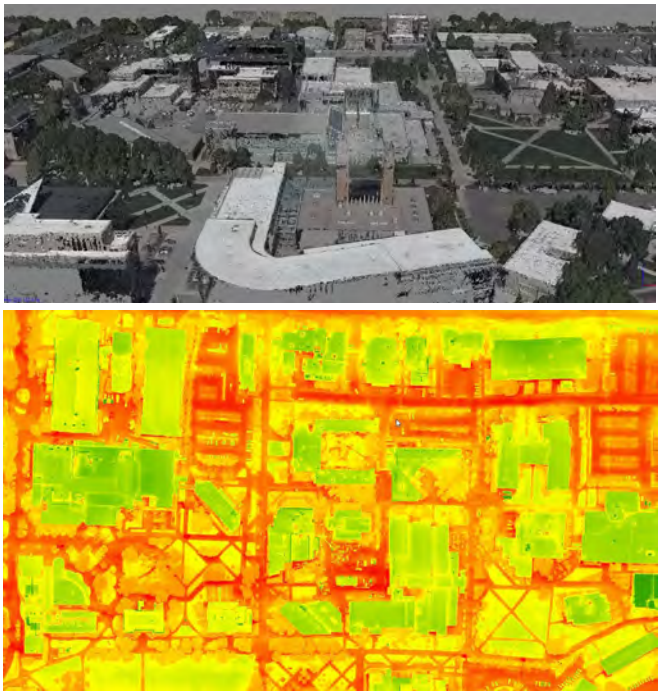


Figure 2: 3D and thermal maps of USU Campus generated by AggieAir photogrammetry data processing

Informational Resources

Contact: Dr. Calvin Coopmans, (435) 764 4579,
E-mail: cal.coopmans@usu.edu.
Website: http://aggieair.usu.edu/.

Publications:

Coopmans, C., Podhradsky, M., and Hoffer, N.V. (2018). Fractional-order complementary filters for small unmanned aerial system attitude estimation. In *2018 11th International Symposium on Mechatronics and its Applications (ISMA)* (pp. 1–7). https://doi.org/10.1109/ISMA.2018.8330140.

Dorafshan, S., Thomas, R.J., Coopmans, C., and Maguire, M. (2018). Deep Learning Neural Networks for sUAS-Assisted Structural Inspections: Feasibility and Application. In *2018 International Conference on Unmanned Aircraft Systems (ICUAS)* (pp. 874–882). https://doi.org/10.1109/ICUAS.2018.8453409.

Torres-Rua, A., Nieto, H., Parry, C., Elarab, M., Collatz, W., Coopmans, C., and Kustas, W. (2018). Inter-comparison of thermal measurements using ground-based sensors, UAV thermal cameras, and eddy covariance radiometers. In *Autonomous Air and Ground Sensing Systems for Agricultural Optimization and Phenotyping III* (Vol. 10664, p. 106640E).

Aboutalebi, M., Torres-Rua, A.F., McKee, M., Kustas, W., Nieto, H., and Coopmans, C. (2018). Behavior of vegetation/soil indices in shaded and sunlit pixels and evaluation of different shadow compensation methods using UAV high-resolution imagery over vineyards. In *Autonomous Air and Ground Sensing Systems for Agricultural Optimization and Phenotyping III* (Vol. 10664, p. 1066407).

Aboutalebi, M., Torres-Rua, A. F., Kustas, W. P., Nieto, H., Coopmans, C., and McKee, M. (2018). Assessment of different methods for shadow detection in high-resolution optical imagery and evaluation of shadow impact on calculation of NDVI, and evapotranspiration. *Irrigation Science*, 1–23.

Feasibility of Integrating UAS Multispectral and Thermal-Infrared Data at Very Fine Pixel Resolutions with the Energy Balance Models

Principal Investigators:
Alfonso Torres-Rua
Mac McKee

Partners/Collaborators:
Various end-users in Utah, E&J Gallo Winery and the ARS/USDA

Project Description

- **Need and Purpose:**

  Agricultural water management in the arid West is beginning to benefit from remote sensing (RS) products that measure crop water consumption, or evapotranspiration (ET), on irrigated lands. These RS estimates rely heavily on freely available satellite data, which means they suffer from coarse pixel sizes and infrequent satellite overpass times. High-resolution imagery can be obtained at any time through use of conventional manned aircraft, which is very expensive, or small unmanned aerial systems (sUAS). However, both are expensive and require use of cameras that have different spectral responses than those of satellites. This creates difficulty in the energy balance models that estimate ET. As sUAS and camera technology continues to develop, costs of deploying sUAS for remote sensing of ET will decrease, but only if techniques are developed that enable sUAS to acquire RS data that are the scientific equivalent of satellite data. This project (1) assesses the feasibility of integrating very fine pixel resolution (less than 0.5 meter) multispectral and thermal/infrared sUAS data (collected using UWRL-developed AggieAir drones) with the two-source energy balance model (TSEB), (2) evaluates the use of the TSEB model for estimating ET at high resolution, and (3) explores ways to use the high-resolution ET estimates to improve the quality of coarse satellite-based approaches.

- **Benefits to the State:**

  The State of Utah and water management agencies in the Upper Colorado River Basin have begun to invest in ground-based technology, such as expensive eddy covariance towers, to measure ET at a limited number of selected locations, and to evaluate different satellite-based ET models. These investments are intended to better quantify the amount of water used by agriculture in Utah and other Upper Basin states. Thermal data is a critical component in energy balance models of ET; however, all satellites that carry thermal cameras have coarse pixel resolutions, resulting in varyingly inaccurate ET estimates. This is especially the case for field crops that are heterogeneous in their plant cover (such as many row crops, orchards, vineyards, etc.) or that are grown on small plots. The technology developed in this project will result in protocols that can be followed to calibrate imagery collected from conventional manned or sUAS RS systems such that their resulting data are equivalent to the data produced at coarser resolution by NASA's best earth observatory satellites. Development of this capability will also turn properly equipped sUAS systems into flying eddy covariance towers that can capture high-quality ET estimates over vastly larger areas than ground-based systems. Such technology could benefit the State by producing much more, and better, ET estimates for irrigated lands in the State.

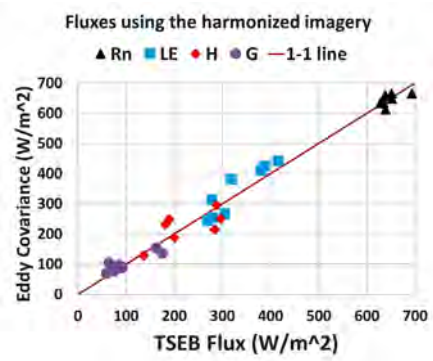
- **Geographic Areas:**

  Study Area: Statewide.
  Areas Benefited: Statewide.

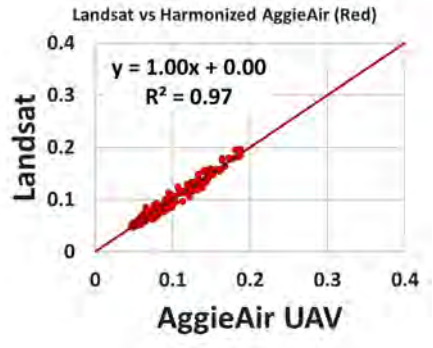
- **Accomplishments:**

  Findings/Results: This project has developed procedures using knowledge of the spectral response of any RS camera and of the point-spread-function (PSF) of the sensors aboard a selected satellite to "harmonize" the

camera data with the satellite so that both provide the same measures of light reflectance in the spectral bands they have in common. Further, these protocols have been tested in the TSEB model against ground-based eddy covariance tower data. The results of these tests indicate that: ET quantities estimated by the TSEB model using high-resolution RS data are the same at any spatial resolution, up to that of Landsat 8 (30 meters) and agree closely with independent measurements from the eddy covariance towers. These findings imply that the sensors flown by the UWRL AggieAir remote sensing group, when used following the calibration protocols developed in this project to provide high-resolution data to the TSEB model, provide ET estimates that are closely comparable to independent eddy covariance estimates. This means the AggieAir sUAS systems and the payloads they carry can be deployed anywhere to obtain ET estimates over very large areas. The estimates can be compared to those derived from satellite data to evaluate the quality of satellite-based ET. Such information can be of value to the State in evaluating ET estimates derived generally from RS approaches and, potentially, in "tuning" satellite data to provide better estimates of ET in areas where irrigated fields are heterogeneous in crop cover or small in size. Numerous technical papers have been published from this work and/or presented in international conferences, and have gained wide attention in the scientific community.



