FY 2022-23
Mineral Lease Fund Report

Utah Water Research Laboratory

for

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

by

David G. Tarboton, Director

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

Submitted January 2024

Utah Water Research Laboratory
UtahStateUniversity

Foreword

Water is a precious and scarce resource, and ongoing research to understand and manage the many issues associated with providing safe water for drinking, ensuring sufficient water for irrigation, municipalities, industries, and the environment, and enabling economic development is critical to helping Utah achieve a sustainable water and environmental future. This report describes the work funded by Mineral Lease funds (MLF) during fiscal year 2022–23 (FY 23) at the Utah Water Research Laboratory (UWRL) in pursuit of its mission to conduct collaborative water and environmental research to advance innovative solutions, promote scientifically informed policy and management decisions, and train tomorrow's leaders. The projects described in this report focus on cutting-edge research to find practical solutions to some of the most pressing water-related problems facing Utah. The research ongoing at the UWRL includes work on innovative sensing to measure and manage flows and water use, assess water and air quality, identify emerging threats (e.g., from cyanotoxins, microplastics, and invasive species) and research ways to address them. UWRL researchers are part of the Great Salt Lake Strike Team, a partnership with the University of Utah and State agencies, formed to recommend policies and solutions to the crisis of low Great Salt Lake (GSL) levels that threaten Utah's economy and environment. Current research reported herein addresses exchanges of salt through the GSL causeway, understanding of which is critical to managing salinity at current lake levels. Other projects address lake stream inflow requirements and the conservation needed to fill the lake to target levels for a range of planning periods. The Logan River Observatory serves as a microcosm for understanding the watershed processes that produce the runoff in western watersheds including the GSL basin. Beyond the GSL, the entire western US remains in the grip of a severe and sustained drought. The exceptionally wet water year of 2023 has mitigated the effects somewhat, but shortages persist. Ongoing research reported here is advancing hydrology scenarios for Colorado River Basin planning and adapting operations to accommodate low flows and storage.

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, the UWRL is able to leverage significant funding from other public and private sources to enhance the scope and impact of our projects. Over $5.8 million in project funding from other sources in FY 23 has provided 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 first, most respected, and unique university-based water research facilities, the UWRL provides data, tools, and solutions to better manage and use Utah's limited water and land resources. We look forward to many more decades of service to 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 MLF-supported active research, training, and service projects over the past fiscal year, along with an accounting of the ML funds for FY 23, budgeted expenditures for FY 24, and planned expenditures for FY 25. 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.

The UWRL is pleased to submit this year's report to the Legislature through the Office of the Legislative Fiscal Analyst. We welcome any comments or questions.

David Tarboton, UWRL Director

TABLE OF CONTENTS

Section 1

Introduction

[Intentionally Blank]

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 first 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 work toward a sustainable water future, it is essential to recognize 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 following several decades, water resources 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. The following year, 1964, Congress approved the Water Resources Research Act that created a water resources 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 resources research institutes.

With USU already acknowledged as world leader in water engineering, the opening of the new Utah Water Research Laboratory building in 1965 provided the State and the university 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 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 58 years has allowed the UWRL to have a significant state, national, and worldwide impact in water resources research and applications.

Productivity

UWRL faculty leverage their expertise by collaborating 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 have served on numerous state, national, and international engineering and science panels and committees.

In addition to our research role, the UWRL is involved in university graduate and undergraduate education through the inclusion of students in hands-on projects, part-time employment, and research assistantships. Graduate student involvement in research leading to masters and doctoral degrees prepares them to enter the workforce as trained water professionals. Undergraduate students involved in UWRL research projects gain skills and experience for their future careers.

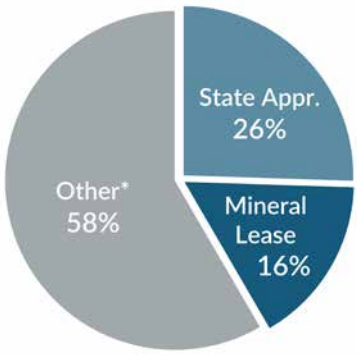
As students graduate and are hired by Utah employers, they carry the knowledge learned at the UWRL into their professional appointments and careers, often serving Utah's water and environmental agencies and organizations. Technology and information are also transferred through collaboration and partnerships with engineers, scientists, and managers of the Utah Department of Natural Resources divisions of Water Resources and Water Rights, the Utah Department of Environmental Quality, the twelve Utah local health departments, and several large water user districts and associations.

The table below summarizes the productivity of the Lab in terms of research, education, outreach, and training. The total research funding through the UWRL in FY 23 of over $9.9 million makes it one of the largest university-based water research institutes in the nation.

UWRL Financial/Academic Summary FY 23	
Number of Active Projects	180
Total Expenditures	$9,959,079
Scholarly Publications in Peer-Reviewed Journals	58
Outreach Activities FY 23	
Short Courses and Field Training	30
UWRL Student Support FY 23	
Graduate Students Supported	49
Undergraduate Students Supported	74
Degrees Granted FY 23	
Doctor of Philosophy (PhD)	2
Master of Science (MS)	11
Master of Engineering (ME)	5

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 23, MLF funding of just under $1.6 million accounted for 16% 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 23 were over $9.95 million.



UWRL Expenditures FY 23

The MLF projects at the UWRL are organized into five major research program areas:

- Environmental
- Hydraulics
- Measurements, Sensing, and Information Systems
- Water Education, Outreach, and Technology Transfer
- Water Resources

The individual projects are under the direction of UWRL researchers and involve collaboration with other departments at Utah State University including:

- Aviation Technology (College of Agriculture and Applied Sciences)
- Biological Engineering (College of Engineering)
- Chemistry and Biochemistry (College of Science)
- Civil and Environmental Engineering (College of Engineering)
- Computer Science (College of Science)
- Electrical and Computer Engineering (College of Engineering)
- Engineering Education (College of Engineering)
- Mechanical and Aerospace Engineering (College of Engineering)
- Plants Soils and Climate (College of Agriculture and Applied Sciences)
- Watershed Sciences (College of Natural Resources)

The project summaries in this report demonstrate the diverse overall UWRL research, education, and training activities related to Mineral Lease funding. However, the totality of the UWRL's programs, taking into account state funds and our external contracts and grants, is even broader. We continue to be involved in advancing hydrologic information systems for data management in support of transparent and reproducible research. 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, engaging our staff in public and professional service, technology and information transfer, and public education. UWRL faculty are also part of the National Oceanic and Atmospheric Administration (NOAA) Cooperative Institute for Research to Operations in Hydrology (CIROH), a large national consortium committed to translating research on the forecasting of floods, droughts, and water quality into actionable operational products supporting the use of water predictions in decision making. A total of 7 projects to 6 UWRL faculty have so far been funded through this cooperative institute. UWRL faculty are also part of a National Science Foundation Institute for Geospatial Understanding through an Integrative Discovery Environment (I-GUIDE). The research in this institute is pursuing an understanding of the complex interactions involved in climate-related disasters where we cannot just look at a single discipline or a single place where a disaster may occur but need to understand how increased vulnerability of our infrastructure, such as aging dams, makes economic sectors like manufacturing and transportation more vulnerable. The institute brings together experts from many fields to tackle these challenges holistically.

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 $146,840 through the U.S. Geological Survey (USGS) that are required to be matched 1:1 with non-federal funds. State ML funds are used for much of this match. This year, the base grant, in combination with ML funds, directly benefits the State of Utah in the following areas:

1. Quantifying evapotranspiration (the combined plant transpiration and evaporation from the soil) and other irrigation water uses in SDI fields irrigated using subsurface drip irrigation (SDI) and nearby sprinkler-irrigated fields, particularly for hay and pasture crops, to show a direct comparison between these methods. applied irrigation, and irrigation efficiencies. This research is looking at a way to reduce consumptive water use and evaporation from applied irrigation, as well as collecting data showing how well SDI irrigation performs to guide future SDI design for hay and pasture crops in Utah and the Intermountain Region.
2. Exploring how antimicrobial resistance genes (ARGs) and microplastics (MPs) interact in in the presence of antibiotics and heavy metals found in wastewater This project aims to increase understanding of MP-ARG interactions in wastewater and the possible harmful effects on public and environmental health and to improve wastewater quality in Utah, particularly as reclaimed wastewater from treatment plants is often used for irrigation.
3. Estimating the water use necessary to sustain urban landscapes using images previously collected by planes and satellites and then comparing the results with actual water use to determine how residents are over- or underwatering. This process could eventually be automated to help water managers and water customers decide how to best use scarce water resources.
4. Sampling and analyzing air samples during active harmful algal blooms (HABs) to detect whether cyanotoxins routinely produced by cyanobacteria found in Utah water bodies have become airborne and pose a threat to people living near or recreating in those waters. Results from this study will improve understanding of potential risks from inhaling airborne toxins during active HABs.

Relevancy and Benefits of the Mineral Lease Fund

As one of the driest states in the union, WATER is the LIFE BLOOD of Utah's economy and quality of life. Our average precipitation of only 13 inches of water per 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 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 ensure a sustainable water and environmental future for Utah's citizens and economy. This requires a broad and deep understanding of 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 land and water use in our arid environment.

In order to focus research on problems and needs that are both relevant and current, 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, as well as a wide range of local, state, national and international professional organizations. These associations give UWRL researchers influence in and a greater understanding of critical water-related research efforts around the nation and the world that are applicable to Utah. Participation in various professional water and environmental organizations helps to bring recognition and external project funding to the state and provides exposure to worldwide research and best practices. These connections also help the UWRL to identify current and future research needs that will affect our state and focus on projects that are relevant to Utah.

The UWRL director, associate directors and faculty members meet periodically with state and federal agency managers and personnel from local water organizations to discuss research needs and identify opportunities for the UWRL to respond to these needs. The UWRL has worked with many State agencies and other local, state, regional, and national organizations over the past few years. Some of these include the following:

State of Utah Agencies

- Department of Environmental Quality (Harmful Algal Blooms Team, Jordan River TMDL Advisory Committee, Long-term Stormwater Management Group, Air Quality Board, Division of Water Quality, Drinking Water Board, Wastewater/Water Treatment Operator's Certification Commissions)
- Department of Natural Resources (Division of Water Resources, Division of Water Rights, Agricultural Water Optimization Task Force)

Local Agencies and Organizations

- Cache County Solid Waste Advisory Board
- Cache Clean Air Consortium
- Cache County State Implementation Plan Team
- Cache Environmental Flows Group

- Crockett Canal Company Technical Advisory Board
- Logan City (Air Quality Board, Renewable Energy/Conservation Advisory Board, Water & Wastewater/ Sewer Board)
- Logan Island Canal Company
- Logan River Task Force
- Logan River Water Users

Other State and National Agencies and Organizations

- California Water Quality Monitoring Council, Environmental Flows Strategic Workgroup
- FEMA Dam Intervention Initiative Advisory Board
- Middle Colorado Watershed Council Technical Advisory Team
- National Dam Safety Review Board
- Texas Integrated Flood Framework Technical Advisory Team
- United States DOD, Industrial Wastewater Treatment of Federal Facilities and Integrated Solid Waste Management and Quality Recycling at Federal Facilities

Professional Organizations

- Air and Waste Management Association – Industrial Wastewater Treatment Waste Management, Federal Facilities Committees
- American Geophysical Union (AGU) – Earth & Planetary Processes Section, Earth & Space Science Informatics, Groundwater committees
- American Institute for Medical and Biomedical Engineering
- American Society of Civil Engineers (ASCE), Environmental Water Resources Institute (EWRI) – Planning & Management Council, Scour at In-stream Hydraulic Structures committees
- American Water Resources Association (AWRA)
- American Water Works Association (AWWA)
- Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)
- Hydraulic Structures Committee of IAHR
- Institute of Biological Engineering, Steering Council
- National Institutes for Water Resources (NIWR)
- National Onsite Wastewater Recycling Association
- National Society of Black Engineers
- Northeast Biotechnology Center and Consortium
- United States Society on Dams, Hydraulics of Dams, Spillways committees

Mineral Lease Fund Expenditures

The table below summarizes the actual, budgeted, and planned expenditures of ML funds allocated to the UWRL for FY 2023 through FY 2025 for research projects in the five major Program Areas. UWRL administration and technology transfer expenditures account for approximately 10% of total MLF budgeted and planned expenditures.

Expenditures differ from budgeted amounts due to fluctuations in the actual amount of ML funds received and due to the time required to properly plan and spend funds received. Funds received are, as noted above,

2.25% of deposits made to the Utah ML account. The $1,605,263 expenditure was less than budgeted last year due to lower state deposits. The budgeted $1,812,000 for this and next year reflects the MLF amount budgeted for the UWRL in the Utah State Legislature higher education base budget. Recognizing that the state deposits received will differ from this budgeted amount, the project budget planning for each program area may include amounts for undesignated research projects, which will only be started if actual ML deposits are sufficient.

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.

Mineral Lease Fund Expenditures: Research Program Area	Actual FY2023	Budgeted FY2024	Planned FY2025
Administration	$171,231	$176,368	$181,659
Environmental	$563,176	$642,571	$586,099
Hydraulics	$127,533	$154,535	$127,293
Measurement, Sensing and Information Systems	$270,235	$325,362	$564,583
Water Education, Outreach and Technology Transfer	$134,874	$133,771	$87,529
Water Resources	$338,214	$379,593	$265,037
TOTALS	**$1,605,263**	**$1,812,200**	**$1,812,200**

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 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.

Environmental

This program emphasizes an integrated engineering and science approach to managing and improving the quality of our land, water, and air resources. The program includes engineering approaches for the treatment, reclamation, recycling, and reuse of municipal and industrial wastewater and biosolids and the sustainable management of stormwater for its capture and reuse using

green infrastructure approaches. The fate of emerging contaminants in water bodies, wastewater, biosolids, soils and crops, and the risks that these emerging contaminants pose to human health and the environment are also topics of active research. Faculty with expertise in nano particles, microplastics, and cyanotoxins are addressing topics of emerging interest in environmental water quality, treatment, and use. 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 $PM_{2.5}$, ozone, and ammonia associated with the Great Salt Lake, winter inversions, animal production, and vehicle emissions. This research encompasses diverse areas of specialization, including environmental engineering, environmental chemistry, environmental microbiology, chemical engineering, soil science, photochemistry, aerosol chemistry, plant science, and modeling.

Hydraulics

The UWRL uses numerical and scaled physical models to evaluate and optimize hydraulic structure design and performance. Hydraulic structure modeling projects include, but are not limited to, dams, reservoirs, spillways, canals, pipelines, tanks, power stations, pump stations, tunnels, and diversion structures. The hydraulics group also performs calibrations and tests on valves, pumps, flow meters and other hydraulic equipment to assist worldwide manufacturers and users. Research in the hydraulics area includes many other topics such as sediment dynamics in river channels to quantify how rivers respond in form and quality and changing sediment inputs associated with wildfires and other disturbances.

Measurements, Sensing, and Information Systems

To be effective, water and environmental managers must have access to relevant data. Sometimes, these data must be available in real-time to support decision-making. The UWRL is a leader in the development of advanced monitoring and sensing systems for collecting environmental and water-related data along with cyberinfrastructure for managing the resulting data and interfacing with user-driven decision support systems for water and environmental planning and management. Another significant area of research focuses on remote sensing technology and data to improve water, agricultural, and environmental resources management. This includes the UWRL's 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, rivers, and riparian environments collecting multispectral high-resolution imagery. The data are then analyzed using innovative image processing techniques and used to enable more efficient irrigation of crops, identify and manage invasive vegetation, and improve water and environmental management.

Water Education, Outreach, and Technology Transfer

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. 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 money 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. 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

https://uwrl.usu.edu/research/owt. Undergraduate and graduate students also participate in projects that involve hands-on, real-world activities.

Water Resources

This diverse program has strengths in both the theoretical and the applied aspects of hydrology and water resources. Hydrologic research includes hydrologic-related data collection and modeling that focuses on rainfall and evapotranspiration processes, snow hydrology, floods, droughts, terminal lakes, erosion and sediment transport, surface water quality and temperature, and groundwater/surface water connectivity. Water Resources management research areas include water conservation, river basin planning, reservoir operating policies, habitat monitoring and restoration, urban water management, and land use change. This program area also addresses various institutional and legal aspects of water, such as water rights transfers, water banking, distributed water demand and supply modeling, and cost allocation and user fee determination.

Information Dissemination

UWRL information dissemination 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.

Professional Service

UWRL Faculty are active professionally and serve on state and local advisory panels to provide technical expertise, input, and review of water-related issues. Faculty also participate in and organize conferences, sessions, and workshops with professional societies. Many serve as journal peer reviewers and editors and assist funding agencies with proposal reviews. UWRL personnel are frequently invited to provide technical and informational presentations before state and national professional groups. Through this work they serve the profession and remain current on emerging research. Key UWRL faculty service activities include the following:

Utah Boards/Committees	Other State/Local Boards/Committees
Utah Department of Environmental Quality – Harmful Algal Blooms Team – Jordan River TMDL Advisory Committee – Long-term Stormwater Management Work Group – Utah Air Quality Board – Utah Drinking Water Board – Utah Water Operators Certification Commission Utah Division of Water Resources, Utah Agricultural Water Optimization Task Force (UDWR) Utah Department of Transportation Advanced Aerial Mobility Working Group	Cache County Solid Waste Advisory Board Cache County Implementation Plan Team Crocket Avenue Project Technical Advisory Board Logan City Renewable Energy and Conservation Advisory Board, Air Quality Task Force Great Salt Lake Strike Team Logan City Water Board Logan River Task Force Logan River Water Users Advisory Committee for Water Prediction Water Environment Association of Utah – Biosolids Committee
Editorial Boards for Professional Journals	**Professional Leadership and Service**
Environmental Modelling & Software Journal, editorial board Frontiers in Control Engineering, editor Hydrological Processes, associate editor International Conference for Unmanned Aircraft Systems, associate editor Journal of the American Water Resources Association Journal of Coastal and Hydraulic Structures, editor Journal of Biological Engineering, editorial board Journal of Bioremediation and Biodegradation, editorial board Journal of Water Resources Planning and Management, ASCE, associate and reproducibility editor WIREs Water, associate editor	American Geophysical Union Committees American Society of Agricultural and Biological Engineers Committees American Society of Civil Engineering Committees Association for the Advancement of Artificial Intelligence European Working Group on Overflowing and Overtopping Erosion Mountain West Association for Uncrewed Systems International National Inventory of Low-Head Dams North American Plant Phenotyping Network Overtopping Protection at Dams and Levees Seminar Series, team leadership Technical Standards in Drone Technology (ASABE) United States Society on Dams Committees
Proposal/Program Review	
National Science Foundation. Review panels and postdoctoral program Utah Agricultural Experiment Station. Proposal review United States Geologic Survey. Proposal review, 104g	

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. 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. The UWRL has evolved into a diverse center of excellence for generating knowledge

related to water challenges. It fills an important role in the US and global community of water research facilities, with the interdisciplinary expertise to develop better ways to measure, monitor, model, understand, and manage 21st century water resources. Good water management recognizes the value of information from many disciplines—from how a single water molecule behaves to the constraints and opportunities created by state or national water laws and policies. 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 the ability of our state and the nation 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 UWRL's achievements and its outstanding reputation for water research and education.