Comparison of energy flux estimates: Eddy covariance measures versus AggieAir-based TSEB RS Model



Example of harmonization of AggieAir red spectrum data against Landsat 8 data

Work Plan FY18/FY19

Discuss the results of this project with personnel in the Utah Division of Water Rights and the Division of Water Resources to determine the extent of interest in using the technology in Utah to improve ET estimates from RS data.

Informational Resources

Contact: Dr. Alfonso Torres-Rua, Phone (435) 797-0397, E-mail: alfonso.torres@usu.edu.
Website: http://aggieair.usu.edu/.

High Frequency Data and Cyberinfrastructure Tools for High Resolution Modeling in Snowmelt Dominated Watersheds

Principal Investigators:
Jeffery S. Horsburgh
Amber Spackman Jones
Stephanie Reeder
Tony Melcher and Bryce Mihalevich (Students)

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

Project Description

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

- **Need and Purpose:**
  This project has advanced the capabilities of water data collection and modeling cyberinfrastructure for watersheds within the state of Utah to (1) better understand hydrologic and water quality processes through instrumentation and data collection; (2) use high-frequency data to inform hydrologic and water quality modeling; and (3) educate next generation engineers and scientists in data collection and management techniques. A better understanding of hydrologic and water quality constituent behavior is important to water managers within the snowmelt dominated watersheds of the western United States. In particular, our high-frequency data collection in Cache Valley watersheds is improving our understanding of the spatial and temporal dynamics of important pollutants like nutrients (nitrogen and phosphorus), sediment, and dissolved organic matter. It is also extending capabilities to better estimate pollutant loading and timing, quantify storm water inputs in urban water systems, and test and implement hydrologic/water quality models. These tools aid in evaluating current and emerging water monitoring systems and the role of cyber-infrastructure in supporting day-to-day data collection, management, and sharing to support the next generation of environmental models.

- **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 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 important pollutants. Results benefit the Utah Division of Water Quality, local canal companies, municipalities, and, in general, utilities and water providers who rely on surface water sources to provide water to their constituents. It is also of use to managers responsible for storm water and other water infrastructure throughout the state. This work has provided valuable information for improving monitoring programs by better characterizing critical periods for pollutant transport and demonstrating the necessary sampling frequency to obtain accurate data needed for load determination or other watershed parameters needed by users. Finally, the cyberinfrastructure and tools developed as part of this project are essential to researchers across disciplines and to water managers in the state who need enhanced capabilities to work with datasets of increasing size and complexity while working on solutions to water resources problems.

- **Geographic Areas:**

  Study Area: Watersheds in Cache County.
  Areas Benefited: River systems statewide.

Figure 2. A mobile water quality monitoring platform enables us to examine spatial patterns in water quality that we cannot observe with grab sampling or fixed sensors

- **Accomplishments:**

  Findings: Combined urban/agricultural water conveyances (canals) are common in the state of Utah and show significant storm water impacts in both hydrology and water quality. In many cases, canal managers must reduce diversion flows during storms to accommodate runoff and avoid flooding. However, reductions in water diverted from the river lead to canal flows predominantly made up of storm runoff from streets, gutters, and parking lots. This reduced water quality can negatively affect downstream canal water users and receiving waters. Current urban storm water models generally lack mechanisms to represent these types of water management activities accurately, but accounting for them is critical to understanding and predicting system hydrology and water quality. Monitoring results show that major pollutant loading occurs during very brief periods during the year (e.g., river systems during spring snowmelt and urban water conveyance systems during storm water events). This underscores the need for continuous high-frequency data collection.

  Results: Our newly developed adaptive monitoring techniques and supporting cyber-infrastructure can better quantify episodic events (e.g., storm water runoff in urban water systems). Our innovative mobile water quality sensing platform enables new measurements of the spatial distribution of water quality variables (e.g., how water quality changes along the length of a stream or canal during an event), instead of a limited number of fixed sensor measurement locations. Our monitoring network within the Northwest Field Canal system in Logan, UT has investigated storm water impacts to combined agricultural/urban water conveyances. Using this first-of-a-kind canal monitoring system, we have examined the impacts to flow and water quality from both storm events and system management. We are now finishing our work by extending results to develop new techniques that incorporate the results of high-resolution monitoring into storm water simulation models to improve how we quantify and predict the effects of storm water runoff on water quantity and quality. We have developed an ongoing collaborative relationship with both Logan City and the Northwest Field Irrigation Company that has resulted in new funding for installation, operation, and maintenance of multiple, continuous monitoring sites. To date, one Masters thesis has been completed and one PhD dissertation is nearing completion.

Work Plan FY18/FY19

Work on this project was completed during FY17/FY18. No new work is anticipated.

Informational Resources

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

Websites: http://gamut.iutahepscor.org.

High Resolution Remote Sensing of Crop Yields from Fields using Deficit Irrigation for Water Conservation

Principal Investigators:
L. Niel Allen
Alfonso Torres-Rua
Mahyar Aboutalebi (graduate student)

Partners/Collaborators:
- ***Local**: Intermountain Irrigated Pasture Research Farm*
- ***State**: Utah Agriculture Experiment Station*

Project Description:

- **Need and Purpose:**

  Effective water conservation practices are needed to reduce consumptive use so that more water is available to meet increasing water needs. Deficit irrigation practices in agriculture reduce consumptive use, but also decrease yields. Using remotely sensed data obtained with unmanned aerial vehicle platforms, we will be able to estimate the impact of deficit irrigation on crop yield.

- **Benefits to the State:**

  Uncertainty about the effect of climate change on water supplies combined with increased demand for water could result in critical water shortages that could dramatically impact all agricultural, municipal, and environmental users. Current research sponsored by the Utah Agriculture Experiment Station is evaluating water conservation by decreasing consumptive use of water in irrigated fields and pastures. This project utilizes Utah State University's AggieAir™ Unmanned Aerial Vehicle (UAV) program to obtain remote sensing data prior to crop yield sampling and harvest. The aerial imagery will provide data to correlate reduced consumptive water use with effects on crop yield.

- **Geographic Areas:**

  Study Areas: Intermountain Irrigated Pasture Research Farm, (Lewiston) and Panguitch Research Farm, Utah.
  Areas Benefited: Statewide and Western U.S.

- **Accomplishments:**

  Findings: We conducted yield sampling and obtained remote sensing data in June 2017, October 2017, and August 2018 at the Lewiston research site and September 2018 at the Panguitch Research Farm. The experimental design for both study area included five irrigation treatments with four replications on pasture blocks of approximately 0.22 acres plus a buffer area for a total area of about nine acres. One treatment was for full season irrigation, one treatment for no irrigation, and others for different irrigation season shutoff dates (approximately July 1, August 1, and September 1). Three yield samples were harvested from each of the 20 treatment plots. The UAV flew over the entire field prior to each harvest. The data collected included RGB, NIR, and thermal band data at a resolution of 6-inch pixels using fixed wing UAV and 1-inch using a multirotor vertical take-off and landing (VTOL). The precise location of the harvested samples was determined using precision GPS equipment. Also, LAI was measured with a LAI-2200C sensor.

Results: The relationship analysis between possible estimators (multispectral bands and vegetation indices or VIs) versus yield indicated a non-linear function except for Blue (Table 1). Results indicate that all VIs are significantly related to the yield and that RVI is a bit more correlated to crop yield than NDVI and LAI. Among the spectral bands, NIR, Green, and Red are more correlated to the yield, respectively, than Blue. However, the correlation between yield and each of the single bands in the optical wavelength is not as high as for VIs.

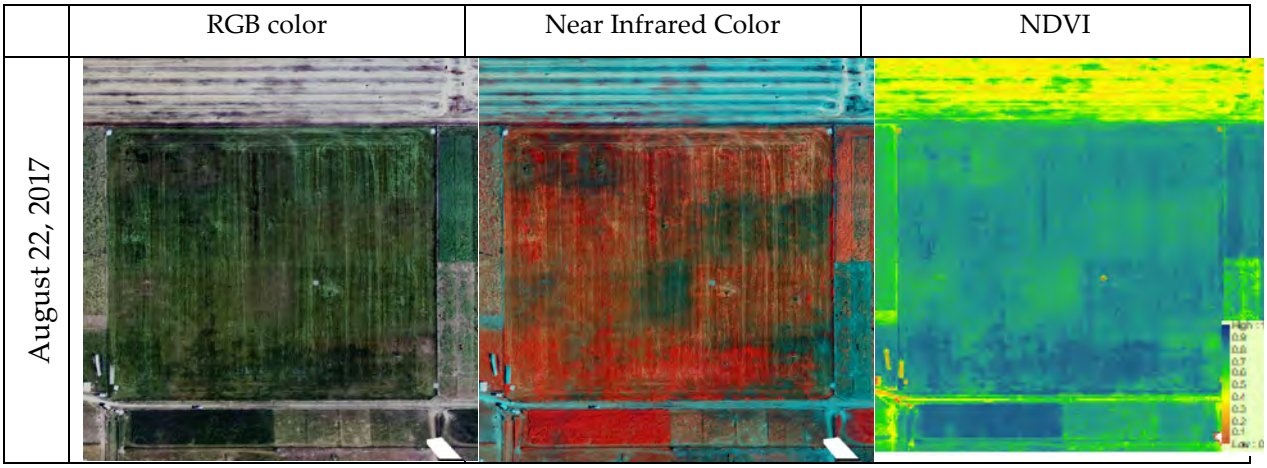


Figure 1. Example of AggieAir UAV imagery and NDVI maps for 2017. Variations in color in the center and right images showing near-infrared color and NDVI (dark patches and light colors, respectively) indicate variations in yield

Work Plan FY18/FY19

Now that UAV imagery collection has concluded, additional statistical analysis on both sites will be performed to integrate the remotely sensed information with other data sources, such as yield measurements, leaf area index, and local weather information. Field and crop irrigation recommendations will be provided in Extension material for producers.

Yield and possible estimators for this study

Name	Trend line type	Correlation Coefficient
Yield-Red	Exponential	0.687
Yield-Blue	Linear	0.450
Yield-Green	Exponential	0.734
Yield-NIR	Power	**0.920**
Yield-NDVI	Power	**0.847**
Yield-LAI	Polynomial	**0.869**
Yield-RVI	Exponential	**0.897**
Yield-Mean of crop height	Linear	**0.840**

Informational Resources

Contact: Dr. L. Niel Allen, (435) 797 3926, n.allen@usu.edu or Dr. Alfonso Torres-Rua, (435) 890 0196, alfonso.torres@usu.edu.

Publications:

Aboutalebi, M., Torres-Rua, A.F. and Allen, N. (2018). Multispectral remote sensing for yield estimation using high-resolution imagery from an unmanned aerial vehicle. In Autonomous Air and Ground Sensing Systems for Agricultural Optimization and Phenotyping III (Vol. 10664, p. 106640K). International Society for Optics and Photonics.

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

Hydraulic and Thermal Characteristics of Habitats and Wetlands in the Lower San Rafael River, Utah

Principal Investigators:
Ian Gowing
Bethany Neilson

Partners/Collaborators:

- ***State**: Dan Keller and Paul Birdsey, Utah Division of Wildlife*
- ***National**: Justin Jimenez, Bureau of Land*

Project Description:

- **Need and Purpose:**

  The purpose of this work has been to investigate Beaver Dam Assist Structures (BDAs) in terms of providing good quality fish habitat for native fish populations throughout the San Rafael River. 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 is examining 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. The Division of Wildlife Resources has conducted fish surveys to investigate and analyze such variables. Temperature sensors were positioned throughout these structures to examine how temperature varies spatially and temporally, especially during critical periods of low flow. Temperature data from these sites is being analyzed alongside longitudinal temperature data being simultaneously collected along 55 miles of the San Rafael to establish if these locations provide more favorable thermal conditions. Collected data will help the researchers to investigate whether these structures reduce the overall incised nature of the river channel. The Division of Wildlife Resources also contracted the AggieAir™ Service Center, to capture high-resolution aerial imagery of a wetland complex just upstream of Cottonwood Wash that may act as a fish barrier and prevent fish migration.

- **Benefits to the State:**

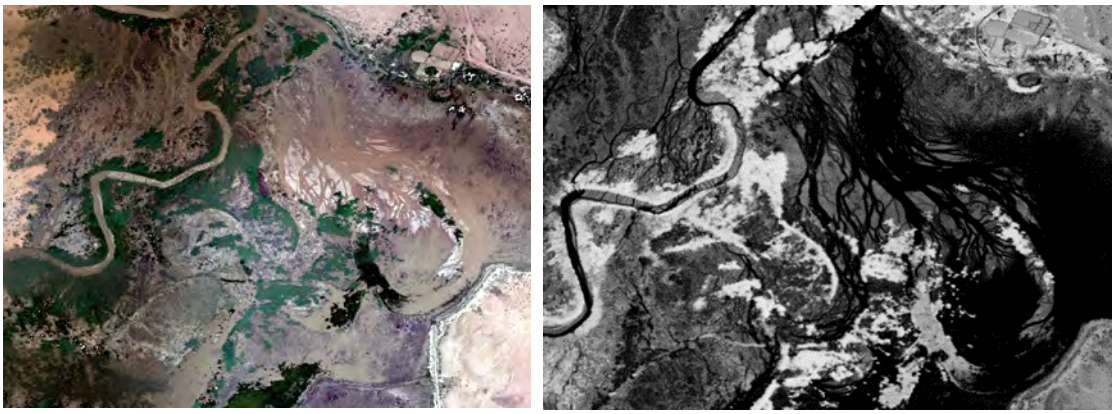
  The San Rafael River is recognized as being in a severely degraded condition and is on the 303D list of degraded waters in the State of Utah. With the implementation of this River restoration scheme, we anticipate (1) restoring the river to a more ecologically acceptable state, (2) providing more comprehensive complex habitat for the native fish, (3) encouraging changes in channel morphology by removing Tamarisk, (4) planting more native riparian species along the river corridor, and (5) removing of man-made barriers to enhance and encourage fish movement/passage throughout the entire drainage.

- **Geographic Areas:**

  Study Areas: San Rafael River, Emery County, Utah.
  Areas Benefited: Emery County and statewide where river restoration projects are being implemented.

- **Accomplishments:**

  Findings: Fieldwork and monitoring in and around the Beaver dam structures were completed April/May 2017. Analysis on the data will continue through to December 2018 when a final report will be produced. The first UAV flight over the San Rafael wetland complex took place June 2017.



AggieAir™ visual color and near infrared aerial imagery of the wetland complex on the San Rafael River, flown June 2017

Results: Preliminary data analysis on data collected in and around the beaver dam structures is on-going and will continue through the end 2018. Imagery from the first AggieAir™ UAV flight is being processed and orthorectified.