[Intentionally Blank]

Section 2

Administration, Advisory Support and Special Equipment

[Intentionally Blank]

ACTUAL, BUDGETED, AND PLANNED EXPENDITURES OF MINERAL LEASE FUNDS

ADMINISTRATION: Area	Actual FY2023	Budgeted FY2024	Planned FY2025
Administration of the MLF Program	$32,801	$33,785	$34,798
Communications and Outreach	$55,406	$57,069	$58,781
Business Services	$83,024	$85,514	$88,080
TOTALS	**$171,231**	**$176,368**	**$181,659**

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 invited to serve on committees or provide 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. Additionally, when research needs arise that require specialized equipment that cannot be made available through other means, MLF resources are sometimes used to acquire these equipment items critical for Utah-based research.

Administration of the MLF Program

The costs of administering the MLF program at the Utah Water Research Laboratory are deliberately held as low as possible to maximize the direct 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 some 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 23 administrative costs represented approximately 2% of total UWRL MLF expenditures.

Communication and Outreach

The UWRL Communications and Outreach 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 23 on these support activities accounted for 3.5% of total MLF funding.

Business Services

Overall, annual research expenditures for the UWRL have generally fluctuated between $ 8 and $ 10 million, and at any point in time, around 200 active research contracts are administered at the UWRL. These projects require significant support from the UWRL Business Services Office in the form of accounting and financial oversight. MLF expenditures in FY 23 on these support activities accounted for 5.2% of total MLF funding.

[INTENTIONALLY BLANK]

Section 3

Project Summaries

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:

- Environmental
- Hydraulics
- Measurements, Sensing, and Information Systems
- Water Education Outreach and Technology Transfer
- Water Resources

Environmental

ACTUAL, BUDGETED AND PLANNED EXPENDITURES OF MINERAL LEASE FUNDS

ENVIRONMENTAL: PI	Project Name	Actual FY2023	Budgeted FY2024	Planned FY2025
Dupont, R.	Evaluation of the Presence, Fate, and Exposure Pathways of PFAS Compounds in Northern Utah Communities	$60,905	$62,732	$64,614
Hou, L.	Effects of Biofilm Colonization on the Dynamics of Microplastics in Aquatic Environments	$24,256	$24,983	$25,733
Hou, L.	Fighting emerging Antibiotic Resistance in Wastewater	$24,255	$24,983	$25,733
Martin, R.	Wintertime ambient ammonia in the Cache Valley	$38,835	$40,000	$41,200
Martin, R.	Potential Abundance of Photochemically-Important Halogens around the Great Salt Lake	$39,054	$40,226	$41,432
McLean, J.	Advanced analytical support for research efforts in environmental quality	$32,952	$33,941	$34,959
McLean, J.	Water treatment and contaminants of emerging concern	$48,843	$50,308	$51,817
Moor, K.	Assessing the Sources, Transport, and Fate of Microplastic in the Logan River Watershed	$15,474	$15,938	$16,416
Moor, K.	Toxicity screening of leachates from sustainable plastic alternatives	$45,428	$46,790	$48,194
Moor, K.	Wildfire impacts on surface water photochemistry	$15,474	$15,938	$16,417
Sims, J.	Mitigation of Methane Emissions from Anthropogenic Sources	$40,393	$41,605	$42,853
Sims, R.	Aerobic composting of wastewater algae-derived bioplastics	$53,907	$55,525	$57,190
Stevens, D.	Assessment and Modeling of Cyanotoxin Presence and Occurrence Risk in Utah Surface Waters	$50,782	$52,305	---
Stevens, D.	Developing cyanotoxin support capabilities and analytical and monitoring guidance for Utah water managers	$50,782	$52,305	---
Su, Y.	Applications and implications of nanoparticles in environmental and agricultural practices	$21,834	$22,492	$23,167
	New projects		*$62,500*	*$96,374*
	TOTALS	**$563,176**	**$642,571**	**$586,099**

Evaluation of the Presence, Fate, and Exposure Pathways of PFAS Compounds in Northern Utah Communities

Research Summary:

Per- and polyfluoroalkyl substances (PFAS) are widely used, long lasting chemicals found in many consumer and industrial products that are also linked to harmful helath effects in humans and animals. This study is providing data on PFAS concentrations in wastewater and biosolids from two treatment plants in northern Utah. High concentrations of two compounds in biosolids led to further evaluation of effective management practices to reduce potential PFAS exposure risk. The concentration of several PFAS compounds significantly increased in one plant while significantly decreasing in another, prompting future analysis of the role of nano-scale iron (prevalent in one plant but not the other) in PFAS transformation.

Why this research?

PFAS compounds represent a wide range of polyflorinated alkyl substances used in everyday items and firefighting foams since the 1940s because of their heat and water-resistant properties. These chemicals persist in the environment and in the human body and have recently been associated with serious human health effects including increased cholesterol levels, low infant birth rates, cancer, and negative effects on the immune system and on thyroid hormone production. Lifetime health advisory levels in drinking water proposed in June 2022 by the US EPA for four of the commonly detected hazardous PFAS compounds limit human exposure to 0.004 to 0.02 ng/L for PFOA and PFOS, respectively, to 10 ng/L for PFBS and 2,000 ng/L for GenX chemicals (traditional PFAS replacement compounds). This project is generating PFAS concentration data for various potential exposure routes (e.g., municipal wastewater treatment plant effluent used for secondary irrigation, municipal biosolids) in northern Utah. Potential human risks from direct exposure to secondary water and ingestion of plants irrigated with treated effluent and contaminated rainwater or grown in contaminated biosolids are being evaluated.

Benefits to the State

This study provides the first data from northern Utah describing PFAS fate and transformation in wastewater treatment plants and lagoons and documents the potential risks of PFAS compounds in reclaimed wastewater, produce grown in urban gardens with reuse water, and biosolids generated from municipal wastewater treatment plants. Identifying treatment and reuse options that limit PFAS risks as necessary, will provide essential information to communities looking to develop future water reuse and beneficial biosolids use projects. Study results can apply broadly to other semi-rural regions in Utah with scarce water and biosolids management issues driving the development of treated wastewater for secondary water reuse and considering beneficial use of biosolids generated in their wastewater treatment plants.

Principal Investigators:

R. Ryan Dupont (PI)
Joan E. McLean (Co-PI)
Randal Martin (Co-PI)

Technicians:

Marissa Li

Students:

Victoria Krull (MS)

Partners/Collaborators:

Local: Angie Pritchette, Hyrum Wastewater Treatment Plant; Logan City Wastewater Treatment Plant

Geographic Areas:

Study Areas: Logan and Hyrum, UT; Cache County Utah

Areas Benefited: Other areas within Utah currently utilizing or planning water reuse projects

Contacts:

R. Ryan Dupont
435.797.3227
ryan.dupont@usu.edu

Publication:

Weidhaas, J, M Olsen, JE McLean, N Allen, L Ahmadi, K Duodu, and RR Dupont. 2022. *Microbial and chemical risk from reclaimed wastewater use for residential irrigation*. Water Reuse. 12(3):289-303. https://doi.org/10.2166/wrd.2022.014.

PRESENTATION:

Krull, V, RR Dupont, M Badr, JE McLean, and S Kozik. 2023. *A Comparison of PFAS in Two Rural Wastewater Treatment Plants.* A poster presented at the 116th Air and Waste Management Association Annual Conference and Exhibit, June 6, Orlando, FL. 1st Place Winner of AWMA MS Student Poster Competition.

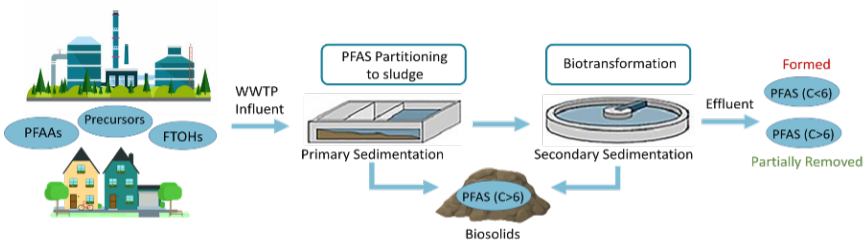
NEW GRANT FUNDING:

Weidhaas, J, RR Dupont, JE McLean. 2023. *Partnership: Elucidating Soil Health Impacts from Contaminants of Emerging Concern in Municipal Biosolids Used for Agriculture.* Proposal funded through USDA/AFRI, based on findings from on-going research at the UWRL associated with this project. ($450,000/3 years).

Work plan FY 23–24

We will complete wastewater reuse system sampling to include biosolids from both wastewater treatment plants. We will further evaluate the effectiveness of high magnetite and subsequent nano-scale iron concentrations on the fate of PFAS during biosolids composting to assess the effectiveness of high-temperature composting in reducing elevated PFAS concentrations in these biosolids, and the role nano-iron may play in enhancing the rate and extent of PFAS transformation during this common solids stabilization process.

PFAS Fate and Transport Associated with Wastewater Treatment



What we did

We are collecting triplicate wastewater influent, effluent, treatment train samples, along with triplicate samples of treatment plant biosolids and soil and plant samples from biosolids application areas and will analyze samples for the presence of 12 PFAS compounds. Soil and biosolids samples were extracted using standard US EPA Method 1633 procedures. Liquid samples and solids extracts were cleaned and concentrated with solid phase extraction using WAX cartridges as specified in EPA Method 1633. Samples were analyzed for PFAS using an Agilent 6490 Triple Quad LC/MS. Method 1633 is used to obtain retention times and compound identifiers used to quantify the compounds. Method quality control procedures ensure the validity and representativeness of all reported results.

What we found

Throughout Cache Valley, we identified a range of PFAS compounds in wastewater influent and treated effluent samples, in vegetables irrigated with secondary water, in municipal biosolids and in forage crops grown in fields amended with biosolids. Comparing study influent concentrations with data reported for other treatment plants across the US shows comparable wastewater PFAS concentrations in both highly urban and rural/peri-urban areas, making risks of exposure by this route universal.

Tracking PFAS compound changes across two mechanical treatment plants in Cache Valley shows that the fate of individual compounds varies significantly based on the treatment technology used as illustrated in Figure 1. Results showed that removal of most PFAS compounds from the wastewater occurs through accumulation within the biosolid, rather than compound destruction based on the compound distribution in the biosolids of the Membrane Bioreactor plant. High concentrations of PFOA and PFOS (>10,000 ng/kg) within biosolids indicated the need for further safe biosolids management.

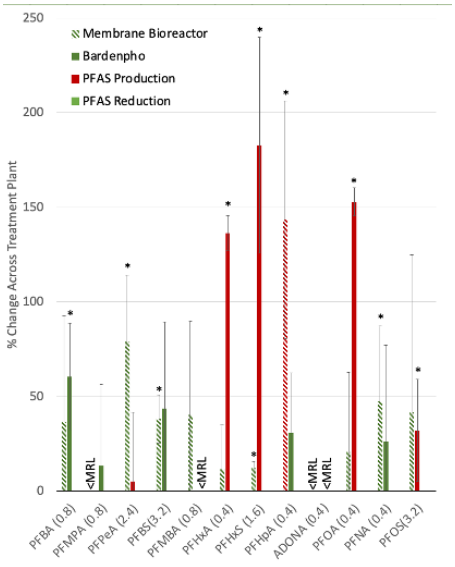


Figure 1: *Comparison of percent change of PFAS concentrations across treatment plants. Error bars indicate 95% confidence interval. Asterisk indicate statistically significant change. Green indicates compound removal; red indicates compound production through each plant. Values in parentheses are compound method detection limits, ng/L.*

Effects of Biofilm Colonization on the Dynamics of Microplastics in Aquatic Environments

Research Summary:

This research investigated the influence of harmful microbial biofilm on the dynamics of microplastics, including settling velocity and dispersion. At this point, relationships between biofilm thickness and microplastics dynamics in aquatic environments are still unclear. We determined the polyethylene terephthalate (PET) microplastics dynamics with biofilms formed by opportunistic human pathogen Pseudomonas aeruginosa at different cultivation stages. We found that longer cultivation of P. aeruginosa leads to dense biofilms with higher protein concentrations, which in turn are associated with slower fall speeds for PET MPs. These results will advance model development to track microplastic origins that may link diseases/infections caused by biofilms.

Why this research?

This study focused on microplastics (MPs) that come from large plastic waste and everyday products and how they act in water when they have slimy layers of harmful bacteria (biofilm) on them. We were interested in determining if the thickness of of the biofilm layer changes how these microplastics move in water. MPs covered in harmful biofilms present a complex threat to both human health and ecosystems.

Benefits to the State

This research holds significant benefits for both public health and the environment in Utah. It aims to track the sources of microplastics associated with diseases caused by harmful biofilms. These findings can help prevent health issues and protect ecosystems and water systems in the state. Additionally, the research results can guide the microplastics

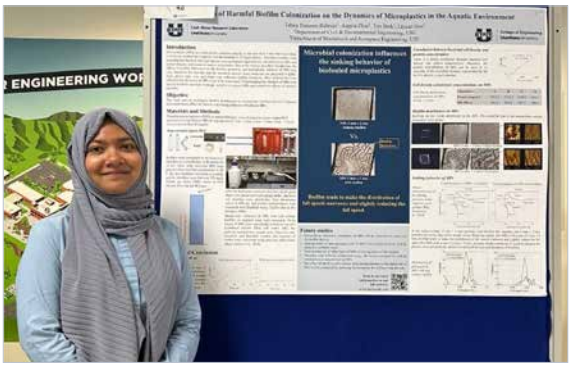


Figure 1: *Tahira Rahman presenting at USU College of Engineering Research Week*

Principal Investigators:

Liyuan Hou (PI)
Tim Berk (Co-PI)

Students:

Tahira Rahman (MS)

Partners/Collaborators:

Local: Tyler Richards, Logan Regional Wastewater Treatment Facility

Geographic Areas:

Study Areas: This was a laboratory study.

Areas Benefited: Microplastics pose a risk to human health and the environment. Understanding the risks of harmful bacteria on microplastics will benefit the entire state.

Contacts:

Liyuan Hou
435.797.1533
liyuan.hou@usu.edu

Tahira Rahman
tahira.rahman@usu.edu

PRESENTATION:

Rahman, TT, A Zhan, T Berk, and J Hou. 2023. *Effects of Harmful Biofilm Colonization on the Dynamics of Microplastics in the Aquatic Environment*. A poster presented at the USU College of Engineering Research Week, Logan, Utah, Poster session], February 21—24, 2023

Work plan FY 23–24

Given the diverse types and shapes of microplastics (MPs) and the varied nature of biofilms, our objectives are threefold, and our future plan includes three aspects:

1. Assess differences in biofilm characteristics for different microbes on microplastics
2. Quantify dispersion and settling dynamics for MPs with biofilms in lab-scale turbulence, and
3. Develop a machine learning model to predict MP transport with biofilms in field-scale situations considering the factors that will be tested in the future.

The application of computational fluid dynamics and machine learning techniques also contributes to technological progress in environmental research, facilitating the assessment of multiple threats posed by microplastics and harmful microbes to human health.

removal systems that are installed in Utah's wastewater treatment facilities. This is essential for improving water quality and reducing health risks linked to microplastics and biofilms. Furthermore, the research provides valuable insights into developing effective strategies and devices for removing microplastics, considering their different characteristics and biofilm coverings. Moreover, it advances our understanding of how biofilms influence microplastic movement in turbulent water systems, vital for managing water quality and health risks in Utah's water bodies.

What we did

Based on our previous findings, the most dominant shapes and types of MPs in wastewater treatment facilities are fiber and fragment, polyethylene terephthalate (PET; higher density), and polyethylene (PE; lower density), respectively. We conducted experiments where we grew biofilms at different stages using the opportunistic human pathogen *Pseudomonas aeruginosa* on PET microplastics. Once the biofilms had colonized the PET microplastics, we placed them into a controlled water basin with uniform turbulence, where we precisely measured their behavior, specifically their sinking velocities. We employed advanced optical measurement techniques for this purpose. Concurrently, we also determined the cell density and protein concentration associated with the surface of these PET microplastics.

What we found

In the water basin, we observed that PET microplastics (MPs) measuring 1 mm × 1 mm and covered in biofilm descended consistently. In contrast, larger PET MPs measuring 3 mm × 3 mm teetered on the border between steady descent and fluttering. Notably, the biofilms did not evenly coat the MPs, possibly due to variations in the plastic's surface properties. We found that, when we allowed *P. aeruginosa* to grow for longer periods, the resulting biofilms became denser and had higher concentrations of proteins/cells. Interestingly, these dense biofilms were associated with a decrease in the sinking speed of PET microplastics because the estimated biofilm wet density (1.14 g/cm3) was lower than PET MPs density (1.38 g/cm3).