Work Plan FY18/FY19

Data analysis will continue through the end 2018. Discussions with UDWR are underway to determine the timing of the second AggieAir™ UAV flight. We anticipate that DWR will use this imagery to assess the effects of high spring flows on the main channel and to assess fish habitat.

Informational Resources

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

Impacts of Climate Variability on Cattle and Hay Production in the Upper Colorado River Basin

Principal Investigators:
L. Niel Allen
David E. Rosenberg
Hadia Akbar (students)

Partners/Collaborators:

- ***Local**: Agriculture Producers in the Colorado River Basin of Utah*
- ***State/National**: Upper Colorado River Commission*

Project Description:

- **Need and Purpose:**

  Recent climate data indicate that the Colorado River Basin is shifting towards a drier and warmer climate. The purpose of this project is to determine effects of such changes in precipitation and temperature on hay and cattle production by studying climate indices and key agriculture production indicators over the last three decades (at the county level) in Utah's Upper Colorado River Basin (UCRB).

- **Benefits to the State:**

  Uncertainty about the effect of climate change on water supplies combined with increased demand for water could result in critical water shortages. This could dramatically affect agricultural, municipal, and environmental water users in the UCRB. Understanding the impact of historical dry years on agriculture production in the UCRB will help the state prepare for and mitigate the consequences of dry years in the future.

- **Geographic Areas:**

  Study Areas: Upper Colorado River in Utah (10 counties).
  Areas Benefited: Statewide.

- **Accomplishments:**

  Findings: At the county level, we use 16 annual climate extreme indices, based on daily temperature and precipitation (such as consecutive dry days, warm spell duration, diurnal temperature range, precipitation events, etc.), and along with other data to determine effects on hay acreage and yield and the number of cattle produced. We use a bottom up approach where relationships between derived climate extreme indices and the production of hay and cattle are tested using Random Forest (RF) regression. The importance ranking of the 16 indices tested in RF is used to identify the most important climate extremes and other parameters effecting hay and cattle production.

Results: At this phase of the study, results suggest that climate variables, such as the number of days of precipitation, length of the dry spell, days of temperature below freezing, total precipitation, or the number of consecutive warm days, have little effect on cattle or hay production (Table 1). The variable that most affects cattle production is acres of hay harvested. Table 1 shows the variables or annual climate indices ranked in the order that they influence cattle production in the region. The percent increase in the mean square error of model is a measure of influence when the corresponding variable is removed in RF regression. For example, the mean square error of predicted values (low values indicate a good prediction) is about 19% higher when acres harvested is not used. We are also exploring other climate and economic influences such as water storage, irrigation depletion, and price of cattle.

Work Plan FY18/FY19

Ongoing efforts will test additional variables and model formulations to determine if agriculture production can be predicted by climate variables.

Table 1. Variables/annual climate indices ranked in the order that they have influence on the cattle production in the region.

Variable or annual climate indices	Rank of influence	Mean square error (%) increase without variable
Acres harvested	1	18.88
Annual sum of precipitation in days where daily precipitation exceeds the 95th percentile of daily precipitation in the base period.	2	4.39
Length of dry spell each year (consecutive dry days)	3	3.89
Alfalfa Yield	4	2.60
Annual count of day when maximum temperature is below freezing	5	2.26
Annual growing season length in days	6	1.99
Annual total precipitation	7	0.78
Annual count of warm spell days (6 more consecutive day above 90^{th} percentile baseline maximum temperature).	8	0.62

Informational Resources

Contact: Dr. L. Niel Allen, Phone: (435) 797 3926, E-mail: n.allen@usu.edu or David E. Rosenberg, Phone: (435) 797-9689, E-mail: david.rosenberg@usu.edu.

Publications:
Website: http://extension.usu.edu/irrigation/ and https://uwrl.usu.edu/people/faculty/rosenberg-david.

Mapping Subsurface Tile Drainage Systems with Unmanned Aerial Vehicles (UAVs)

Principal Investigators:
Ruijie Zeng
L. Niel Allen
Alfonso Torres-Rua
Rui Gao (graduate student)

Partners/Collaborators:

- ***Local**: Bracken Henderson, Northern Utah Conservation District*

Project Description:

- **Need and Purpose:**

  Subsurface tile drainage systems are commonly used in irrigated areas with a high groundwater table to remove excess water from soil. In addition to increasing crop yields and reducing yield variability, tile drainage systems also change the surface and subsurface hydrologic characteristics of the site. Nitrates and other chemicals leached from soils become concentrated at drain outlets, and these higher levels of nonpoint source pollutants degrade the downstream water quality.

  In order to reduce the effect of agricultural water use on downstream water quality, we need a more detailed evaluation of current drainage systems. Unfortunately, the information for subsurface drain locations is usually missing or incomplete. This project will collect high-resolution remote-sensing images using unmanned aerial vehicles. By analyzing the spatial heterogeneity of the topsoil caused by drainage, we can determine the location of drainage systems. Such information will then be used to design improvements and more effectively manage drainage systems in irrigated agriculture.

- **Benefits to the State:**

  The largest irrigation water diversions from the Bear River are in Box Elder County. Subsurface drainage systems have been installed to drain the fields due to the flat terrain and high groundwater water table along the hills. Most of the fields grow alfalfa as the main crop. This perennial land cover crop makes it unsuitable for drainage detection since the crops cover the soil over the entire year. However, the main crops in the Bear River City area are vegetables harvested annually. During the non-growing season when the top soil is exposed, the remote-sensing platform can capture the spatial heterogeneity of topsoil moisture. In addition, drainage systems installed 4–5 years ago have good digital records that can be used to validate the image detection results. This will aid in the identification of subsurface drains where records are missing.

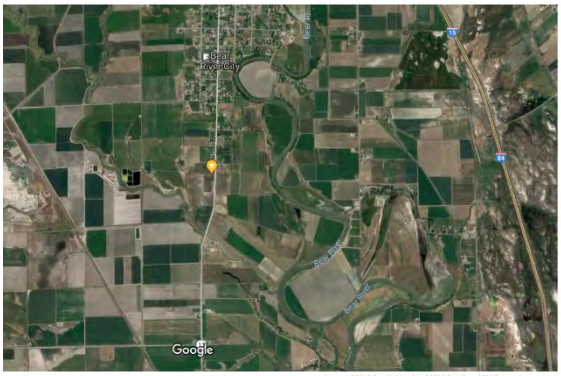
  A more complete mapping of subsurface drainage systems will provide a better understanding of groundwater-streamflow interactions in the lower Bear River. In addition, the study will provide the foundation for assessing the impact of subsurface tile drain systems on hydrologic and water quality changes, and serve as a basis for better managing agricultural drainage at farm and watershed scales.

- **Geographic Areas:**

  Study Areas: This project focuses on the agricultural drainage from farms in Bear River City area of Box Elder County, Utah.
  Areas Benefited: The area directly benefited is irrigated agriculture and Bear River water quality in Box Elder County. The results will be applicable to irrigated agriculture and stream water quality throughout Utah and the Intermountain West.

- **Accomplishments:**

  Findings/Results: So far this year, we have identified and selected the project sites and contacted the landowners. The actual drainage location records have been obtained from Bear River City.



Domain of fields on Bear River City with subsurface drainage systems (left); and onion fields with drip irrigation system and subsurface drainage after harvest (right)

Work Plan FY18/FY19

Oct. 2018–Apr. 2019: The first AggieAir flight will be around the first week of October after the vegetables and grains are harvested and before the winter wheat germinates. We will match the existing drainage records with the thermal images.

Apr. 2019: The second AggieAir flight will take place after the farms grow the early crops. We will examine how drainage systems change the soil moisture after a precipitation event.

May 2019: The third AggieAir flight will take place around late May when irrigation is applied to the fields. Since the fields have both flood irrigation and drip irrigation systems, we will capture how drainage systems respond to different irrigation practices.