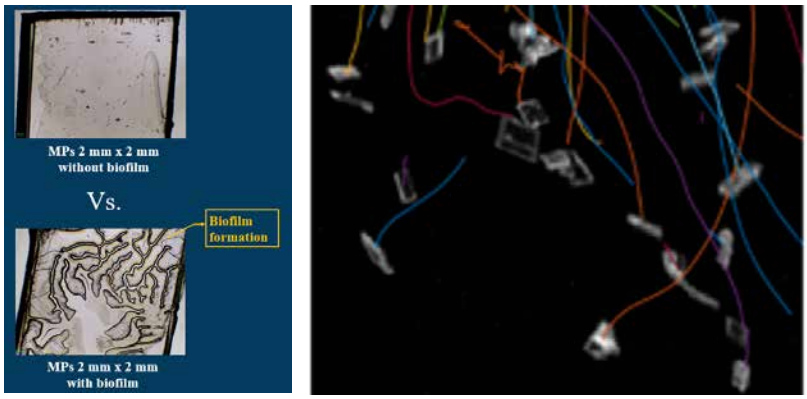


Figure 2: *MPs with biofilms and without biofilms (left); Measurement of the steady-state velocities of MPs with and without biofilms in stagnant water (right)*

Fighting Emerging Antibiotic Resistance in Wastewater

RESEARCH SUMMARY:

This project focuses on antibiotic resistance issues in wastewater. Wastewater contains various bacteria, which can develop resistance to antibiotics through gene transfer in biofilms and threaten human health. We have isolated and identified antibiotic-resistant bacteria from a local wastewater treatment plant and explored natural compounds that can hinder bacterial biofilm formation. Initial results indicate the presence of multiple antibiotic-resistant strains, including some with double or triple resistance. Additionally, certain natural compounds, such as curcumin, quercetin, and resveratrol, show promise in inhibiting biofilm formation. These findings suggest that natural antioxidants may help combat antibiotic resistance and superbug development in wastewater.

Why this research?

Wastewater contains numerous microbes, with 95% being bacteria. However, some of these microbes in wastewater may acquire antibiotic resistance through gene transfer within biofilms, posing a serious threat to the environment and human health. Thus, this project aimed to isolate and identify antibiotic resistant bacteria from a local wastewater treatment plant (WWTP) and investigate natural compounds that can prevent bacterial biofilm formation.

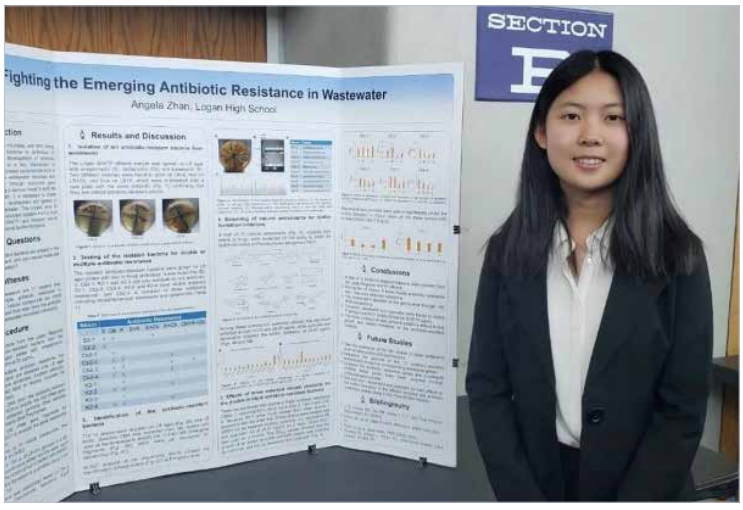


Figure 1: *Angela Zhan was awarded the Regeneron Science Award for high school students at the 2023 University of Utah Science and Engineering Fair and competed at the 2023 Regeneron International Science and Engineering Fair.*

PRINCIPAL INVESTIGATORS:

Liyuan Hou (PI)

STUDENTS:

Angela Zhan (HS volunteer)

PARTNERS/COLLABORATORS:

Local: Phil Heck, Central Valley Water Reclamation Facility

GEOGRAPHIC AREAS:

Study Areas: This was a laboratory study.

Areas Benefited: Antibiotic resistance poses a risk to human health. Understanding the which natural compounds can hinder bacterial biofilm formation will benefit the entire state.

CONTACTS:

Liyuan Hou
435.797.1533
liyuan.hou@usu.edu

Angela Zhan
angela.zhan728@gmail.com

Presentation:

Angela Zhan, Logan High school. 2023. *Fighting the Emerging Antibiotic Resistance in Wastewater*. This poster received the Regeneron Science Award for high school students at the University of Utah Science and Engineering Fair in March 2023 and competed at the 2023 Regeneron International Science and Engineering Fair, May 13-19, 2023, Dallas, TX..

Media Mention:

https://twitter.com/ S77 Joanna/status/1640906266682720256?s=20

Work plan FY 23–24

Future work includes:

1. Testing the resistance of the ten strains to other antibiotics such as tetracycline and erythromycin.
2. Sequencing the genome of the 10 antibiotic-resistant bacteria and locate the corresponding resistance genes.
3. Comparing the antibiotic resistance genes and investigating whether these genes have been acquired through horizontal gene transfer.
4. Testing curcumin, resveratrol and quercetin for their effects on the biofilm formation in the effluent bacteria and antibiotic resistance spread using a Drip Flow Biofilm Reactor.

Benefits to the State

Utah faces water scarcity, particularly in arid and semi-arid regions. The State uses non-traditional sources such as reclaimed wastewater to meet the increasing water demand for irrigation. For instance, both Hyrum and Logan Regional WWTPs in Utah distribute effluent for irrigation during dry seasons. However, antimicrobial resistance genes (ARGs) exist in WWTP effluent. Forty-seven ARGs have been detected in the reclaimed wastewater from Hyrum WWTP and its irrigation areas and plants. It would be beneficial for local wastewater treatment facilities to act promptly regarding the use of reclaimed wastewater at high risk of ARGs, and to develop effective management plans to minimize their negative impacts. This project is of interest to various stakeholders, including the public health community, the water and wastewater industry, and environmental protection agencies aiming to control ARGs.

What we did and what we found

The hypotheses of this research are:

1. Bacteria from wastewater can develop double or multiple antibiotic resistance, and
2. Certain natural compounds can inhibit bacterial biofilm formation and slow down the spread of antibiotic resistance in the wastewater microbial community.

To test these hypotheses, Luria-Bertani agar plates with different antibiotics have been applied to select corresponding resistant bacteria from the Logan regional WWTP effluent. A total of 10 strains have been isolated, including two kanamycin-resistant, four carbenicillin-resistant and four streptomycin-resistant bacteria. Notably, five of the strains exhibited double antibiotic resistance and one exhibited triple antibiotic resistance. These strains were identified at the species level based on 16S rRNA sequencing. Furthermore, a screening of 11 natural compounds showed that curcumin, quercetin, and resveratrol effectively inhibited biofilm formation of *Pseudomonas aeruginosa* PAO1 at 26.67 μg/mL. These findings suggested that natural antioxidants have the potential to inhibit bacterial biofilm formation and prevent antibiotic resistance spread and the development of superbugs in wastewater.

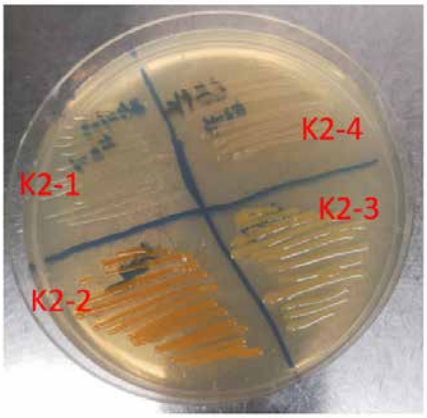


Figure 2: *Isolation of antibiotic-resistant bacteria from Logan WWTP effluent from LB agar plates with antibiotics.*

Wintertime Ambient Ammonia in the Cache Valley

RESEARCH SUMMARY:

In wintertime atmosphere of northern Utah, especially the Cache Valley, it is well-known that the abundance of gas-phase ammonia (NH3) significantly contributes to the formation of fine particulate matter (PM2.5). Following a region-wide avian influenza outbreak, it was hypothesized that the resultant decrease in local poultry populations could subsequently lead to a significant decrease in available NH3, which in turn could reduce levels of ammonium nitrate based PM2.5. During the winter of 2022/23 we deployed a network of samplers and found that NH3 concentrations were up to 50% of those found in previous years. However, during the test period, several inversion episodes were observed and PM2.5 levels still reached unacceptable levels.

Why this research?

Air quality in northern Utah has been plagued by excessive levels of particulate matter ($PM_{2.5}$) in the winter and ozone gas (O_3) in the summer. It is well-established that local $PM_{2.5}$ across all airsheds is dominated by a compound called ammonium nitrate (NH_4NO_3). In Cache Valley multiple studies have shown an overabundance of ambient ammonia (NH_3) to such a degree that emission reductions were not likely economically or logistically practicable. However, the depopulation of almost 1.5 million chickens at a major poultry producer owing to an outbreak of avian influence, allowed for the assessment of a significant, if unplanned, NH_3 emissions reduction scenario and the result NH_3 availability for $PM_{2.5}$ formation within the Cache Valley airshed.

Benefits to the State

Along with advancing the State of the Science on atmospheric ammonia, this study will directly feed into potential remediation approaches addressing wintertime $PM_{2.5}$ and summertime O_3 within northern Utah's airsheds.

What we did

The Cache Valley ammonia study involved establishing a network of monitors throughout the Cache Valley during January and February of 2023 to measure week-long sample periods, followed by subsequent quantification at the Utah Water Research Laboratory. These values were then compared to previously produced concentration maps.

PRINCIPAL INVESTIGATORS:

Randal Martin (PI)

STUDENTS:

Himalaya Sapkota (MS)
Megan Lambright (UG)
Megan Wilson (UG)
Ian Parvin (UG)
Donald Olsen (UG)

PARTNERS/COLLABORATORS:

USU: Janet Quinney Lawson Institute for Land, Water and Air (ILWA)
Cache County

State/National: Utah Division of Air Quality (UDAQ)

GEOGRAPHIC AREAS:

Study Areas: Cache Valley, UT

Areas Benefited: This study benefits the Cache Valley (UT-ID) airshed in regards to PM2.5 maintenance status.

CONTACTS:

Randal Martin
435.797.1585
randy.martin@usu.edu

Brian Steed (ILWA)
brian.steed@usu.edu

Publications:

Lambright, M et al. 2023. *Ambient Ammonia in Cache Valley*. Project report to ILWA

Media Coverage:

- Utah State Today (article/ video). *Atmospheric Ammonia: USU Researchers Looking into Cache Valley's Ammonia Concentrations*. March 6, 2023. https://engineering.usu.edu/news/main-feed/2023/usu-professor-and-students-investigate-air-pollution-in-cache-valley
- Cache Valley Daily (article) USU researchers looking at Cache Valley's ammonia concentrations. March 2, 2023. https://www.cachevalleydaily.com/news/archive/2023/03/02/usu-researchers-looking-at-cache-valleys-ammonia-concentrations/

Conference Presentations:

- Lambright, M at el., 2023. *Ambient Ammonia in Cache Valley*, presented at the 7th Annual Science fort Solutions: Air Quality conference, SLC, UT, Mar. 30, 2023, 1st Place student poster.
- Martin, M et al., 2023. *Ambient Ammonia in Utah's Cache Valley: Assessing the Impact of the Temporary Shut Down of a Large Poultry Facility*, Paper #1402621, presented at the 116th Annual Conference and Exhibition of the Air & Waste Management Association, Orlando, FL, June 5-8, 2023

What we found

Even though the poultry facility had begun significant animal repopulation just prior to the ammonia study, the average, valley-wide NH_3 concentrations were found to be 15-50% of previous years studies. This suggests that changes at the poultry facility, in both bird numbers and manure management strategies, may have had an impact on ambient NH_3 levels. However, during this same time frame, Cache Valley's $PM_{2.5}$ levels exceeded the 24-hr at least eight times in the early winter of 2023, more times than it had in the past decade and threatening the airshed's attainment status. One of the project's concluding recommendations was to reassess CV ammonia on a periodic schedule (e.g. every five years or so).

Work plan FY 23–24

The Cache Valley (CV) NH_3 project is complete.

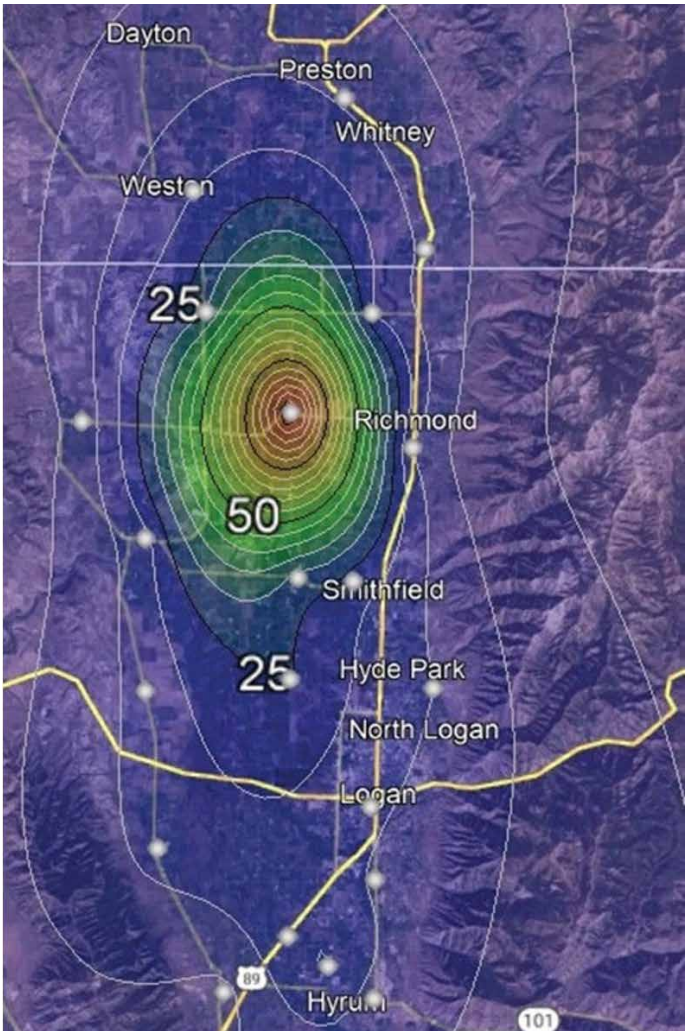


Figure 1: *Cache Valley average ambient ammonia concentrations, winter 2023.*

Potential Abundance of Photochemically Important Halogens around the Great Salt Lake

Research Summary:

Based on previous studies, we speculated that halogen-related species (e.g. chlorine, Cl, and bromine, Br) could be significant to photochemical production of air pollutants, including ozone (O_3) and fine particulate matter ($PM_{2.5}$). While the presence of the Great Salt Lake (GSL) may suggest the presence of such species, a preliminary study suggested stack emissions from U.S. Magnesium, located near the southwest corner of the GSL, may overwhelm the background lake contributions. We initiated a study to characterize air-borne halogens surrounding the GSL during the Jan/Feb 2023 when the facility was down for routine maintenance, with plans to replicate the study when the facility returns to full production. The initial study, with U.S. Magnesium not in production, found halogen levels slightly above what is considered background. The highest levels, although still low, were within the Salt Lake City urban corridor—likely attributable to road salt usage.

Why this research?

Air quality in northern Utah often suffers from excessive levels of particulate matter ($PM_{2.5}$) in the winter and ozone gas (O_3) in the summer. One study, the 2017 Utah Winter Fine Particulate Study (UWFPS), suggested that halogen species, mainly chlorine- and bromine-related compounds, likely emitted for the US Magnesium on the Great Salt Lake's southwest corner, could significantly contribute to both winter $PM_{2.5}$ and summer O_3 photochemical formation chemistry. An effort to quantify the background

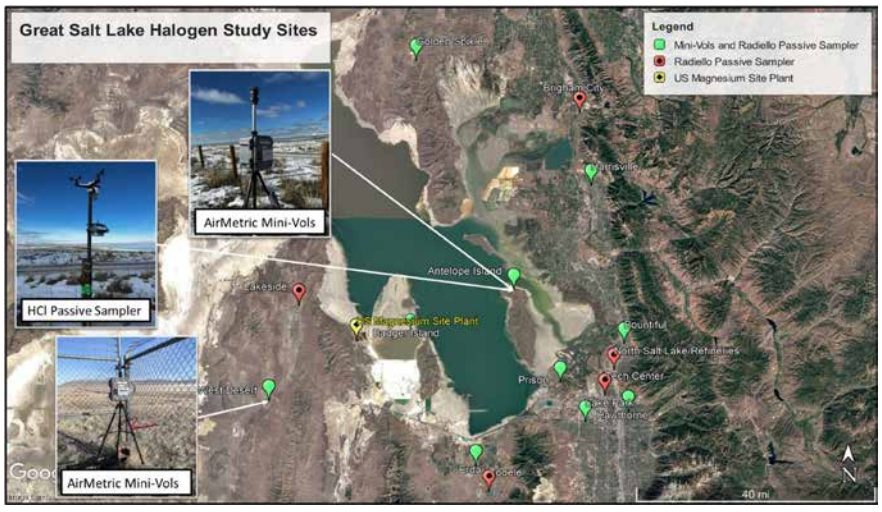


Figure 1: *GSL Halogen Study Sites.*

Principal Investigators:

Randal Martin (PI)
Nancy Daher (UDAQ, Co-PI)
Rachel Edie (UDAQ, Co-PI)
Chris Pinnell (UDAQ, Co-PI)
Christina Jaramillo (UDAQ-Co-PI)

Students:

Himalaya Sapkota (MS)
Megan Lambright (UG)
Megan Wilson (UG)
Ian Parvin (UG)
Donald Olsen (UG)

Partners/Collaborators:

State: Utah Division of Air Quality (UDAQ)

Geographic Areas:

Study Areas: Northern Wasatch Front surrounding the Great Salt Lake

Areas Benefited: This study benefits the northern Wasatch Front (WSF) airshed in regards to both PM2.5 and ozone non-attainment status.

Contacts:

Randal Martin
435.797.1585
randy.martin@usu.edu

Nancy Daher
ndaher@utah.gov

Media Coverage:

- Utah State Today (video), *What's in Our Air? USU Researchers Investigating Halogen Concentrations around the Great Salt Lake*. March 22, 2023. https://www.usu.edu/today/story/whats-in-our-air-usu-researchers-investigating-halogen-concentrations-around-the-great-salt-lake
- KSL News (article/video) July 5, 2023. https://ksltv.com/565172/study-seeks-causes-for-air-pollution-in-great-salt-lake-area/

Conference Presentations:

Sapkota, H et al., 2023, *Great Salt Lake Halogen Study*, presented at the 7th Annual Science fort Solutions: Air Quality conference, SLC, UT, Mar. 30, 2023, 1st Place student poster. https://byu.app.box.com/v/s4s-2023-posters/file/1188808999915

Work plan FY 23–24

The halogen project will continue through the winter of 2023–2024 and through the spring/summer of 2024, depending on US Magnesium's return to full operation.

halogen species in the airshed completely surrounding the Great Salt Lake was suggested to coincide with a planned industrial shutdown of the facility during the winter of 2022–2023. And then, once the facility returns to full production, an additional study will be performed to assess the added impact the US Magnesium at full operation.

Benefits to the State

Along with advancing the State of the Science on halogen abundance and photochemistry, a topic that has been particularly understudied in the region, this study will directly feed into potential remediation approaches addressing wintertime $PM_{2.5}$ and summertime O_3 within northern Utah's airsheds.

What we did

The initial phase of the halogen study also took place over five weeks during January and February 2023. During this study, 15 sites stretching from the Golden Spike Monument in the north, down the populated areas of the Wasatch corridor, along the GSL's southern reaches, and out into the West Desert. These sites included passive samplers for hydrochloric acid and stacked filter samplers for total $PM_{2.5}$ mass, particle-bound ionic species, and gas-phase halogenic acids. The GSL halogen study was also repeated in the summer of 2023, with plans to replicate it in the winter and summers of 2024.

What we found

The wintertime GSL halogen study found HCl concentration generally above typical continental concentrations (<1 ppb), but still relatively low (1–3 ppb) and centered around Salt Lake City's urban core. Speculations suggest that much of the observed atmospheric halogens during this study could likely be associated with road salts. It should be noted the preliminary summertime data show slightly higher halogen concentrations in the region, but the impact of US Magnesium emissions has yet to be assessed as the company has not yet returned to full production status.

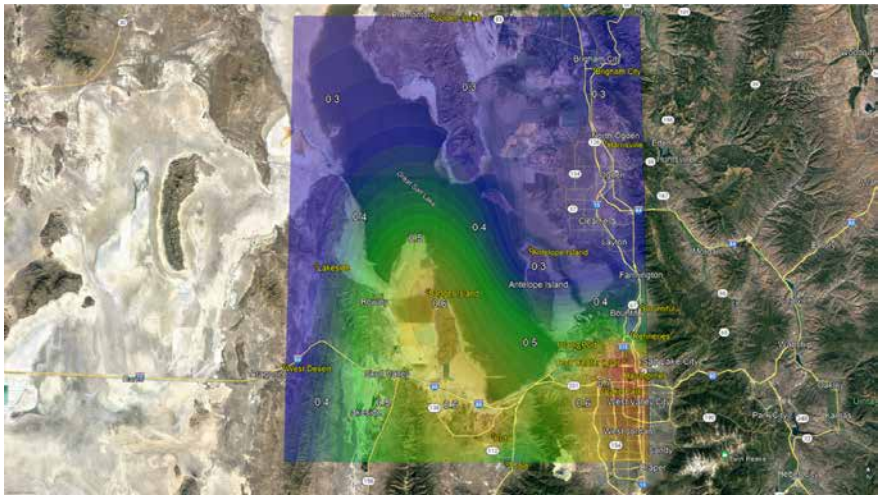


Figure 2: *2023 average wintertime GSL study HCl winter concentrations.*

Advanced Analytical Support for Research Efforts in Environmental Quality

Research Summary:

We develop methods for the analysis of contaminants in the environment in water, soil, and air. These efforts support research efforts of faculty and students at the Utah Water Research Laboratory and various faculty across the USU campus and provides services to State and local agencies regarding evaluating environmental health.

Why this research?

The Environmental Quality Laboratory's (EQL's) mission is to provide technology, expertise, services, and training in advanced analytical science supporting today's water and environmental students, researchers, and stakeholders. Environmental research at the EQL emphasizes an integrated engineering and science approach to the environmental quality of land, water, and air. A multidisciplinary group of engineers and scientists conducts basic and applied laboratory and field research aimed at understanding and finding sustainable solutions to water challenges that occur in the

Figure 1: *Sediment sampling at the Great Salt Lake for potential dust hazards containing arsenic (USGS 104b) (left); Soil and plant sampling from biosolid treated fields for chemicals of emerging concern such as PFAS and pharmaceutical (USDA) (top right); Extraction of DNA to quantify toxic producing cyanobacteria (Utah DEQ) (bottom right).*

Principal Investigators:

Joan E. McLean (PI)
Joshua Hortin (Co-PI)
Xia Li (Co-PI)

Partners/Collaborators:

Local: Departments across USU campus, Bear River Health Department

Geographic Areas:

Study Areas: All counties in Utah

Areas Benefited: All counties in Utah

Contacts:

Joan E. McLean
435.797.3199
joan.mclean@usu.edu

Work plan FY 23–24

We will continue to develop advanced analytical methods to serve the research needs of UWRL faculty and the USU campus. These advanced analytical methods also support various Utah agencies.

innumerable interactions between humans and water. These pressing challenges include: monitoring and preventing harmful algal blooms and cyanotoxin production; evaluating cyanobacteria DNA presence as early warning of cyanotoxin release; assessing the fate and transport of pharmaceuticals, personal care products, and fluorinated substances in biosolids from wastewater treatment applied to soils and crops; evaluating the geochemical cycling of arsenic in Great Salt Lake sediments under wetting and drying conditions with potential for transport in dust; investigating the breakdown of plastics and microplastics in the environment; monitoring pollutant loading from stormwater; and other urgent matters that arise.

Benefits to the State

We provide advanced analytical support to researchers across the USU campus and to state and local agencies.

What we did

Methods under development include nano- and micro-plastic analysis in environmental samples, single particle analysis of nano materials in plant-soil systems, cyanotoxin sampling and analysis in air, DNA analysis as a tool for early warning of harmful algal blooms.

Analytical procedures have been developed for pharmaceutical and personal care products (PPCPs) in water, soil, and plants; per- and polyfluorinated alkyl substances (PFAS) in water, biosolids, soil, and plants; cyanotoxins in drinking and ambient waters; plant and rhizosphere metabolites; low detection limits for nutrient (P and N) in water, and trace element analysis.

Methods have been developed for faculty researchers in the departments of Natural Resources, Chemistry, Civil and Environmental Engineering, Biological Engineering, and Plants, Soils and Climate, as well as for the Bear River Health Department and the Utah Department of Environmental Quality.

Figure 2: *Water and aerosol sampling from Utah Lake for cyanotoxins (USGS 104B).*

Water Treatment and Contaminants of Emerging Concern

RESEARCH SUMMARY:

Modern society is dependent on the use of plastics. Even with recycling efforts most plastics enter the environment. These plastics break down to small particles that are difficult to remove from waters used as drinking water sources. We are exploring properties of the plastics and water quality to enhance the removal of the small plastics from drinking water using electrochemical methods.

Why this research?

Conventional drinking water and wastewater treatment systems are not designed for the safe removal/disposal of contaminants of emerging concern. These contaminants include pharmaceuticals and personnel care products, poly- and per-fluorinated alkali substances (PFAS), flame retardants, metal containing nanoparticles, and micro- and nano-plastics. The present research is focused on the removal of nano-plastics (NP) from drinking water supplies using electrocoagulation.

Benefits to the State

Drinking water treatment for the removal and safe disposal of emerging contaminants is a critical need across the State of Utah.

What we did

Conventional water treatment has used chemical addition, such as alum, to remove suspended solids though coagulation and flocculation followed by sedimentation and filtration. Electrochemistry is employed in electrocoagulation with Al- or Fe- electrodes acting as the anode for oxidation of the metal electrode to Al^{3+} or Fe^{3+} and the cathode for the reduction of water producing hydroxide and hydrogen gas (Fig 1). The removal process follows the same principals as conventional coagulation technology but is more effective at removing small particles such as NPs. The effectiveness of electrocoagulation is dependent on the type of plastic, water quality parameters, and selected electrochemical conditions. We are optimizing electrochemical conditions for effective and efficient removal of NPs in waters of Utah.

What we found

Preliminary data support the effectiveness of electrocoagulation for removal of NPs from drinking water sources. Under our test conditions, water quality parameters are critical for the effective removal of NPs whereas

PRINCIPAL INVESTIGATORS:

Joan E. McLean (PI)
Yiming Su (Co-PI)

STUDENTS:

Emmanuel Aduhene (MS)

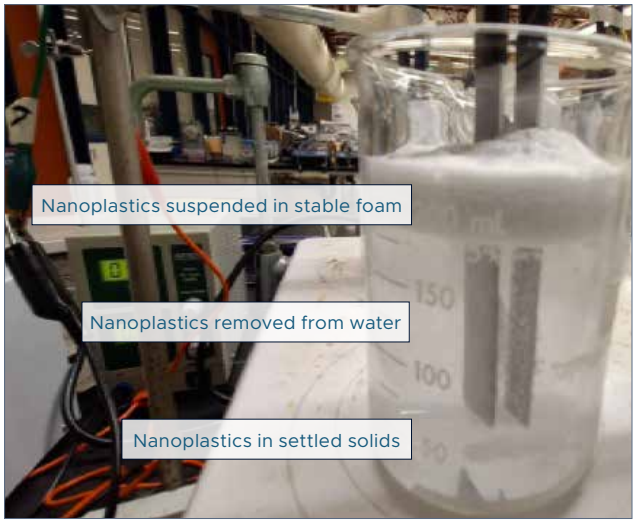
GEOGRAPHIC AREAS:

Study Areas: all counties in Utah.

Areas Benefited: All counties in Utah

CONTACTS:

Joan McLean
435.797.3199
joan.mclean@usu.edu



Left electrode:
$Al = Al^{3+} + 3e^-$

Right electrode:
$2H_2O + 2e^- = 2OH^- + H_2$

$Al^{3+} + 3H_2O = Al(OH)_{3(solid)} + 3H^+$

NPs interact with Al^{3+} and $Al(OH)_{3(solid)}$ forming larger particles that are either suspended in the foam or settle out of solution

Figure 1: *Electrochemical reactor to evaluate removal of nanoplastics (NPs) from drinking water.*

electrochemical conditions have minor influence. Coagulation/flocculation reactions are dependent on pH with optimal conditions between pH values of 7.4 to 9. The resulting pH is influenced by the water chemistry of the system.

One challenge with the removal of NPs is our ability to quantify their concentration. Often indirect measurements are used such as turbidity, but samples with below detectable turbidity still contain significant concentration of NPs. New techniques are being developed for characterizing and quantifying the NPs still in solution after electrochemical reactions using dynamic light scattering and single particle-ICPMS (Fig. 2).

Work plan FY 23–24

We will continue to develop methodologies for the detection and quantitation of NPs, along with the optimization of conditions for effective/efficient removal of NPs from drinking water.

Figure 2: *Recently purchased instrumentation to characterize (dynamic light scattering and zeta potential) and quantify (single particle ICPMS) NPs.*

Assessing the Sources, Transport, and Fate of Microplastic in the Logan River Watershed

RESEARCH SUMMARY:

Microplastic pollution is a global threat to human and environmental health. These small plastic pieces are found in nearly every environmental setting (including in remote wildlands), persist for decades to centuries, and elicit toxic responses. Altogether, microplastic pollution is one of the greatest environmental challenges facing society today that has potential to irreversibly disrupt earth system processes at a global scale. This project addresses key unknowns about the amount of microplastics in mountain ecosystems and how they degrade with sunlight exposure.

Why this research?

Microplastic is a growing global issue, yet many aspects of the plastic cycle remain unknown and unquantified. Little is known about the concentrations of microplastics in wildland environments and whether plastics accumulate in or are transported out of mountain ecosystems. Additionally, major unknowns exist related to the degradation pathways of microplastic in the environment. Degradation in the presence of sunlight, referred to as photodegradation, is a potential loss pathway for microplastic, especially in high-elevation remote environments that receive intense solar radiation. However, we know little about how quickly these reactions proceed (photodegradation rates). These knowledge gaps need to be addressed to more completely understand the impacts of microplastic on pristine, remote environments like those found throughout Utah. In this project, we aimed to determine the concentrations and photochemical fate of microplastic in the Logan River watershed as an example of other human-impacted mountainous areas in the Intermountain West.

Benefits to the State

Microplastic exists in many environments, surprisingly even in remote mountainous ecosystems. Yet, we do not know the extent of microplastic pollution (concentrations) and how long microplastic exists there (degradation rates). These are important questions to answer because microplastic may impact these pristine, remote ecosystems. Outdoor recreation is an important part of the State of Utah's national and worldwide identity. At this time, we do not know how microplastic pollution impacts these remote environments that are found throughout Utah's National and State Parks. By studying microplastic fate in these areas, we will answer this question.

PRINCIPAL INVESTIGATORS:

Kyle J. Moor (PI)
Janice Brahney (Co-PI)
Bethany T. Neilson (Co-PI)

STUDENTS:

Shahin Sujon (PhD)

GEOGRAPHIC AREAS:

Study Areas: Logan, UT; Northern Utah

Areas Benefited: Remote Environments in Utah

CONTACTS:

Kyle Moor
435.797.0937
kyle.moor@usu.edu

Publications:

Sujon, SA, A Fabiszak; KJ Moor. *Photochemical Dissolution of Plastics in Natural Waters: Translating Laboratory Aging to Solar Kinetics*. In preparation.

Conference Presentations:

- Sujon, S, KJ Moor. 2023 *Wavelength sensitivities of plastic photodissolution*. Oral Presentation. American Chemical Society National Meeting. Indianapolis, IN. March 2023.
- Sujon, S, KJ Moor. 2023. *Plastic photolysis in surface waters: Connecting laboratory aging to sunlight*. Oral Presentation. USU Spring Runoff Conference. Logan, UT. March 2023.

What we did

In this project, we aimed to determine the concentrations and photochemical fate of microplastic in the Logan River watershed as an example of other human-impacted mountainous areas in the Intermountain West. We developed microplastic sampling methodologies to determine how much microplastic exists in the Logan River watershed and investigated photodegradation rates of microplastic to estimate the lifetime of plastic in the environment. We performed a microplastic sampling campaign in the Logan River watershed along a transect that spans remote headwaters to a semi-urban population center.

What we found

We found microplastic in most samples, with varying concentrations and compositions. This sampling informs laboratory experimental work to measure the photodegradation rates of plastic. We have measured the photodegradation rates of plastic using light-emitting diode (LED) photoreactors, using the production of dissolved organic carbon as a metric to assess the extent of degradation. We have investigated how plastic chemistry—e.g., polyethylene (polymer in plastic bags) vs. polyethylene terephthalate (polymer in water bottles)—changes photodegradation rates.

Work plan FY 23–24

This project is complete.

Figure 1: *Sunlight-weathered polystyrene films showing yellowing with weathering and highlighting the effect of sunlight exposure.*

Figure 2: *Ultraviolet light-emitting diodes used for aging plastic.*

Toxicity Screening of Leachates from Sustainable Plastic Alternatives

Research Summary:

New sustainable materials are needed to replace plastic. These materials need to originate from sustainable resources and present minimal environmental impacts when they degrade. In this project, we studied engineered biocomposites made from natural materials and the chemicals released when in contact with water. We evaluated the toxicity of the chemicals released, providing insight into the environmental impacts of engineered biocomposites as they degrade.

Why this research?

Plastic pollution threatens human and environmental health. An even greater danger than microplastics are the chemicals leached from plastic. When in contact with water, plastics release thousands of unique chemicals. These chemicals originate from the many additives used in plastic formulations, impurities in starting materials, and byproducts formed in plastic processing and during environmental degradation. This complex mixture of leached chemicals, often called leachate, remains poorly characterized with only a fraction of the individual chemicals identified. Even though the exact chemical composition of plastic leachates remains unknown, these leachates possess considerable in-vitro toxicity. Leachates from a wide variety of conventional and biodegradable plastics elicit varying degrees of toxicity.

There is growing interest in replacing conventional petroleum-derived plastic with materials from sustainable resources that degrade to products with minimal environmental impacts. One option is engineered biocomposites made from natural materials such as starch, cellulose, cotton, and wool. While these biocomposites are made from natural materials, little is known about the toxicity of their leachates. This is a critical step that needs to be addressed to ensure that sustainability does not come at the cost of negative environmental impacts.

Benefits to the State

Understanding the impacts and safety of plastics and new plastic-replacing biocomposites will directly impact the lives of all Utahns. Plastics are used in nearly every aspect of life, leading to high levels of exposure. By studying the toxicity of the chemicals released from biocomposites, we can ensure safe use and minimal health impacts to Utahns.

Principal Investigators:

Kyle J. Moor (PI)
Kimberly Hageman (USU, Chemistry, Co-PI)

Students:

Malavige Lamal Jasura Perera (PhD)
Anna Fabiszak (UG)

Partners/Collaborators:

Business/Industry: Dr. Stephen Taylor, Natural Fiber Welding, Inc.

Geographic Areas:

Study Areas: Laboratory research

Areas Benefited: Sunlit surface waters and terrestrial environments

Contacts:

Kyle Moor
435.797.0937
kyle.moor@usu.edu

Work plan FY 23–24

In the future, we plan to build on the baseline toxicity assays and test the toxicity of biocomposite leachates using additional cell-based assays. The next assays will test specific mechanisms such as oxidative stress responses and endocrine disrupting activity. This more complete suite of assays will paint a clearer picture of the toxic responses of biocomposite leachates.

What we did

We explored leachate generation from biocomposites when weathered under ultraviolet (UV) light exposure. We then assessed the baseline toxicity with a widely used cell-based assay to test toxic effects. We generated dose-response curves to calculate inhibitory concentration (IC50) values, a common metric to compare toxic responses of different chemicals.