Jun. 2019–August 2019: We will process and compare the images from AggiesAir taken under different land surface and water conditions to evaluate their effectiveness in detecting subsurface drainage systems.

Informational Resources

Contact: Dr. Ruijie Zeng, Phone: (435) 797 4147, E-mail: ruijie.zeng@usu.edu.

Websites: AggieAir remote-sensing platform at (https://aggieair.usu.edu/).
Drainage images will be located at Hydroshare (https://www.hydroshare.org/).

Metering Non-Residential Water Users to Identify Conservation Opportunities

Investigators:
David E. Rosenberg
Jeffery Horsburgh
Nour Atallah (Graduate student)

Partners/Collaborators:
- ***Local:*** *Jed Olson, Logan City; Cameron Draney, Logan City; Paul Lindhardt, Logan City; Mark Nielsen, Logan City; Tyson Griffin, Logan City; James Geier, Logan City*

Project Description

- **Need and Purpose:**

  Nearly all urban water use monitoring, modeling, and conservation research has focused on a large but relatively homogenous group of residential water users. Non-residential business and commercial establishments, industries, and institutions also use significant volumes of water. However, the diversity of non-residential uses has made them difficult to monitor and study due to their varying types of water uses in terms of the amount, timing, location and other factors. Newer "smart" meters can now measure and record water use at very high temporal frequency. In this project, we are using smart meters to determine total water use, timing, and the component end uses to better understand current water use practices in non-residential user groups. With these better data records, we can identify water-saving opportunities that will help meet Utah's water conservation goals.

- **Benefits to the State:**

  The principal benefits to the state are to (1) expand current water metering methods, enhance existing monitoring data, and estimate peak demand and the timing of demands for commercial/industrial users, (2) demonstrate and test methods for identifying opportunities for conservation, and (3) quantify the effects of any conservation activities undertaken by our partners in their efforts to help the State meet its overall water conservation goals. In addition, the data collected could help the Utah Division of Drinking Water update its Minimum Sizing Requirements for public water systems (R309-510) for any of the non-residential establishments considered.

- **Geographic Areas:**

  Study Area: Logan City, Cache County, Utah.
  Areas Benefited: Logan City and other municipal water providers throughout Utah.

- **Accomplishments:**

  Findings and Results:

  - To date, we have recorded water use at 5-second and 5-minute frequencies for up to 10 months at four manufacturing and two assisted-care facilities in Logan, Utah.
  - We have developed an algorithm to process the 5-second water use traces and classify multiple indoor, process, and outdoor end uses of water and identify their volumes, timings, durations, and frequencies (Figure 1).
  - We have shared observations and results with facility and Logan City managers and used discussions to validate observations and improve the classification algorithm.

- Except for October, businesses apply water to their landscapes at rates of 1.4x to 5x the landscape water need.
- Shower flow rates for manufacturing facilities often exceed the U.S. Energy policy act standard of 2.5 gallons per minute whereas shower flow rates for assisted care facilities meet the standard (Figure 2).
- Summertime peak water use occurs in nighttime hours when facilities irrigate their landscaping (Figure 3).
- Per person water use by assisted care facilities is at or slightly above the Utah average for indoor use of 62 gallons per capita per day. In contrast, manufacturing use is at or below the Utah level of 12 gallons per employee per day.

Work Plan FY18/FY19

- Finalize results and submit MS thesis and journal article.
- Publish anonymized results in an open data repository.
- Use results in follow-up smart data for smart modeling work.

Informational Resources

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

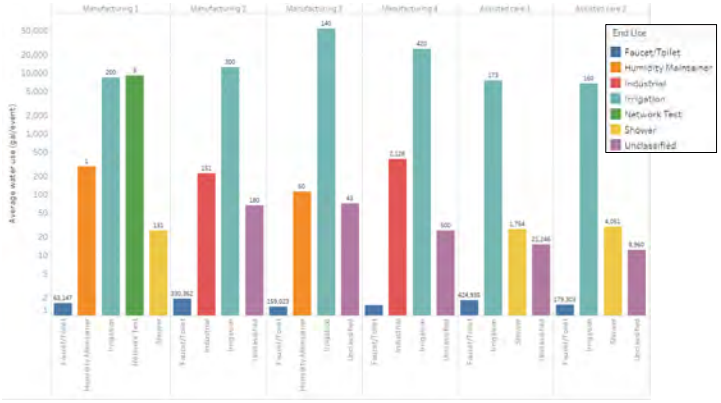


Figure 1. Volume of non-residential water use by business and end uses. Numbers above bars indicate number of events

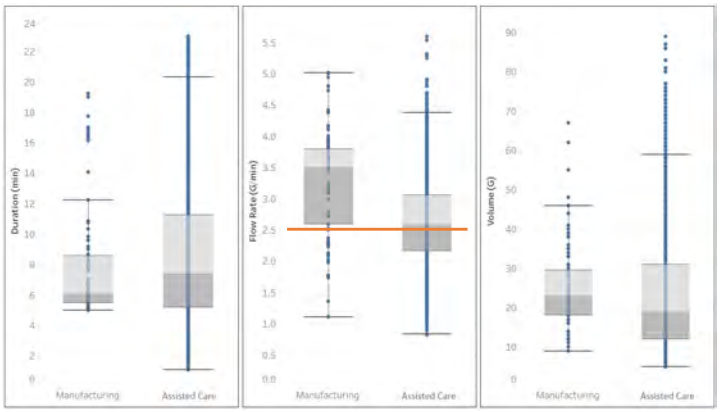


Figure 2. Distributions of duration, flow rate, and volume of shower events by business type. Orange line shows 2.5 gal/min flow rate mandated by U.S. Energy Policy Act

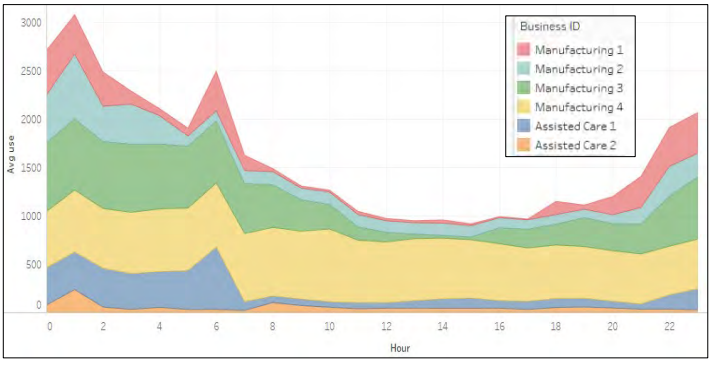


Figure 3. Summer water use by hour of the day

OpenET Upper Colorado River Basin

Principal Investigators:
Alfonso Torres-Rua
L. Niel Allen

Partners/Collaborators:

- ***State/National**: UT, WY, AZ, NM, NV Divisions of Water Resources, Nevada Desert Research Institute*
- ***Federal**: NASA, US Bureau of Reclamation*
- ***Business/Industry**: Environmental Defense Group, Habitat Seven, Google, World Bank*

Project Description:

- **Need and Purpose:**

  Currently, Western states water agencies incorporate research from academia to enhance and extend monitoring of water use in agriculture. Recent advances in measuring plant water use are based heavily on satellite data and modeling efforts. These advances have matured to the point that they can now be implemented by private water users or state agencies for managing irrigation water use. Nevertheless, the actual operational costs for maintaining, processing, archiving and accessing satellite derived data is significant, and even more so for pasture and hay crops (most of Utah).

  With funds from NASA and private organizations, and with technical support from Google, a large-scale project called OpenET (www.etdata.org) was launched in 2017 to provide every Western state free access to plant water use information. It incorporates the latest advances in water use information for agricultural lands, and is expected to be completed in 2020. Under the current project implementation, different water related organizations in different geographical locations, including the Great Basin and the Upper Colorado River Basin, will maintain communication to improve, refine and tailor the products.