What we found

We found that biocomposites generated leachates that possessed a baseline toxicity response. Comparing inhibitory concentration values to a known toxic chemical, we found that biocomposite leachates were less toxic. We speculate that biocomposites possess minimal toxic responses for baseline toxicity, but further testing is necessary to fully support this conclusion.

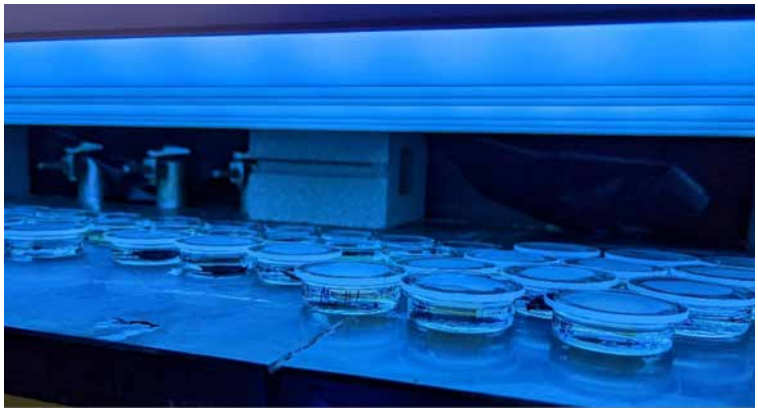


Figure 1: *Biocomposites weathering under UV lamps.*

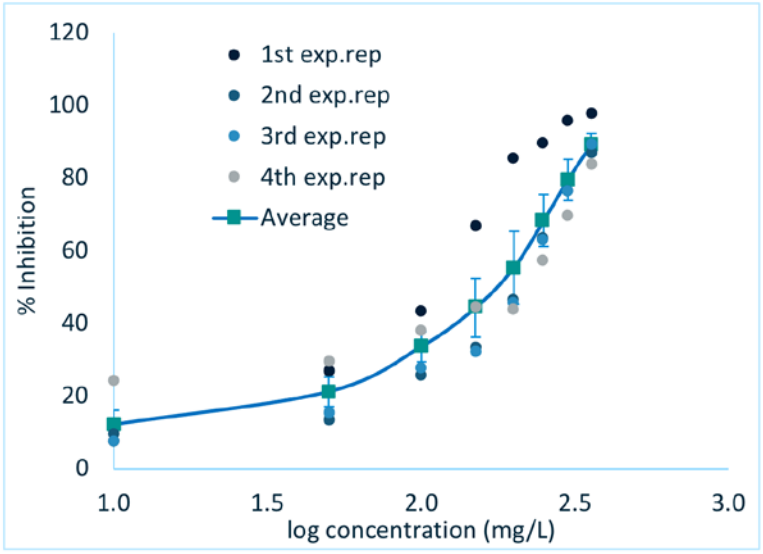


Figure 1: *Dose-response curve for biocomposite leachate. Higher concentrations of leachate induce toxicity and generate inhibition in the toxicity assay. EC50 value, the concentration that represents 50% inhibition, can be seen at 159 mg/L.*

Wildfire Impacts on Surface Water Photochemistry

RESEARCH SUMMARY:

Wildfires or prescribed fires release pyrogenic dissolved organic matter into the environment. This changes the type of organic carbon in surface waters, impacting biogeochemical processes and pollutant degradation. One of the major pollutant degradation pathways it may impact is photodegradation. Pyrogenic dissolved organic matter photochemically produces singlet oxygen in sunlit surface waters. In this project, we explored the singlet oxygen generation abilities of pyrogenic dissolved organic matter.

Why this research?

Wildfires or prescribed fires generate chars and ash, leading to release of pyrogenic forms of organic carbon into the environment. This pyrogenic carbon can be dissolved into surface waters and create pyrogenic dissolved organic matter. This new dissolved material changes the composition of organic carbon in rivers and streams. This will impact many biogeochemical processes and what happens to pollutants that reside in surface waters. One of the key biogeochemical processes that pyrogenic dissolved organic matter may impact is sunlight-driven surface water photochemistry. In surface waters, dissolved organic matter is excited by sunlight and generates reactive species that degrades pollutants, eliminating them from waterways. Pyrogenic dissolved organic matter possesses a different composition than typical dissolved organic matter, common sources include generation from microbes and breakdown of plant material and may have very different capabilities to generate reactive species and degrade pollutants.

Benefits to the State

Utah has largely avoided major wildfires compared to other states in the Western US; however, due to the changing climate, Utah will likely be impacted by larger, more intense wildfires. This project reveals the role of pyrogenic carbon inputs from wildfires on pollutant fate and persistence in Utah's surface waters.

What we did

We explored the generation of singlet oxygen, a reactive species that degrades pollutants in surface waters, from pyrogenic dissolved organic matter. Our samples included wood chars created in the laboratory through controlled

PRINCIPAL INVESTIGATORS:

Kyle J. Moor (PI)

STUDENTS:

Monika Madhiyan (PhD)

GEOGRAPHIC AREAS:

Study Areas: Laboratory research

Areas Benefited: Wildfire-impacted areas of Utah

CONTACT:

Kyle Moor
435.797.0937
kyle.moor@usu.edu

CONFERENCE PRESENTATION:

Madhiyan, M, KJ Moor. 2023. *Singlet Oxygen Production from Pyrogenic Dissolved Organic Matter*. Oral Presentation. American Chemical Society National Meeting. Indianapolis, IN. March 2023.

combustion and real wildfire wood char. We leveraged state-of-the-art time-resolved singlet oxygen phosphorescence to measure the quantum yields and kinetics of singlet oxygen.

What we did

We found that pyrogenic dissolved organic matter possessed similar singlet oxygen generation abilities as plant- and microbe-derived dissolved organic matter. Overall, we found that the input of pyrogenic dissolved organic matter following wildfires will not strongly impact pollutant degradation processes that are mediated by singlet oxygen.

Work Plan FY 23–24

This work revealed significant differences in observed ability to generate singlet oxygen based on experimental technique. In the next year, we will directly compare our novel measurement technique (time-resolved singlet oxygen phosphorescence) to chemical probes, the standard approach to measure singlet oxygen in surface waters.

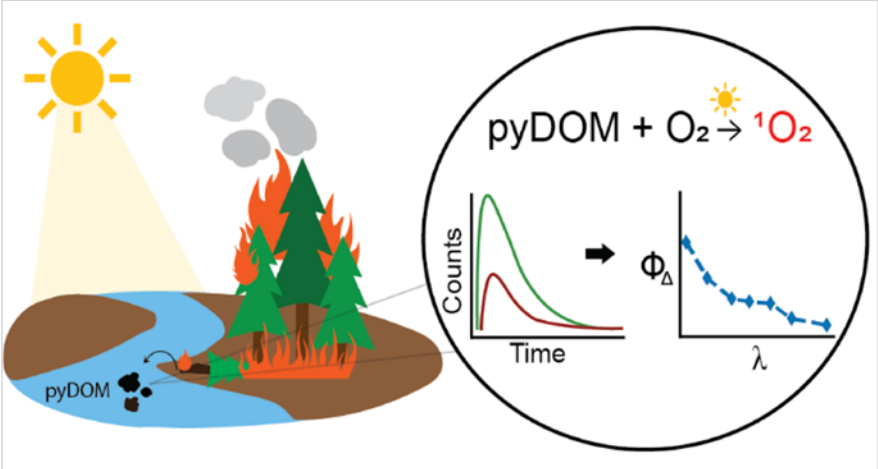


Figure 1: *Schematic illustrating pyrogenic dissolved organic matter (pyDOM) input following wildfires and resulting singlet oxygen production.*

Mitigation of Methane Emissions from Anthropogenic Sources

RESEARCH SUMMARY:

The use of Methylotuvimicrobium alcaliphilum, a methane-degrading microorganism, for the bioremediation of methane (CH_4), looks to be one of the most promising methods of reducing the negative environmental impacts of CH_4 emissions while simultaneously providing an economic incentive through the production of ectoine, a high value by-product. Ectoine is used as an active ingredient in skin care and sun protection products.

Why this research?

Increasing atmospheric greenhouse gas (GHG) concentrations have necessitated development of methods to not only reduce GHG emissions, but also to increase GHG treatment. Because of their large quantity, carbon dioxide (CO_2) emissions receive most of the attention given to GHGs. However, CO_2 is not the most potent GHG. Pound for pound, methane (CH_4) is over twenty-five times more effective than CO_2 at trapping heat in the atmosphere over a 100-year period. CH_4 is the second largest contributor to the total global atmospheric greenhouse effect, accounting for approximately 20 percent of global emissions on a CO_2 equivalent basis. Globally, CH_4 emissions in 2020 were estimated by the EPA to be 9,390 million metric tons of CO_2 equivalent.

Atmospheric CH_4 levels reached above 1850 ppb in 2018, over 2.5 times higher than the estimated pre-industrial equilibrium value in 1750. The large increase in the atmospheric concentrations in that time frame can be mostly attributed to anthropogenic emissions, which include agriculture, energy industry, and waste from homes and businesses, among other sources. With regards to waste from homes and businesses, CH_4 is generated as waste decomposes in landfills and wastewater treatment, as well as in composting.

Anthropogenic CH_4 emissions are difficult to treat. In this project we are investigating the efficacy of a potential method to mitigate the impacts of methane produced from anthropogenic sources such as landfills, wastewater treatment sites, energy production, mining, and agriculture. Unfortunately, research is lacking regarding the upscaling of *M. alcaliphilum* cultures to an industrial scale. The purpose of this research is to test upstream and downstream techniques at bench-scale (10 L) to better understand the feasibility and efficiency of industrial conversion of CH_4 gas to ectoine.

Benefits to the State

This project will directly benefit the State of Utah by targeting local anthropogenic methane sources such as landfills and wastewater treatment

PRINCIPAL INVESTIGATORS:

Judith L. Sims (PI)

Ronald Sims (Biological Engineering, Co-PI)

Charles Miller (Biological Engineering, Co-PI)

STUDENTS:

Jaden Storrer (MS)
Ethan Rico (BS)
BoDee Hancock (BS)

PARTNERS/COLLABORATORS:

Local: Issa Hamud, Environmental Director, City of Logan

Industry: Phillip Heck, General Manager, Central Valley Water Reclamation Facility

GEOGRAPHIC AREAS:

Areas Benefited: Methane emitting facilities and sources throughout the State of Utah.

CONTACTS:

Judith L. Sims
435.797.3230
judith.sims@usu.edu

Ronald Sims
435.797.3156
ron.sims@usu.edu

POSTER PRESENTATION:

Storrer, J, C Miller, R Sims, J Sims, E Rico. 2023. *Upscaled Valorization of Methane into Ectoines*. Annual Conference, Institute of Biological Engineering, Aimes, IA, April 13-15.

PROJECT VIDEO:

Storrer, J. 2023. Bioprocessing Animation. Student project, informational training video.

Work plan FY 23–24

During this FY, we will complete the upstream scale-up experiments using tangential flow filtration and prepare project final reports.

facilities for methane reduction. Potential pilot scale studies of the technology could be applied at locations in Utah include landfills in Cache and Carbon County as well as anaerobic digestors at the Central Valley Water Reclamation Facility located in Salt Lake County.

What we did

During FY 22-23, Cultures of *M. alcaliphilum* were successfully grown in a 10 L system using methane as the sole carbon source. We developed an air and methane gas-mixing system to deliver gas to the reactor at approximately 4% methane concentration (below the Lower Explosive Limit) at approximately 0.7 L/min. Cultures were able to grow to a maximum density of 3.28 ± 0.12 g/L. Cultures were observed to remove anywhere from 20–25% of the methane introduced into the system.

We also made progress in developing a novel downstream process to separate ectoine from the cultures without the need for cell lysis. This method implemented a "bio-milking" process using Tangential Flow Filtration (TFF). "Bio-milking" is accomplished by alternating osmotic shocks from high-salinity to low-salinity environments that impact the bacteria, resulting in release of ectoine from microbial cells into the media for easier separation and harvesting. Previous literature for bio-milking *M. alcaliphilum* utilized a centrifugation method, which proved successful but is not ideal for scale-up.

What we found

Bio-milking with TFF proved successful, showing an ability to excrete 51.25 mg ectoine/g dry cell weight (DCW). Cell viability data was also collected for cultures subjected to bio-milking treatment, both TFF and centrifugation, to determine if one method was superior for cell survival. TFF generally had a higher cell survival rate than centrifugation, suggesting it may be ideal for systems that desire to implement cell recycle.

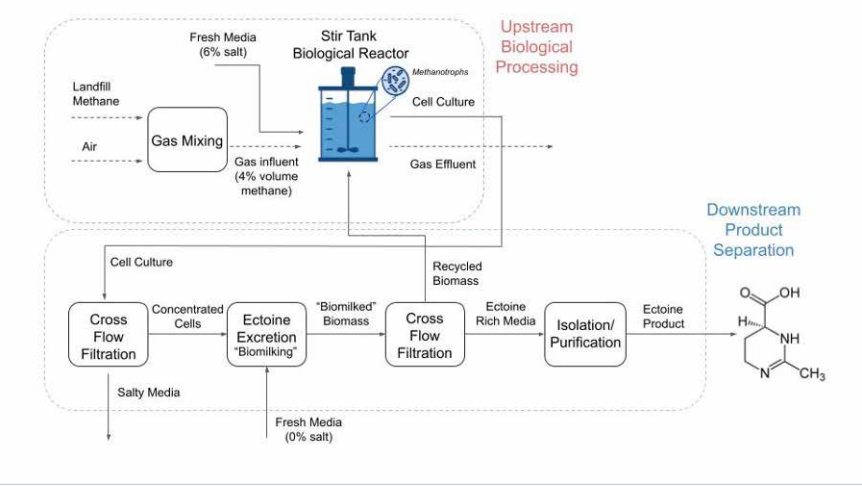


Figure 1: *Preliminary design visual for a M. alcaliphilum based method of landfill gas treatment.*

Aerobic Composting of Wastewater Algae-derived Bioplastics

RESEARCH SUMMARY:

Producing bioplastic materials from plants (algae) will assist in integrating renewable and carbon-neutral materials into society that protect and will enhance human health and the environment. Composting algae-derived bioplastic materials will also add economic value to the compost bioproduct, while maintaining and recycling nutrients within the biosphere. This research project partners with Algix to create a biopolymer using algae cultivated as a biofilm in treating reclaimed water containing struvite, a natural plant fertilizer. This research is determining the rate and extent of biodegradation of algae-based bioplastics infused with struvite. This research will help quantify the potential for struvite-infused algae bioplastics to efficiently compost at water reclamation facilities and add fertilizer value to wastewater-derived compost.

Why this research?

Nearly 34 million tons of plastic waste are generated annually worldwide with 93% of this waste ultimately disposed of in landfills or oceans. Bio-based polymers reduce environmental impact by utilizing renewable carbon sources, while biodegradable plastics reduce environmental damage by easily disintegrating when discarded into the environment. Microalgae feedstocks for bioplastic production can be produced on non-arable land, be used to reclaim wastewater, and increase CO_2 sequestration by enhancing global photosynthetic capacity. The oldest plants on earth, algae, are being used to address problems related to wastewater treatment to reduce nutrients entering lakes, streams, and rivers, and related to the proliferation of plastic materials that resist degradation in the environment and accumulate in marine life and land animals and humans.

Figure 1: *Algae biofilm reactor (RABR) at the Central Valley Water Reclamation Facility. Algae grows as a biofilm on the surface of 100% recycled plastic shelves and is harvested using mechanical scraping with a squeegee.*

PRINCIPAL INVESTIGATORS:

Ronald C. Sims (PI)
Joanna Hou (Co-PI)
Ashton Zeller (Algix, Co-PI)

STUDENTS:

Clayton Lords (MS)

PARTNERS/COLLABORATORS:

National: US Department of Energy Bioenergy Technologies Office (BETO)

Business/Industry: Jim Judd, WesTech-Inc. Environmental Engineering SLC, UT

Phil Heck, Plant Manager, Central Valley Water Reclamation Facility, SLC, UT

Algix, Meridian, MI

GEOGRAPHIC AREAS:

Study Areas: State of Utah and Intermountain West

Areas Benefited: State of Utah water reclamation facilities, including specifically the Central Valley Water Reclamation Facility in South Salt Lake, UT.

Contacts:

Ronald C. Sims
435.797.3156
ron.sims@usu.edu

Conference Presentations:

- Lords, C and R Sims. 2023. *Aerobic Composting of Algae-derived Bioplastic Materials*. Poster presentation at Institute of Biological Engineering (IBE) Annual Conference, Iowa State University. April 13-15, 2023.
- Sims, R. 2022. *Biodegradable Plastics from Microalgae Aerobic Composting*. Presentation at Intermountain Biological Engineering Conference (IBEC), Utah State University. October 28-29, 2022.

Work plan FY 23–24

We will be evaluating more bioplastic materials and conducting testing for 45–90 days. Also, the biodegradable plastic material will be composted at the Central Valley Water Reclamation Facility (CVWRF) through a 3-month cycle used at the site for producing compost at full-scale. The extent and rate of biodegradation at the CVWRF will be quantified and then can be used by the management as input to future management options for composting bioplastic materials.

Figure 2: *One RABR shelf with algae cultivated on recycled plastic support.*

Figure 3: *Harvested algae have a "paste" consistency when removed from the RABR using a rubber-bladed squeegee.*

Figure 4: *Example of a bioplastic product made from algae.*

Benefits to the State

Benefits to Utah for cultivating algae and transforming that biomass into compostable bioplastics include reducing or eliminating nutrients from wastewater that enters Utah Lake, The Great Salt Lake, and other lakes that cause algae blooms, odors, and health risks to the animals and people using these bodies of water for recreation and/or fishing for food. Also, bioplastics can add fertilizer value to composting materials increasing the economic value of the bioproduct.

Figure 5: *Bioplastic made from algae provided by Algix for biodegradation testing.*

What we did

Algae biomass was cultivated as a biofilm "crop" that was used to remove nutrients, including nitrogen and phosphorus, from wastewater. The cultivated algae were sent to Algix to be manufactured into bioplastic materials. The bioplastic materials were then composted at Utah State University using aeration and mixing that simulated composting operation at the largest water reclamation facility in the state of Utah, the Central Valley Water Reclamation Facility located in South Salt Lake, Utah. The amount of biodegradation was determined by the amount of CO_2 produced over time, and the CO_2 produced can be used as a feed to algae to cultivate more algae through carbon sequestration.

What we found

Biodegradable bioplastic material demonstrated significant biodegradation that was indicated by the generation of more CO_2 over a 35-day period of composting. Testing will continue until CO_2 production ceases so that the extent and rate of biodegradation can be quantified.

Assessment and Modeling of Cyanotoxin Presence and Occurrence Risk in Utah Surface Waters

Research Summary:

During this project, we extensively reviewed modern literature on the modeling of cyanobacteria blooms and toxin production. We have also carried out laboratory experiments to assess the importance of environmental factors on the production of toxins in cultures of the cyanobacteria *Microcystis spp*., commonly found in Utah water supply and recreational reservoirs.

Why this research?

Cyanotoxins are chemicals and chemical classes that are produced by cyanobacteria found primarily in lakes, oceans, and reservoirs. Many cyanobacteria are abundant in Utah lakes and reservoirs that have an excess of the nutrient phosphorus, especially in the late summer and autumn. The cyanotoxins are among the more potent natural poisons among those that affect the nervous system and liver function in mammals, including humans. Some evidence suggests links between cyanotoxins and neurological disorders such as Lou Gehrig's disease. At a recent meeting of State water administrators, cyanotoxins were listed as one of the top three concerns in drinking water systems nationwide.

Although cyanotoxins have been known since the 19th century studies on their presence in drinking water supplies and the subsequent risk to water consumers are relatively few. A key part of the proposed project is to assess the perceived need for information on the part of public utilities and the actual data needed to carry out assessment of the cyanotoxin risk in Utah. Using survey data from those utilities, we identified and investigated current and anticipated problems with source waters.

Cyanobacteria blooms have been reported in several Utah reservoirs used for drinking water supplies (e.g., Scofield Reservoir in Carbon County and Pineview Reservoir in Weber County), and additional water suppliers have noted cyanobacteria blooms in late summer and fall in their source waters. The EPA published results of a 2007 lake survey in which 8 of 28 Utah reservoirs sampled had a moderate to high risk for exposure to cyanotoxins.

Benefits to the State

Specific benefits to Utah include (1) guidance for development of long-term monitoring programs for cyanotoxins, (2) preliminary data collection and database development for cyanotoxin-related information, and (3) an assessment of the current risk of cyanotoxins in water supplies along with identification of problem supplies that are at risk of increasing cyanotoxin presence.

Principal Investigators:

David Stevens (PI)
Joan McLean (Co-PI)

Students:

Brent Jacobson (MS)

Technician:

Marissa Li

Partners/Collaborators:

Local: Brigham City, UT
Scofield, UT
Pineview, UT

State: Kate Naleway, Utah Division of Water Quality

Eva Nieminski, Utah Division of Drinking Water

Grant Koford, Bear River Health Department

Geographic Areas:

Study Areas: Weber County

Areas Benefited: Drinking water utilities statewide will benefit from this work

CONTACTS:

David Stevens
435.797.3229
david.stevens@usu.edu

PUBLICATIONS:

Echard, J. 2021. *A review of harmful algal bloom prediction models for lakes and reservoirs*. All Graduate Plan B and other Reports. 1519. https://digitalcommons.usu.edu/gradreports/1519

Work plan FY 23–24

We are preparing to carry out PCR/QPCR analysis to identify which specific genera and species of cyanobacteria are present in the culture, which will help to inform future experiments.

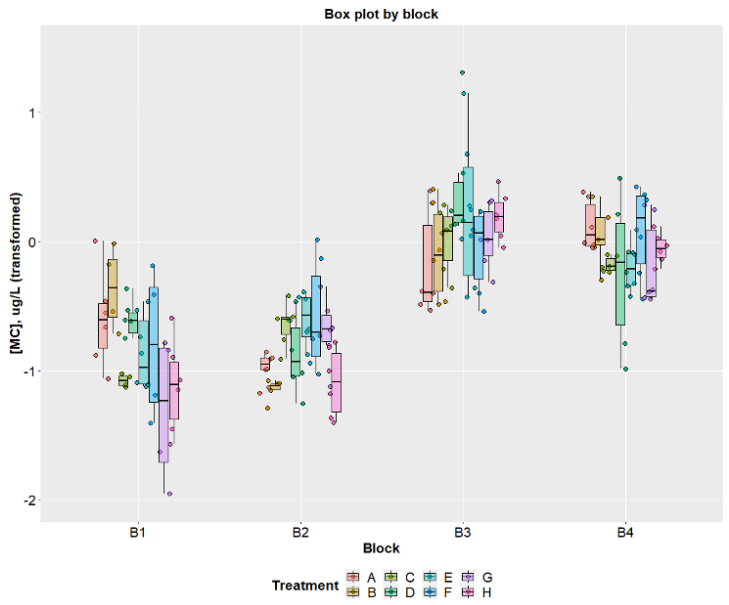
We will be completing laboratory experiments in August 2023 and statistical analysis will be carried out on the results. The MS student will complete his thesis in December 2023. The remainder of the tasks to develop a decision support tool will be completed by July 2024.

What we did

The literature review of mathematical models for cyanobacteria growth and cyanotoxin production is complete. We have been working with the State of Utah and the Bear River Health Department to monitor, identify cyanobacteria in Utah waters, and assess the levels of toxin in recreational waters and drinking water supplies. The Division of Water Quality carried out an extensive cyanobacteria monitoring program at many Utah reservoirs and lakes and, at our request, obtained samples of cyanobacterial blooms for isolation of individual cyanobacterial species. By microscopic analysis, we confirmed the presence of three toxin-production species. The samples of cyanobacteria blooms from DWQ were used to identify types of cyanobacteria, and to try to isolate specific types of organisms for growth in microcosms. Serial dilution techniques were used for the isolation.

What we found

In Bear River Health Department samples, we measured the toxins *anatoxin-a*, *microsystins*, and *cylindrospermopsin* from May–September in 6 lakes and reservoirs. The data for these samples show that for most cases the concentrations of cyanotoxins were below detection limits, except for anatoxin-a in Mantua surface waters, and in two systems (Mantua and Pioneer Park) where levels of *microcystins* were high enough to cause concern. Attempts to develop static cultures were not successful for any of the dilutions. However, later shake cultures are sustaining growth with simulated sunlight over 50% of the day and have been subjected to considerable visual examination. Monitoring at Mantua and other lakes and rivers in Cache, Box Elder, and Rich counties resumed in spring 2022 (after lake thawed). We have been culturing cyanobacteria native to Pineview Reservoir (microcystis spp.), to prepare stock cultures for kinetics experiments. The result of those studies will be an improved kinetic model for growth and toxin production from the cyanobacteria types listed above.



Monitoring for Assessment of Cyanobacterial Hazards in Five Drinking Water Reservoirs in Utah

Research Summary:

This work gathered information about cyanotoxicity observation in Utah recreational and water supply reservoirs for the purpose of helping managers decide if taking action to protect public health is warranted. We observed cyanotoxins, presence of toxin-producing bacteria, and environmental conditions in order to relate toxins to those conditions.

Why this research?

The State of Utah has observed harmful cyanobacterial blooms (HABs2) with increasing frequency as climate warms. Most famously, Utah Lake (Utah County), though not a drinking water supply, experienced widespread cyanobacterial blooms in the summer of 2016, prompting closure of recreational activities on the lake due to nutrient excess. Other reservoirs that are used for water supplies have experienced a large number of blooms as well, including in Pineview, Scofield, and Starvation reservoirs, which serve nearby urban populations. These blooms have prompted expansion of the State of Utah Division of Water Quality's monitoring program (https://deq.utah.gov/water-quality/monitoring-water-quality) for key reservoirs in order to protect drinking water supplies, while county health departments have also increased monitoring for bathing beaches and other recreational uses of nondrinking water supplies. Due to the difficulty in predicting the onset of cyanobacteria blooms and cyanotoxin production, better methods of designing monitoring systems will benefit monitoring agencies like the DWQ and local utilities, ultimately better protecting public health and minimizing costs.

Benefits to the State

The primary result of this project will be a set of tools and protocols for developing monitoring programs tailored for specific Utah drinking water reservoirs and conditions using the literature and existing monitoring data. These design tools will be developed to be adaptable to the types of reservoirs found in Utah and the Intermountain West. The deliverable will enable water utilities to design and adapt monitoring programs to current conditions so that management decisions can be identified and action taken to protect public health.

What we did

The first objective was to establish working partnerships with surface water supply utilities in Utah that are subject to cyanobacteria blooms and to protect water treatment plants and the public from the worst of their

Principal Investigators:

David Stevens (PI)
Joan McLean (Co-PI)

Students:

Brent Jacobson (MS)

Partners/Collaborators:

Local: Brigham City, UT
Scofield, UT
Pineview, UT

State: Kate Naleway, Utah Division of Water Quality

Eva Nieminski, Utah Division of Drinking Water

Grant Koford, Bear River Health Department

Geographic Areas:

Study Areas: Utah reservoirs

Areas Benefited: Drinking water utilities statewide will benefit from this work

Contacts:

David Stevens
435.797.3229
david.stevens@usu.edu

Media Coverage:

NBC News (Article): https://www.nbcnews.com/health/health-news/toxic-bacteria-algae-water-zion-national-park-rcna97845. April 2, 2023.

effects, namely toxin production. We accomplished this by collaborating with an ongoing project between the UWRL and Utah Water Quality and Drinking Water Divisions for sampling and analysis of toxins and genetic identification of toxin-producing bacteria. The second objective was to fully understand the current cyanobacteria situation by gathering existing water quality data in a consistent searchable format from sources as disparate as the utilities themselves, the Water Quality Division of the State DEQ, citizen scientists' data, and monitoring results from the project, and through discussions with plant managers and operators, monitoring staff of the utilities and the Utah Water Quality and Drinking Water Divisions and other state and national experts. This work is ongoing and is supported by the UWRL. Third, we will set up and execute a monitoring program using our best judgement and modify that plan by incorporating data collected during this project. Finally, the information collected will be used to create updateable monitoring tools tailored to the utility, using statistical methods for adapting to new conditions and extending the protocols to other utilities. The last two objectives are also ongoing.

What we found

The work is ongoing; however, the USU's collaboration with UDEQ has already resulted in a large database of environmental conditions and cyanotoxins in many Utah lakes and reservoirs.

Work plan FY 23–24

At the conclusion of the monitoring program in November 2023, we will complete data assessment and will combine these results with work carried out since 2016 to create decision guidance for water utilities and recreation managers for action when cyanobacteria and cyanotoxins may present public health problems.

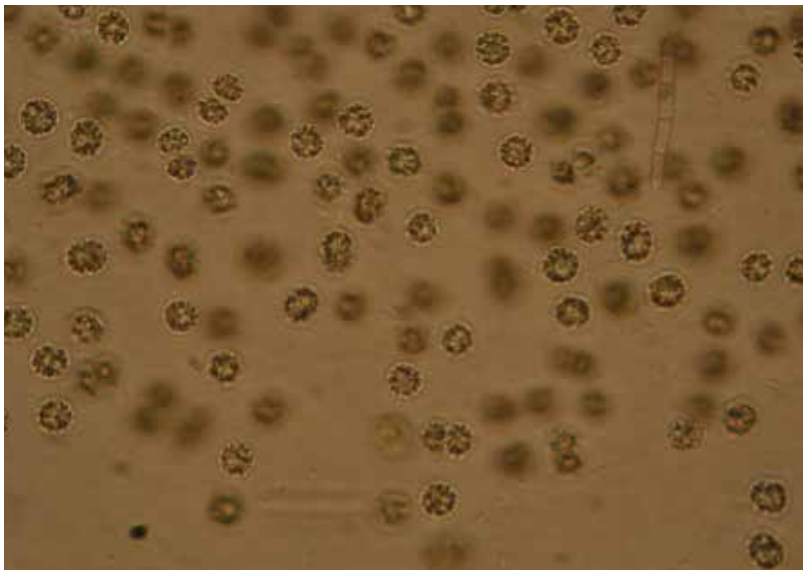


Figure 1: *Cyanobacteria under a microscope.*

Applications and implications of nanoparticles in environmental and agricultural practices

RESEARCH SUMMARY:

This projects developed analyzing methods for detecting and quantifying nanoplastics from water, soil, plant samples; removed nanoplastics in drinking water treatment systems through both conventional and innovative processes; investigated the effectiveness of biochar for remediating nanoplastic pollution in soil and improving crop yield; and developed nanofertilizer to enhance nutrient supply and plant resistance to drought.

Why this research?

Nanoplastics (NPs), defined as plastic particles one dimension smaller than 1 μm, have become an increasingly urgent issue in drinking water system, and agroecosystems due to their potential accumulation in crops and the food chain. Since they have been demonstrated to accumulate in liver, kidneys, and guts of mice and even humans, and pose a health risk, it is important to assess such pollution in Utah's water and soil.

Utah's drinking water systems have various water sources, such as groundwater, springs, creeks, and reservoirs. While groundwater has low levels of microplastic, surface water has high levels. understanding potential plastic pollution in Utah's source waters is essential. Conventional treatment may fall short of removing nanoplastics, and advanced techniques may be needed. The different operating conditions also affect nanoplastics removal performance. Therefore, a thorough survey is needed on nanoplastics removal in different drinking water treatment plants with the same and/or different types of treatment trains.

NP pollution in soil, especially cropland, remains largely hidden due to the lack of reliable methodology. Microplastics/NPs in soils and croplands result from plastic mulch films, irrigation water (especially reclaimed municipal wastewater) soil amendments (i.e., sludge, compost, and other MPs/NPs contaminated biomass), and atmospheric deposition. Unfortunately, MPs/NPs pollution has not been regulated. Sustainable agriculture has become increasingly critical due to dramatic weather changes. Droughts have recently imposed huge food security issues around the world, thus, maintaining and improving crop yield under drought stress is essential. Nanoparticles (NPs) have been promoted as novel fertilizers with potential to address current problems of efficiency, environmental pollution, etc., and are reported to be able to increase water retention significantly. Innovating nanofertilizers for high nutrient use efficiency and water retention capacity can help minimize environmental pollution and maximize benefits to plants under drought stress.

PRINCIPAL INVESTIGATORS:

Yiming Su (PI)

STUDENTS:

Junjie Tang (PhD)

Marwa Rabie Ahmed (Beni-Suef University, Egypt)

GEOGRAPHIC AREAS:

Study Areas: Utah

Areas Benefited: worldwide application

CONTACTS:

Yiming Su
435.797.1534
yiming.su@usu.edu

PUBLICATIONS: (SELECTED)

- Elkobrosy D, AA Al-Askar, H El-Gendi, Y Su, R Nabil, A Abdelkhalek, S Behiry. 2023. *Nematocidal and Bactericidal Activities of Green Synthesized Silver Nanoparticles Mediated by Ficus sycomorus Leaf Extract*. Life, 13(5):1083. https://doi.org/10.3390/life13051083
- Soliman SA, AA Al-Askar, S Sobhy, MA Samy, E Hamdy, OA Sharaf, Y Su, SI Behiry, A Abdelkhalek. 2023. *Differences in Pathogenesis-Related Protein Expression and Polyphenolic Compound Accumulation Reveal Insights into Tomato–Pythium aphanidermatum Interaction*. Sustainability, 15(8):6551. https://doi.org/10.3390/su15086551

- Y Su, X Zhou, H Meng, T Xia, H Liu, P Rolshausen, C Roper, JE McLean, Y Zhang, AA Keller, D Jassby. 2022. *Cost–benefit analysis of nanofertilizers and nanopesticides emphasizes the need to improve the efficiency of nanoformulations* for widescale adoption. Nature Food, https://doi.org/10.1038/s43016-022-00647-z

PATENT

Patent submitted 08/2023 to USU: *Mobile electro-redox-adsorption module for water purification.*

MEDIA COVERAGE:

- USU today (Article): https://www.usu.edu/today/story/nanotechnology-could-improve-fertilizer-study-from-utah-water-research-laboratory-finds. December 9, 2022.
- KSL (Article): https://www.ksl.com/article/50560446/farming-in-the-future-utah-state-university-lab-develops-nanotech-fertilizer January 22, 2023.

Work plan FY 23–24

We will: (1) continue to develop methods for isolating and quantifying nanoplastics from environmental samples and plants samples, (2) investigate biochar's effectiveness for remediating nanoplastics pollution in soil and increasing crop yield, (3) innovate and optimize treatment unit for nanoplastics contaminated water, and (4) develop nanofertilizers and nanoagents for mitigating nutrient deficiency and drought impact.

Benefits to the State

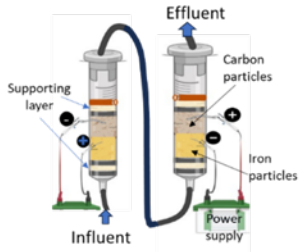
The significant risks to water and food quality from nanoplastics pollution in natural water bodies, drinking water system, and crop land remains unknown in Utah. This research will protect Utah residents from nanoplastic contaminated water and food. The nanofertilizer innovation could help to alleviate the negative impacts of drought and relatively high salinity in irrigation water.

What we did

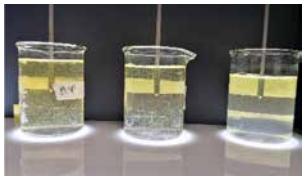
We (1) synthesized nanoplastics in the lab and tested a series of methods and instruments for analyzing nanoplastics from environmental samples; (2) developed an innovative electro-adsorption process for removal of emerging contaminants; (3) ran both conventional and electro-coagulation and flocculation/filtration experiments to investigate the effectiveness for nanoplastic removal; (4) grew the plant in nanoplastic contaminated soil/water with the absence/presence of biochar; ; and (5) analyzed the cost-effectiveness of nanofertilizers from the majority of existing scientific results.