  The UWRL's has strong and unique capabilities in remote sensing, satellite, and aerial image data processing, large data base management, irrigation systems control, operation and management, and modeling of crop water demand and productivity in agricultural systems. Consequently, UWRL will be a key participant in the OpenET project.

- **Benefits to the State:**

  By having free, unrestricted access to historical and forecasted crop water use at farm scale, Utah irrigators, canal water companies, state agencies, academia, industry and others can incorporate this information in their decision-making activities, be better informed, and track impact from changes in weather seasonality and longer period changes, such as droughts.

- **Geographic Areas:**

  Study Areas: Upper Colorado River Basin and Great Basin.
  Areas Benefited: Utah, Western States.

- **Accomplishments:**

  Findings/Results: The project is only in the initial stages, with no results as yet.

Work Plan FY18/FY19

Investigators will participate in the upcoming meetings with OpenET for the Upper Colorado River Basin to determine data characteristics and information needs.

Informational Resources

Contact: Dr. Alfonso Torres-Rua, Phone: (435) 797 0397, E-mail: a.torres@aggiemail.usu.edu.

Website: OpenET project at https://etdata.org/.

Organizing and Synthesizing Water Management Data to Support Modeling

Investigators:
David E. Rosenberg
Adel Abdallah (Student)

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*
- ***U.S.:*** *David Rheinheimer, University of Massachusetts, Amherst*
- ***International:*** *Julien Harou, Stephen Knox, University of Manchester*

Project Description

- **Need and Purpose:**

  Modeling of complex water systems requires multi-disciplinary hydrologic, ecologic, economic, operation, engineered infrastructure, network connectivity, and other data. These data reside in different places, are managed by different entities, vary in space and time, and use different formats (e.g., shapefile, text files), data types (e.g., time series, parameters, text), and terminology (e.g., dam vs. reservoir). Water managers and scientists, therefore, spend considerable time gathering and organizing data before they can run a model or conduct an analysis. Thus, a persistent informatics method is needed to organize and integrate diverse water resources data.

- **Benefits to the State:**

  This project develops an easy-to-use informatics tool to organize, compare, and synthesize diverse water resources data. Use of the tool will decrease the time water managers, scientists, and engineers spend gathering and interpreting water management data and increase the time they spend modeling, analyzing, and managing their water systems. The tool will also allow managers and engineers to (1) more quickly interpret water resources data correctly, (2) use the same data to develop and run multiple models in the same study area and compare results, and (3) archive results from one model for reuse as input to other models to identify the integrated effects of coupled human-hydrologic components of our water systems.

- **Geographic Areas:**

  Study Area: Utah's Cache, Box Elder, Rich, and Salt Lake Counties.
  Areas Benefited: Water managers and researchers statewide in all counties.

- **Accomplishments:**

  Findings and Results:

  We developed the Water Management Data Management system (WaMDaM) and supporting software tools to allow users to more easily interact with the data system.

  - We loaded 13 national, state, and local data sources for the Bear River basin into the system (Figure 1). These data sources have different spatial and temporal coverages.
  - Data queries show six data sources can be used to expand an existing Water Evaluation and Planning (WEAP) model for the Bear River to the Idaho and Wyoming portions of the basin.

- Further queries identify differences in network connectivity among models, stream flow values, water demand, reservoir storage-elevation curves (Figure 2), and model scenarios.
- Auto-serving query data to a WEAP model for the Bear River shows deliveries and unmet demand at the Bear River Migratory Bird Refuge are more sensitive to changes in streamflow at Stewart dam, Idaho and Cache County agricultural demand than Hyrum Reservoir volume-elevation relationships (Figure 3).
- An interactive Jupyter notebook allows users to replicate results.

Work Plan FY18/FY19

- Build a software ecosystem that allows WaMDaM users to connect with other open-source tools to visualize network data and publish model data as a Hydroshare repository.
- Extend WaM-DaM to export loaded data in the format needed to run other models. Use the exporter to run and compare results of two models for the same location.

Informational Resources

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

Website: https://wamdam.org/
Website: https://github.com/WamdamProject/WaMDaM_JupyterNotebooks

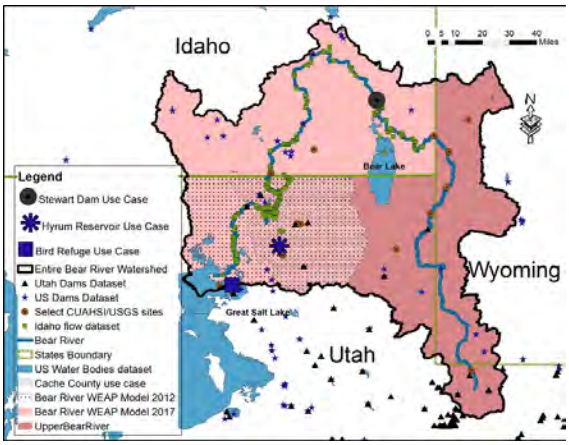


Figure 1. Spatial availability of 13 datasets for the Bear River basin loaded into WaMDaM

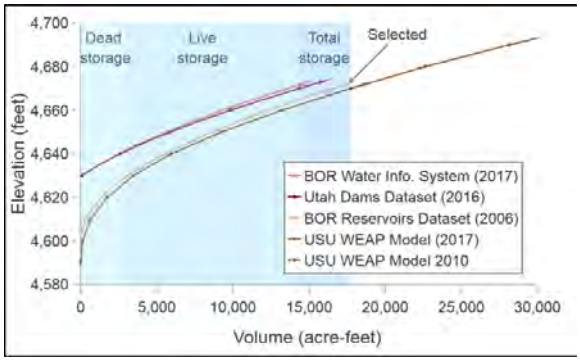


Figure 2. Differences among five datasets in elevation-volume bathymetry data for Hyrum Reservoir.

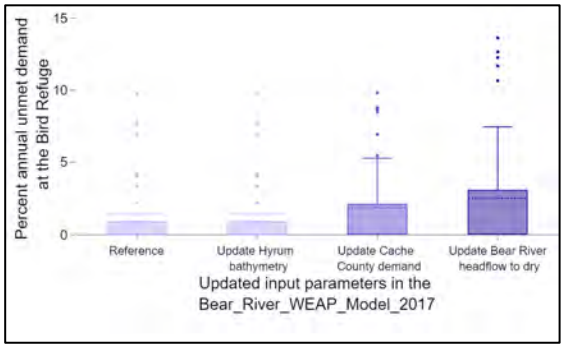


Figure 3. Sensitivity of WEAP model annual unmet demand at the Bear River Migratory Bird Refuge, Utah, over the simulation period 1966–2006 to queried data.

UAV Remote Sensing Service Center

Principal Investigators:
Ian Gowing
Cal Coopmans
Nathan Hoffer
Mac McKee

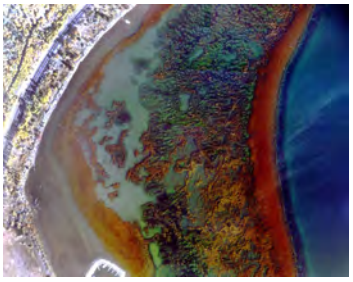
Partners/Collaborators:
Various end-users in Utah

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, and are not updated frequently enough to be useful for many applications. Our small unmanned aerial vehicles (sUAVs), developed at the Utah Water Research Laboratory (UWRL) and collectively called AggieAir™, overcomes these deficiencies by providing low-cost, high-resolution multispectral aerial imagery and other remote sensing data quickly and frequently. The AggieAir research group has created stable and robust platforms and highly flexible payloads. Since no runway is needed for takeoff and landing, AggieAir platforms can deploy almost anywhere. The payload sensor systems collect valuable data for a variety of applications and research: agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, fish and wildlife tracking, air quality monitoring, and many others.