What we found

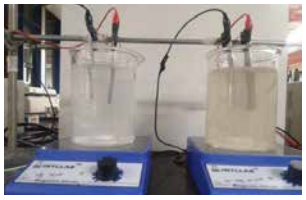
We found that (1) the Confocal-Raman plus Agilent 8900 series inductively coupled plasma-triple quadrupole mass spectrometer (ICP-MSMS) is able to identify nanoplastics; (2) both conventional and electro-coagulation and flocculation/filtration processes are able to remove nanoplastics, but the electro-based process is more efficient.; (3) nanoplastic can translocate from soil/water into plants, and (4) biochar demonstrated some capability to remediate nanoplastic pollution in soil/water, and the nanofertilizer/nanoagent could contribute to sustainable agriculture as it effectiveness improves.



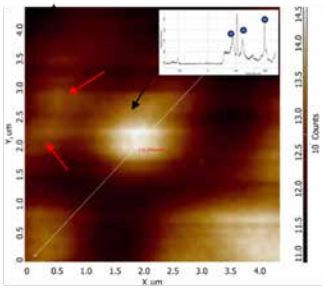
Electro-adsorption process developed in laboratory.



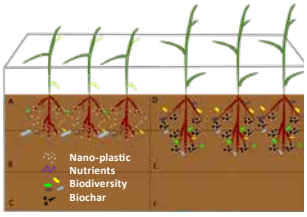
conventional coagulation/ flocculation and sedimentation process.



electro-coagulation/ flocculation process.

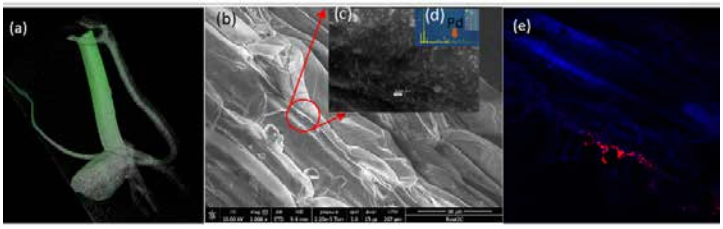


Confocal-Raman nanoplastic detection.



Nanoplastic immoblization by biochar in soil.

Identification of nanoplastics in plant shoots and roots.



Hydraulics

ACTUAL, BUDGETED AND PLANNED EXPENDITURES OF MINERAL LEASE FUNDS

HYDRAULICS: PI	Project Name	Actual FY2023	Budgeted FY2024	Planned FY2025
Bay, J.	Optimizing instrumentation in dams based on potential failure mode analysis	$16,853	$17,359	$17,879
Crookston, B.	Hydraulic Design Guidance for Stepped Spillways	$17,690	$18,221	$18,767
Crookston, B.	Predicting Density-driven Exchange Flows through the Great Salt Lake West Crack Breach	$6,608	---	---
Phillips, C.	Collaborative Research: Separating the Climate and Weather of River Channels: Characterizing Dynamics of Coarse-Grained River Channel Response to Perturbations across Scales	$19,157	$19,731	$20,323
Phillips, C.	High-Resolution River Physical Water Quality Dynamics	$19,157	$19,731	$20,324
Rice, J.	Evaluation of the progression of backward erosion piping: rate of progression and effects of multiple loading events	$28,634	$29,493	---
Tullis, B.	Using computational fluid dynamics for predicting hydraulic performance of arced labyrinth weirs	$19,434	---	---
	New projects		*$50,000*	*$50,000*
	TOTALS	**$127,533**	**$154,535**	**$127,293**

Optimizing Instrumentation in Dams based on Potential Failure Mode Analysis

RESEARCH SUMMARY:

This research will assist dam engineers in both designing and interpreting dam instrumentation. It will also help in dam risk assessments in assessing failure modes relating to pore water pressures and seepage.

Why this research?

Earthen dams are generally instrumented to detect changes in the seepage regime in order to detect the development of potential failure modes related to seepage and internal erosion. In the past, many of the instrumentation plans consisted of randomly placed instruments (generally piezometers) throughout the embankment and foundation. However, in many cases the development of a penitential failure mode only affects a small region around the concentrated seepage and be completely missed by instruments only a few feet away. Therefore, this study aims to provide guidance for designing the instrumentation plans to specifically address the most critical potential failure modes. Such guidance will address the location as well as the type of instrumentation.

Benefits to the State

Utah has a large number of earth dams within its borders, many of which are privately owned and under the jurisdiction of the Department of Water Resources. This information will allow owners and regulators to assess the adequacy of existing instrumentation and, if need be, efficiently design new instrumentation.

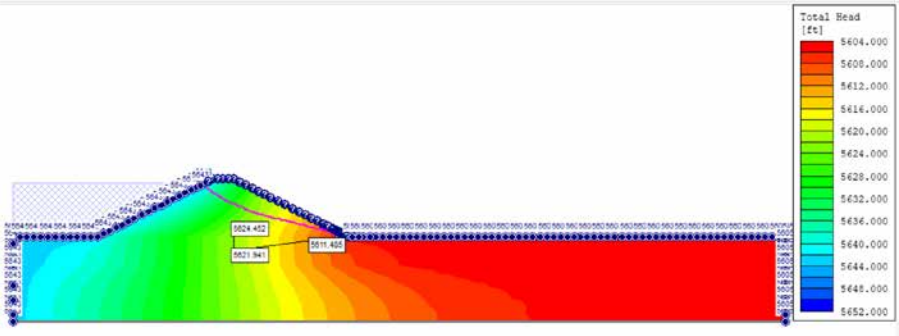


Figure 2: Finite element seepage analysis resulty (total hydraulic head contours) for Hallenbeck Dam in Colorado

PRINCIPAL INVESTIGATORS:

John Rice (PI)
James Bay (Co-PI)

STUDENTS:

Pranish Dahal (PhD),

GEOGRAPHIC AREAS:

Study Areas: Computer modeling project.

Areas Benefited: All areas in Utah with dams where dam owners and regulators needing to design instrumentation programs intended to detect seepage and internal erosion failure modes.

CONTACTS:

John Rice
435.797.8611
john.rice@usu.edu

James Bay
435.797.2947
jim.bay@usu.edu

What we did

While still in the early stages of this research, we have begun the initial study by developing two- and three-dimensional numerical models of existing dams in order to model existing behavior and compare modeled behavior with that observed in the existing instrumentation system. These models, and similar models of real and hypothetical dams, will then be used to determine instrumentation types and locations to address the critical potential failure modes for the dam.

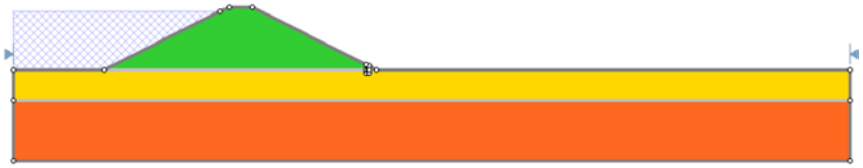
What we found

This project is in the early stages and is expected to produce initial results in the next year.

Work plan FY 23–24

In the following year we will continue to develop seepage models and hypothetical potential failure modes in order to develop the intended guidance. Three existing dams and three hypothetical dams will be analyzed in order to assess the effects of moving instrumentation around in the embankment and foundation. Data from these models will be used to optimize an instrumentation plan for these dams.

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Phi b (deg)	Air Entry (psf)
Embankment		120	Mohr-Coulomb	0	35	0	0
Alluvium		120	Mohr-Coulomb	0	32	0	0
Bedrock		120	Mohr-Coulomb	4000	40	0	0
Drain		120	Mohr-Coulomb	0	36	0	0



Material Name	Color	Model	KS (ft/s)	K2/K1	K1 Angle (deg)	Soil Type
Embankment		Simple	3.28e-07	0.6	0	General
Alluvium		Simple	0.228	0.2	0	General
Bedrock		Simple	3.28e-10	0.2	0	General
Drain		Simple	0.428	1	0	General

Figure 1: Finite element seepage and slope stability model for Hallenbeck Dam in Colorado.

Community Vulnerabilities to Water Disasters

RESEARCH SUMMARY:

The World Meteorological Organization (2021) reported that in the past 50 years more than 8,745 water disasters have impacted communities throughout the globe resulting in 1.1 million reported deaths and $3.1 trillion in economic damages (**https://public.emdat.be**). Storms and floods are by far the most significant of all natural disaster types in event magnitude, number of events, mortality, and monetary losses. Even Cache Valley in northern Utah recently experienced flooding along the Logan and Black Smith Fork Rivers. However, community vulnerability to water disasters is due not only to a changing climate, but also to human generated influences such as urbanization of floodplains and aging infrastructure. Indeed, risk mitigation efforts (such as flood mapping) often do not consider the most recent conditions of a river, the condition of infrastructure in a river reach, nor the effects of sediment on flooding.

Why this research?

Considerable research on flooding has been done at different spatial scales, from field studies and river models for short river reaches or specific communities, to regional and even global flood studies. One of the main outcomes of these efforts is a map identifying the inundation extents and macro hydraulic properties such as flood stage and average flow velocities. It is not uncommon for such maps to rely on pre-scripted generalized map development guidance and for the flood models to be based upon limited terrain and hydrologic information. This leads to variation in the accuracy or reliability of any given flood map and limitations on the usefulness of such results in the context of the aforementioned challenges. Considerable research has also occurred on flood management, such as river restoration efforts to increase natural flood protections and catchment management efforts to reduce runoff during storm events. However, to improve flood management efforts and reduce impacts from flooding, flood studies should be based upon flood models that incorporate the latest river corridor surveys (bathymetry and adjacent terrain), appropriate boundary conditions and roughness, a variety of climatic scenarios, and consideration for infrastructure.

This research study is strongly aligned with the Utah Water Research Laboratory's mission statement and will focus on these research questions:

1. What are the primary characteristics of flood risks in the US by region?
2. Why are US communities and the built environment so vulnerable to

PRINCIPAL INVESTIGATORS:

Brian Crookston PhD, PE

STUDENTS:

Ishwar Joshi (PhD),

PARTNERS/COLLABORATORS:

Local: City of Logan

GEOGRAPHIC AREAS:

Study Areas: Cache Valley and Intermountain West, specifically the Blacksmith Fork and Logan rivers.

Areas Benefited: This research is of benefit to the State of Utah as it focuses on flood hazards and potential impacts from climatic variabilities.

CONTACTS:

Brian M. Crookston
435.797.0247
brian.crookston@usu.edu

WEBSITES:

https://uwrl.usu.edu/hydraulics/

flood impacts, and will this change in the future? Is a new framework needed for the future?

3. Which paths forward are most viable in effectively modeling floods to reduce flood impacts?

Benefits to the State

This research benefits the State of Utah and, in the immediate future, the Cache Valley communities where we are actively mapping flood conditions during the 2023 spring runoff and low flow conditions, are preparing to use remote sensing again in the 2024 spring runoff. Using technology to better estimate flood impacts is of interest to Logan City and others in Utah.

What we did

We are conducting field work along the Blacksmith and Logan rivers. We have compiled flood data and USGS stream gage data for upcoming river flood modeling efforts.

What we found

This project has just begun, but we are already finding the effects of urbanization and climate on flood impacts in Cache Valley.

Work plan FY 23–24

- **Fall 2023**—complete field campaign for 2023.
- **Spring 2024**—prepare river models for flood scenarios and sediment transport modeling and conduct field campaign during peak river flow conditions using remote sensing and UAVs.
- **Summer 2024**—complete initial river flood model efforts and consider publication opportunities.
- **Fall 2024**—Expand efforts to specific cases in the intermountain west.

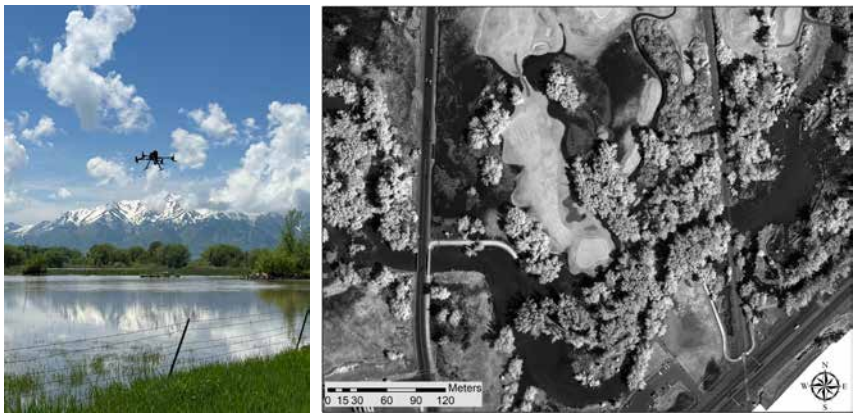


Figure 1: *AggieAir remote-sensing UAS flying the Logan River during spring runoff flooding 2023 (left); the water shows dark in the infrared image (right)*

Predicting Density-Driven Exchange Flows through the Great Salt Lake West Crack Breach

RESEARCH SUMMARY:

Low lake levels at Utah's Great Salt Lake from are posing an unprecedented threat to the lake's ecosystem and the industry it sustains. This project used computational fluid dynamics (CFD) and a deep neural network (DNN) coupled with a physics-based model to quantify and predict the density driven flow of water passing through the West Crack Breach in the causeway that divides the north and south arms of the lake. This CFD modeling quantifies the net flow through the breach to accurately predict the salt balance between the two sides of the GSL and help managers adapt rapidly amid a changing climate.

Why this research?

The Great Salt Lake is of environmental and economic value yet is threatened by various factors including drought and water diversion for irrigation purposes. A railway causeway separates this hypersaline lake into north and south sections that have developed differing salinity levels over time. A breach in the causeway, called the West Crack Breach, allows density-driven flow to pass through. Management efforts are required to preserve this saline lake; such efforts include accurately estimating the exchange flow through the West Crack breach. Within the breach and north of the railroad, a submerged berm allows for management efforts. The berm serves as a control structure for buoyancy-driven flows moving north-to-south. Depending on current or anticipated conditions, the berm can be modified with construction equipment by removing submerged causeway materials or by adding additional materials, thus increasing or lowering the crest elevation of the berm. In this project, we used numerical modeling and field data to quantify and predict flow through the breach.

Benefits to the State

This research is of benefit to the State of Utah as management of the Great Salt Lake requires an accurate estimate of flows passing through this breach, which influences salt-balance models for the lake and decisions linked to salinity for mineral extraction, brine shrimp farming, etc.

What we did

We studied salt exchange through the West Crack Breach via numerical modeling and a field campaign. We investigated two modeling

PRINCIPAL INVESTIGATORS:

Brian Crookston (PI)
Som Dutta (Co-PI)

STUDENTS:

Diana Dunn (MS)

PARTNERS/COLLABORATORS:

State/National: Laura Vernon and Craig Miller, Utah Dept. of Natural Resources

Ryan Rowland and Christine Rumsey, US Geologic Survey

GEOGRAPHIC AREAS:

Study Areas: West Crack Breach, Great Salt Lake

Areas Benefited: Northern Utah

CONTACTS:

Brian M. Crookston
435.797.0247
brian.crookston@usu.edu

Ryan Rowland
rrowland@usgs.gov

Christine Rumsey
crumsey@usgs.gov

approaches for predicting these discharges: a physics-based computational fluid dynamics model and a data-driven artificial neural network model. Publicly available data measured and reported by USGS was used for training the machine-learning neural network model.

What we found

Good agreement was found between both models, and the advantages each provides to water management efforts are noted. Results indicate that, regardless of the modeling tool, accurate field data is invaluable when studying a hydraulic structure.

The CFD model results indicate that indeed the north-to-south flows are influenced by this submerged berm and that either a lowering of the lake elevation or a raising of the berm would decrease such flows. As an additional detail the flows in the streamwise or y direction can exceed 1 m/s with a densimetric Froude number of about 0.7. The CFD results clearly show this denser saltwater plunging beneath the less-dense south-to-north flows as was observed in the Utah State University field campaign for a July 2021 condition.

Work plan FY 23–24

This project is complete.

Figure 1: *The Great Salt Lake's West Crack Breach*

PUBLICATION:

Crookston, BM, M Rasmussen, E Larsen, H Kartchner, and S Dutta. 2022. *Predicting density-driven exchange flows through the west crack breach of the Great Salt Lake Causeway with CFD and ANN*. In Proceedings of 9th International Symposium on Hydraulic Structures. Roorkee, India. October 24-27, 2022, pp. 488-496. https://digitalcommons.usu.edu/ishs/2022/fullProceedings2022/1/

PRESENTATIONS:

- Dutta, S, B Crookston, M Rasmussen, H. Kartchner. 2022. *Modifying the salinity Driven Exchange Flow through the Breach in the Causeway of the Great Salt Lake for Adaptive Management under Changing Climate*. Poster presented at the 2022 American Geophysical Union Fall Meeting, Abstract H22W-1150, https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1199386
- Larsen, E, S Dutta, B Crookston, A Crook. 2022. *Predicting Salinity-driven Exchange Flow at the Great Salt Lake, UT using Machine-Learning in conjunction with Physics-based model*. Oral presentation at 2022 American Geophysical Union Fall Meeting, Dec 14, 2022. Abstract H33A-08, https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1188524

Collaborative Research: Separating the Climate and Weather of River Channels: Characterizing Dynamics of Coarse-Grained River Channel Response to Perturbations across Scales

RESEARCH SUMMARY:

Mountain rivers are critical freshwater sources for drinking water, hydropower generation, recreation, and irrigation. Mountain rivers are highly susceptible to the compound hazards presented by global climate change as increasing precipitation intensity results in more frequent flooding and landslides, while drought enhances the threat of wildfire, vegetation loss, and associated extreme erosion risks. This project aims to develop a physics-based model to assess the sensitivity of mountain river channels to shifting changes in climate, water, and their associated compound hazards.

Why this research?

The scientific and engineering aim for this project is the development of models and toolkits to predict and assess river susceptibility to changes in climate and land use. The results will represent a foundation from which predictive models for assessing river stability will be developed.

Benefits to the State

The state of Utah is facing an uncertain water future as drought results in diminish water resources and increased wildfire risk. Despite limited rainfall, the intensity of rainfall during storms is expected to increase. The compound hazard of increased wildfire and intense precipitation results in extreme erosion, sedimentation, and river instability leading to reductions in water quality within Utah's critical water source regions. Identifying how rivers will respond to these changes and assessing their susceptibility to change will allow for the development of future-looking mitigation strategies.