  The funds generated from these applications support continued AggieAir research and development. The AggieAir Service Center (AASC) at the UWRL (see http://AggieAir.usu.edu) handles operational and maintenance needs so that R&D work can progress effectively and efficiently. Feedback from the AASC also helps steer future AggieAir activities in directions that are most beneficial.



AggieAir imagery capturing data about submerged vegetation in Fish Lake

- **Benefits to the State:**

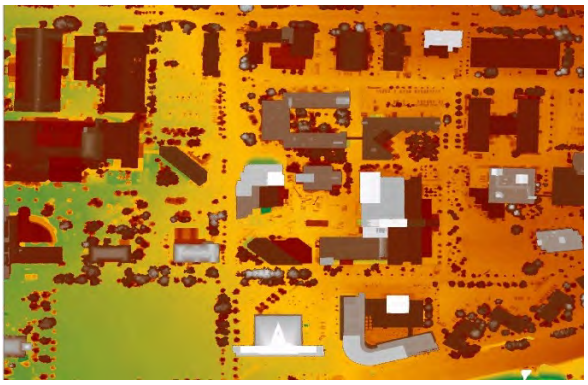
  The AASC provides data that helps to save water and better manage state environmental resources. The Center supports research that develops cost-effective capabilities for mapping water consumption and soil moisture to help farmers irrigate their crops more efficiently and gathers the necessary data for canal operators to manage water diversions more effectively. AggieAir UAV's can also survey roads before, during, and after construction, monitor the quality of the asphalt, and update road inventory information, such as number of lanes, signs, and culvert crossings. Research supported this year has resulted in software that automatically identifies cracks in concrete, thus greatly reducing the personnel time needed for road inspection. UAV's can obtain current data for wetlands managers on plant species distribution and can monitor the success of management practices to control invasive plants. Resources managers responsible for monitoring and managing water quality can get accurate, high-resolution thermal images that show temperature distributions along all reaches of a stream or river.

  In the long term, the AASC is the first step toward a new business that will be based around the AggieAir UAV platform. The Center allows us to test business models and gain the experience necessary to transition to a viable industry. As such, the service center will directly and indirectly provide new jobs and economic growth to Utah.

- **Geographic Areas:**

  Study Area: Statewide.
  Areas Benefited: Statewide.

- **Accomplishments:**



Digital Elevation Model of the USU Logan Campus

Findings/Results: This project has developed and fully equipped the AASC at the UWRL. The AASC supports the AggieAir UAV platforms and sensors in providing aerial images for various research projects that benefit from remote sensing data (examples show maps generated by AggieAir). Water, agriculture, environmental, and infrastructure management problems can benefit from imagery analysis in a broad range of situations.

The AASC developed user manuals to train those who have purchased UAVs from USU. Organizations including Oklahoma State University, UC Merced, and Texas State University have purchased AggieAir aircraft and technology to use for their own remote sensing purposes. 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.

This year, the AASC has supported a very large number of flights deployed for a wide array of resources management problems in Utah and several other states. Examples include gathering and processing remote sensing data on San Rafael River flow and riparian conditions; river corridor mapping of several streams in south-central Utah to address habitat questions in support of the Utah Division of Wildlife Resources; thermal mapping of the USU main campus in support of university energy efficiency programs; conducting flights over Scofield Reservoir near Price, Utah, to explore the possibility of identifying harmful algae blooms that threaten water supplies and recreational resources; and many others. The AASC has supported work to improve monitoring of watershed recovery investments and increase our understanding of ozone sources and concentrations along the Wasatch Front, including the Great Salt Lake's influence on ozone. AASC personnel continued to work in collaboration with Box Elder County, Tooele County, Northrup-Grumman, and the Governor's Office of Economic Development to develop a UAV test facility in Utah.

The FAA granted several Certificates of Authorization (COA) to the AASC in the past year that certify the AggieAir platform's airworthiness and authorize its use subject to FAA rules. New payloads developed this year include a broader array of sensors that ensure the highest level of scientific quality data. A new airframe (BluJay) is now being integrated into the AggieAir fleet. Its capability is superior to all other small UAVs now being sold anywhere in the world.

Work Plan FY18/FY19

Build the AASC business base by expanding the number of research contracts.

Informational Resources

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

Water Management in the Event of Recurring Long-Term Historical Droughts

Investigators:
David E. Rosenberg
Tammy Rittenour
James Stagge

Partners/Collaborators:
- ***Local:*** *Derek Johnson, Weber Basin Water Conservancy District; Darren Hess, Weber Basin Water Conservancy District; Chris Slater, JUB Engineers, Josh King,*
- ***State:*** *Candice Hasenyager, Utah Division of Water Resources; Scott McGettigan, Utah Division of Water Resources*
- ***Federal:*** *Justin DeRose, U.S. Forest Service*
- ***Business/Commercial:*** *Eve Davies, PacifiCorp; Con Baldwin, PacifiCorp; Greg Hansen, Hansen and Associates; Seth Arens, Western Water Assessment*

Project Description

- **Need and Purpose:**

  New data for annual climate and streamflow series dating back 1,200 years have been reconstructed from tree rings. These data provide water managers with a sense of the magnitude, frequency, and duration of extreme events that we face today or in the future. At present, reconstructed time series of annual flows have limited spatial coverage to only one stream flow value per year. They are also not well integrated into water systems models or drought planning efforts, specifically because of the spatial and time limitations. To make use of these long, valuable records, water managers need streamflow estimates at higher spatial and temporal resolutions. This project is producing monthly flow reconstructions from existing annual reconstructions derived from tree ring data that date back to the year 1605 AD on the Logan River, 1430 AD on Weber River at Oakley, and 800 AD at the uppermost Bear River gage on the Utah-Wyoming border. We have incorporated these flows into a Utah Division of Water Resources (UDWR) model for the Weber Basin Water Conservancy District (WBWCD) to identify impacts of paleo, observed, and future droughts should they re-occur in the near future.

- **Benefits to the State:**

  The project is benefitting Utah in several ways: (1) better quantify historic droughts, (2) compare drought susceptibility under historic, observed, and future forecasted climate, and (3) extend an existing water simulation model for the Lower Bear River (Utah) to include Idaho and Bear Lake.

- **Geographic Areas:**

  Study Area: Bear River and Weber River basins; Rich, Cache, Weber, Morgan, Summit, Davis, and Box Elder Counties, Utah.
  Areas Benefited: Weber River and Bear River basins and other basins throughout Utah for which tree ring, reconstructed flows, and water systems data are available.

- **Findings and Results:**

  - We simulated reservoir levels and deliveries through droughts during the paleo, observed, and future climate periods and found that droughts longer than 3 years in duration lower reservoir storage the most (Figure 1).

- While droughts in the 1500s, 1580s, 1630s, 1640s, 1930s, and 1960s AD would draw down the present-day reservoir system to severe or extreme levels, droughts in a future hot-dry climate would be more extreme (Figure 2).
- Extended a Water Evaluation and Planning (WEAP) model for the lower Bear River (Utah portion) derived from a UDWR 2010 Bearsim model to include more irrigation and urban demand sites in Cache County, irrigation demands in Idaho, and Bear Lake.
- Presented drought work at the European Geophysical Union conference (April 2018).

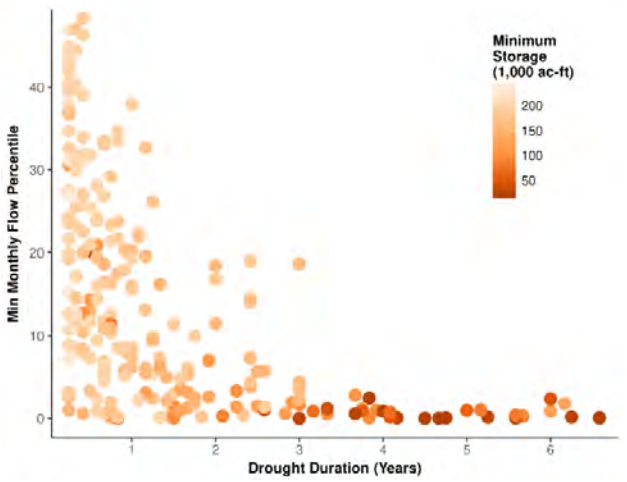


Figure 1. Minimum flow, duration, and minimum total Weber Basin reservoir storage for droughts between 1430 and 2006 AD

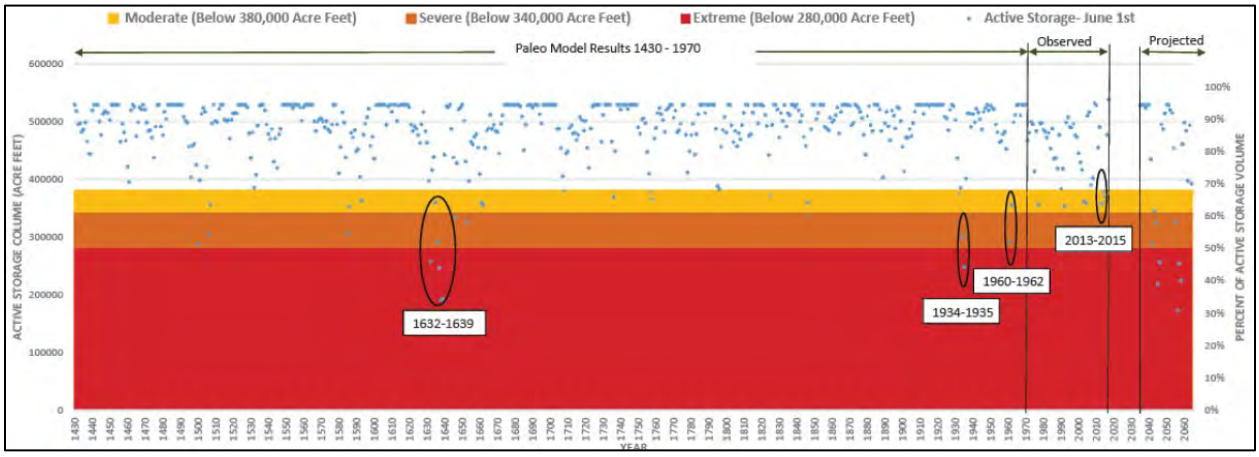


Figure 2. Simulated Weber Basin reservoir storage over paleo, observed, and projected future (hot/dry) periods. Yellow, orange, and red shading indicates drought trigger levels

Work Plan FY18/FY19

- Validate WEAP model for the Bear River. Improve representation of reach gains/losses, return flows, Cutler reservoir storage-elevation data, and urban water uses for Box Elder County. Also, add urban water uses for Idaho and add stream gaging stations in South Cache County.
- Start a new project with WBWCD to identify vulnerability of the Weber Basin water system to factors like monthly paleo drought flows (reconstructed from tree rings), population growth, per-capita water use, reservoir evaporation, landscape evapotranspiration, and system management.

Informational Resources

Contact: Dr. David E. Rosenberg, Phone (435) 797 8689, E-mail: david.rosenberg@usu.edu.
Website: http://www.paleoflow.org
Software: paleoAPR package. https://github.com/jstagge/paleoAPR

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 T. 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, Business Office Manager
Carri Richards, Public Relations Specialist
Jan S. Urroz, Administrative Supervisor

Utah Water Research Laboratory Faculty

Mac McKee, PhD, Director UWRL/UCWRR; Professor, CEE/UWRL
Niel Allen, PhD, Associate Professor, CEE/UWRL
Steven L. Barfuss, MS, Research Associate Professor, CEE/UWRL
Brian Crookston, PhD, Assistant Professor, CEE/UWRL
William J. Doucette, PhD, Associate Director, UWRL/UCWRR; Professor, CEE/UWRL
R. Ryan Dupont, PhD, 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 Dean, College of Engineering
Belize Lane, PhD, Assistant Professor, CEE/UWRL
Randal S. Martin, PhD, Research Associate Professor, CEE/UWRL
Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
Joan E. McLean, MS, Research Professor, CEE/UWRL
Laurie S. McNeill, PhD, Professor, CEE/UWRL
Bethany T. Neilson, PhD, Assistant Director, UWRL/UCWRR; Associate Professor, CEE/UWRL
Richard C. Peralta, PhD, Professor, CEE/UWRL
David E. Rosenberg, Ph.D., Associate Professor, CEE/UWRL
Zac Sharp, Ph.D., Research Assistant Professor, CEE/UWRL
Judith L. Sims, MS, Research Associate Professor, BE/UWRL
Ronald C. Sims, PhD, Professor, BE/UWRL
David K. Stevens, PhD, Professor, Head of Environmental Engineering Division, CEE/UWRL
David G. Tarboton, PhD, Professor, CEE/UWRL
Alfonso Torres-Rua, PhD, Assistant Professor, CEE/UWRL
Blake P. Tullis, PhD, Associate Director, UWRL/UCWRR; Professor, CEE/UWRL;
Head of Water Engineering Division, CEE/UWRL
Tianfang Xu, PhD, Research Assistant Professor, CEE/UWRL
Ruijie Zeng, PhD, Assistant Professor. CEE/UWRL
Anhong Zhou, PhD, Associate Professor, BE/UWRL

Research Faculty, Professional, and Support Staff

Utah Water Research Laboratory Staff

Leila Ahmadi, PhD, Postdoctoral Fellow
Scott Black, BS, Sr. Analyst Programmer
Marianne Brown, Staff Assistant
Tracy Brown, MS, Business Office Manager
Caleb Amoa Buahin, Postdoctoral Researcher
Hunter L Buxton, AggieAir Lead Safety Pilot
Mark Cannon, BS, Research Engineer
Andrea Carroll, Accounting Technician
Brittanie Carter, BS, Coordinator of PR and Marketing
Peg Cashell, MS, Soil Scientist
Cal Coopmans, PhD, Research Assistant Professor
Pabitra Dash, PhD, Programmer/Analyst Sr.
Maria Gates, BS, Business Officer III
Ian Gowing, BS, Research Engineer
Tessa Guy, BS, Research Assistant I
R. Ivonne Harris, MS, Publications Specialist
Joshua Hortin, MS, Researcher II
Fengwei Hung, PhD, Postdoctoral Researcher II
Richard Jex, Research Assistant
Amber Jones, MS, Research Engineer
Andrew Lee, Engineering Technician
Barbara Madsen, Office Assistant
Milada Majerova, PhD, Researcher
Jessica Powell, Accounting Assistant
Carri Richards, BS, Public Relations Specialist
Daniel Robinson, Aviation Technician
Patrick Strong, BS, Research Engineer I
Shannon Syrstad, MS, Research Engineer
Chad Taylor, Engineering Technician
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
NeCole Walton, BS, Accountant
Mindy Whiteley, BS, Staff Assistant/Receptionist
Mark Winkelaar, BS, Research Engineer

Adjunct Appointments and Emeriti Faculty

Lloyd Austin, MS, Adjunct Professor, CEE/UWRL/Utah Department of Natural Resources
Jay M. Bagley, PhD, Professor Emeritus, CEE/UWRL
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
William J. Rahmeyer, PhD, Professor Emeritus, CEE/UWRL
J. Paul Riley, PhD, Professor Emeritus, CEE/UWRL
Darwin L. Sorensen, PhD, Research Professor Emeritus, BE/CEE/UWRL
Norman E. Stauffer, PhD, Adjunct Professor, CEE/Utah Department of Natural Resources
J. Paul Tullis, PhD, Professor Emeritus, USU Foundation, CEE/UWRL
Wynn Walker, PhD, Professor Emeritus, CEE/UWRL