What we did

We have developed tools to extract river geometry from high-resolution lidar topography allowing for an unprecedented view of river features. These measurements leverage state investments in high-resolution topography and provide the foundation for changing single site field surveys into large data assemblages covering entire river systems. This data analysis effort has resulted in an ability to identify and quantify changes within river systems due to natural variability and changes that resulted in river instability and widespread erosion.

PRINCIPAL INVESTIGATORS:

Colin Phillips (PI)

Claire Masteller (University of Washington in St. Louis, Co-PI)

STUDENTS:

Justin Blaylock (UG)
Forest Van Iwaarden (UG)
Christopher Garner (UG)
Parker Achenbach (UG)
Jill Woodhouse (UG)

PARTNERS/COLLABORATORS:

Local: Logan River Observatory, Native American Summer Mentorship Program

GEOGRAPHIC AREAS:

Study Areas: Primary field areas: Logan and Strawberry Rivers, Utah. Eel River, California. Limited field areas: CA, OR, ID, AZ, UT, WY NM, CO, MT, NE, OK, MO, IA, MI, TN, OH, FL, NC, WV, VI, PA, NY, MA, PR.

Areas Benefited: Rivers and streams especially in areas following disturbances such as wildfire or flooding.

CONTACTS:

Colin Phillips
435.797.0938
colin.phillips@usu.edu

PUBLICATION:

Hosseiny, H, C Masteller, J Dale and CB Phillips. 2023. *Development of a Machine Learning Model for River Bedload*, Earth Surface Dynamics. https://doi.org/10.5194/esurf-11-681-2023

MEDIA COVERAGE:

Viewpoints Radio, *The Effects of Extreme Weather Felt Across the Globe*. December 11, 2022.

CONFERENCE PRESENTATIONS:

- Phillips, CB and C Masteller. 2023. *High resolution channel response to flooding, wildfire and debris flows*, 2023 Land Surface Hazards Modeling Expo, CLaSH. https://www.geoclash.org/2023/03/23/may-1-2-2023-land-surface-hazards-modeling-expo/
- Masteller, C, R Kostynick, G Benitez, and CB Phillips. 2022. *Wiggles in width: Insights into alluvial channel dynamics from variability in high-resolution downstream hydraulic geometry*. GSA Connects, GSA
- Phillips, CB, J Blaylock, J Woodhouse, G Benitez, R Kostynick, and C Masteller. 2022. *An exploration of variability in bankfull river width*. AGU Fall Meeting, Chicago, IL, Dec. 2022. Abstract EP52A-02.
- Kostynick, R, C Masteller, G Benitez, and CB Phillips. 2022. *Quantifying Downstream Variability in Bankfull Width from Digital Elevation Models*. AGU Fall Meeting, Chicago, IL, Dec. 2022 Abstract EP33A-03.

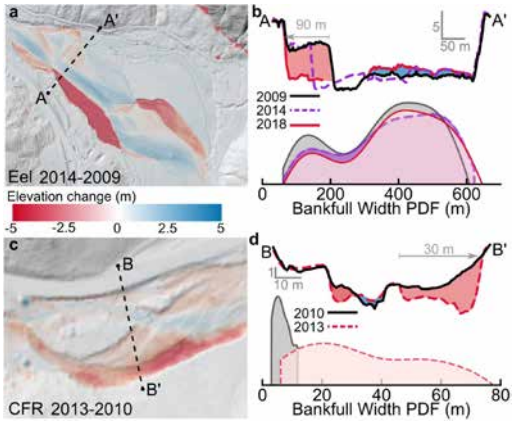


Figure 1: *Data analysis output for the Eel River (a) showing how 90 meters of bank erosion (red) over five years is well within the variability (b) experienced by the river over the river reach. The erosion experienced during the Colorado Front Range floods resulted in complete destabilization of the previous river form and a new channel system (red is new channel while blue shows the previous river).*

What we found

Analysis of the Strawberry River post wildfire and flood revealed that sediment pulses from debris flows posed the greatest risk to infrastructure. While the flood was significant, only river sections with debris flows resulted in significant erosion of roadways. This result was only revealed through the high-resolution data extraction and further highlighted how flooding and sediment hazards may alter risk within a watershed.

Work plan FY 23–24

This project has completed one of three National Science Foundation funded years of work. Ongoing analysis is being automated to allow for the rapid extraction of results to be paired with physical experiments conducted at the Utah Water Research Laboratory to determine the mechanisms that lead to river instability, widespread erosion and increased flooding.

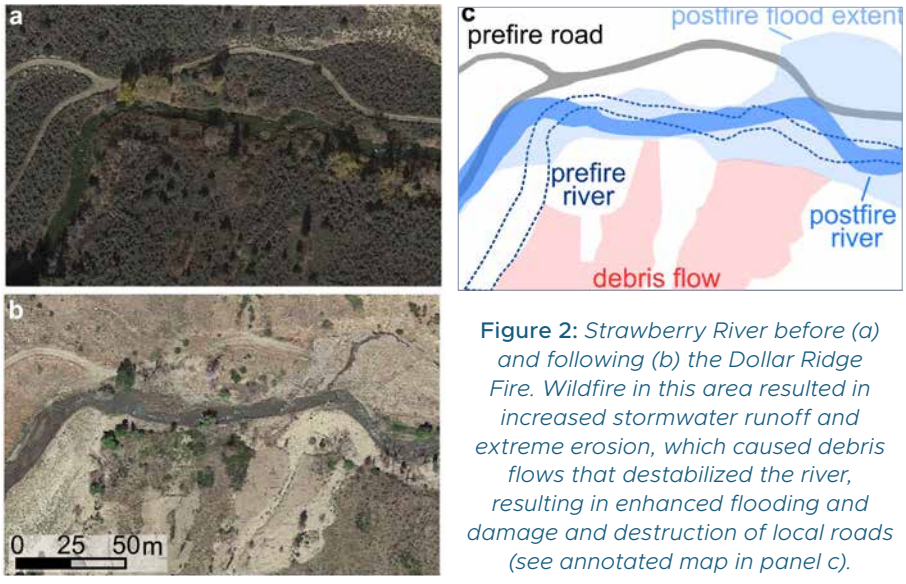


Figure 2: *Strawberry River before (a) and following (b) the Dollar Ridge Fire. Wildfire in this area resulted in increased stormwater runoff and extreme erosion, which caused debris flows that destabilized the river, resulting in enhanced flooding and damage and destruction of local roads (see annotated map in panel c).*

High-Resolution River Physical Water Quality Dynamics

RESEARCH SUMMARY:

This project is developing both physically and geospatially based models to predict the flux and concentration of suspended sediment within Utah's rivers and acraoss the continental United States. When the suspended sediment concentration is too high or low it represents a critical water quality concern and impacts aquatic habitat. High concentrations can also reduce the storage capacity of reservoirs. The model developed provides a strong prediction of the total sediment yield for time spans greater than 1 year, but pooor performance for shorter time periods. Addressing this poor performance is the topic of ongoing work.

Why this research?

Rivers are critical freshwater sources for drinking water, hydropower generation, recreation, and irrigation. The sediment load that rivers carry poses a significant challenge to physical water quality (turbidity) and sedimentation within reservoirs and in-stream structures. Effective river management requires an understanding of the sediment load carried by rivers without the need for extensive costly and time-consuming data collection. The prediction of physical water quality in the face of increasing storm intensity and wildfire risk is an increasingly vital tool to effectively manage fresh water.

Benefits to the State

The prediction of suspended sediment concentration and load within watersheds from limited data and geospatial watershed attributes represents a key step for effective management of physical water quality. These analyses represent the foundation from which predictive models for water quality and reservoir sedimentation can be built. The state of Utah faces an uncertain water future as drought results in diminished water resources, but the limited rainfall is predicted to increase in intensity. This combination of more intense rainfall over drier climates compounded with increasing wildfire results in increased erosion and reduced water quality within the critical water source regions. Prediction and greater understanding of these hazards will allow for the development of successful mitigation strategies.

What we did

Utilizing over 400,000 records of fine sediment we have developed a simple physically based model that demonstrates that rate at which fine sediment is transported is determined by the size of the river (larger rivers carry more material) and the size of the sediment supplied by the watershed. These

PRINCIPAL INVESTIGATORS:

Colin Phillips (PI)

STUDENTS:

Aaron Sigman (MS)

PARTNERS/COLLABORATORS:

State/National: Grand Canyon Monitoring and Research Center

GEOGRAPHIC AREAS:

Study Areas: Clearwater River, ID; Green River and Colorado Rivers within CO, UT, and AZ.

Areas Benefited: Watersheds across the country (+1000 sites).

CONTACTS:

Colin Phillips
435.797.0938
colin.phillips@usu.edu

CONFERENCE PRESENTATION:

Sigman, A and CB Phillips. 2022. *Analyzing Near Channel Inputs to Suspended Sediment Concentration*, Poster Abstract H15L-0936.

Work plan FY 23–24

During the coming year, we will complete a higher resolution geospatial assessment within areas with high resolution sampling and poor model performance to provide thorough test and validation of the suspended sediment yield model. The sites are primarily within the Green and Colorado Rivers within Colorado, Utah, and Arizona.

observations have resulted in a parallel path of inquiry where we have utilized geospatial data to determine how the average concentration of suspended sediment at a US Geological Survey sampling location corresponds to the watershed attributes upstream. The second mode of inquiry has focused on utilizing a limited number of field sites with very high resolution to develop a statistical model from which to predict the total annual or larger yield of suspended sediment delivered from a watershed. The geospatial approach has confirmed that suspended sediment concentration can be reasonably predicted based on geospatial attributes, including climate, soil properties, and watershed elevation (our model describes the color pattern observed in figure 1).

The statistical model used to predict suspended sediment yield, which is the primary culprit in reservoir sedimentation and infilling, was developed in a prior year. The earlier results demonstrated that the probability distributions of suspended sediment concentration followed a similar function across the United States lending significant support to modeling the yield from the function alone. This statistical model is being tested on high resolution data where the 10-year yield for the sampling site is known.

What we found

Currently our results indicate that for timespans greater than 1 year, the model provides a strong prediction of the total yield and provides an over prediction for timescales less than a year. The statistical model can be calibrated based on a limited number of physical samples or using the completed geospatial attribute model and can therefore be applied in a wide variety of settings across Utah and the United States.

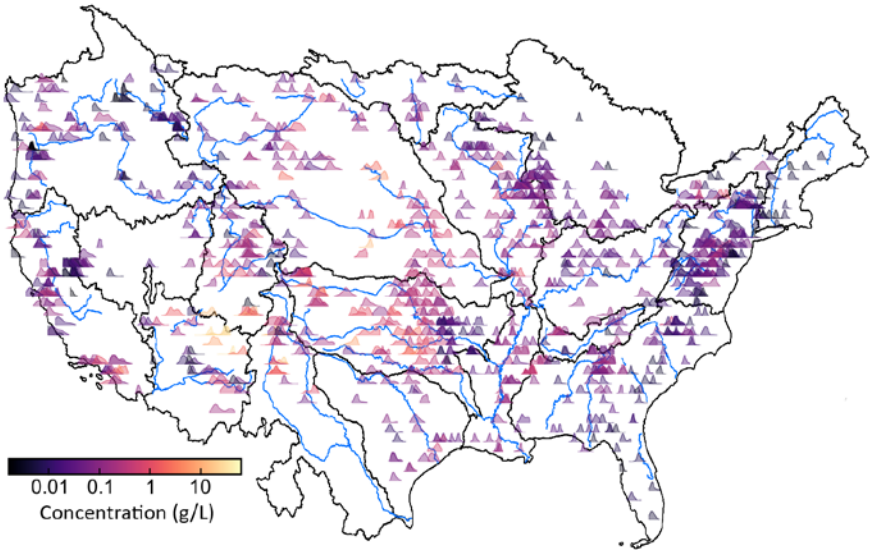


Figure 1: *Suspended sediment database for the United States. Color represents the concentration in grams per liter. The highest concentrations in the nation are located in southern Utah and northern Arizona.*

Evaluation of the Progression of Backward Erosion Piping: Rate of Progression and Effects of Multiple Loadin Events

RESEARCH SUMMARY:

Backward Erosion Piping (BEP) is one of the leading causes of dam and levee failures around the world. This project is using laboratory models to evaluate the rate of BEP progression and the effects of multiple hydraulic loading events (i.e. subsequent flood events on a levee) to evaluate the hazards from BEP. The laboratory device applies a hydraulic load to a circular cell containing approximately one cubic meter of soil. Water flows in from the outside edges of the device and exits through a circular exit on the top of the device. BEP progression is monitored through a Plexiglas cover on the model.

Why this research?

Evaluating the rate at which BEP progresses and the effects of multiple loading events the risk of BEP leading to a dam or levee failure can be assessed with more accuracy. Hydraulic loading on levees and dams is often not a steady-state load and is often quite transient. Thus, the potential for dam or levee failure is often a function of the loading duration and the rate at which the BEP progresses. By understanding how BEP progresses in a range of different soil types, the hazard and risk to these structures can be better evaluated.

Benefits to the State

Backward Erosion Piping (BEP) is one of the leading causes of dam and levee failures around the world. By evaluating the rate of BEP progression and the effects of multiple hydraulic loading events the hazard that BEP represents to dams and levees can be better evaluated.

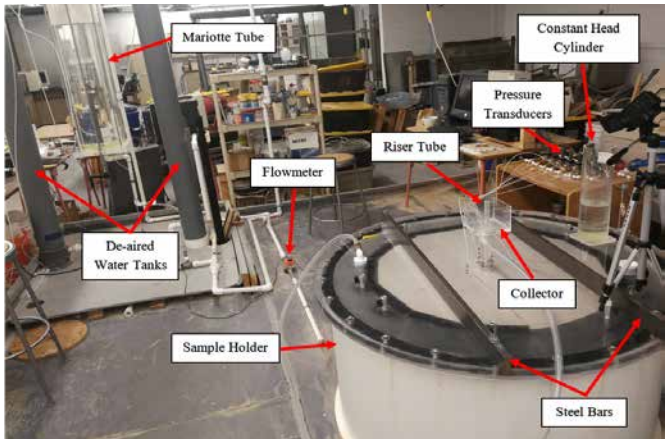


Figure 1. Overview of lab equipment.

PRINCIPAL INVESTIGATORS:

John Rice (PI)

STUDENTS:

Deepika Ghorasaini (PhD)

GEOGRAPHIC AREAS:

Study Areas: Laboratory modeling project

Areas Benefited: Dams and levees at risk of failure due to backward erosion piping

CONTACTS:

John Rice
435.797.8611
john.rice@usu.edu

Work plan FY 23–24

In the next few months, the we will refine the testing procedure to address the effects of multiple loading events. We will then develop a testing matrix to address the effects of different loadings and different soil types. In the coming year we will perform a large number of tests and refine the testing matrix as we see modifications necessary to develop the desired outcomes.

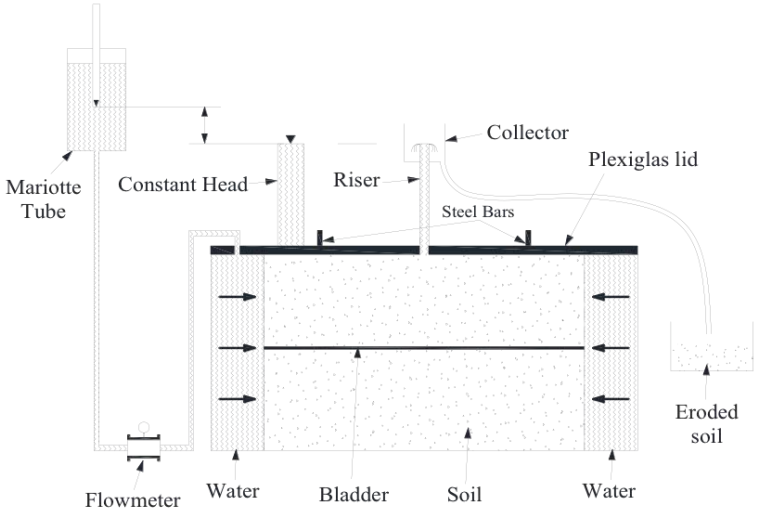


Figure 2. *Schematic of testing apparatus.*

The State of Utah has numerous dams, levees, and canal banks; all of which are susceptible to BEP. Assessing the risk to these structures from a number of different potential failure modes allows for more efficient use of money and resources to maintain and reduce the risk from these structures. This research will provide tools for providing such assessments.

What we did

We are currently in the early stages of the research and have developed the testing device. Initial testing will progress in the next few months after which the full testing program will be developed. The 3D model provided valuable insight to the performance of the structure, beyond the capability of the 1D and 2D models.

What we found

Work is in the preliminary stages. The testing apparatus has been tested and refined and the method for interpreting the results has proved effective in assessing project data. We are now in the process of refining our testing procedure to address the time rate of progression and effects of multiple loading events.

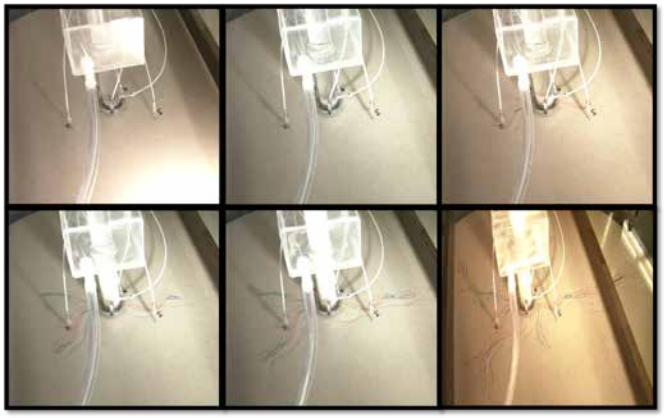


Figure 3. *BEP development with an oblique angle view through the Plexiglas lid from video.*

Using Computational Fluid Dynamics for Predicting Hydraulic Performance of Arced Labyrinth Weirs

RESEARCH SUMMARY:

This study evaluated two computational fluid dynamics modeling software packages for ease of use and accuracy of output compared to laboratory data. The resulting data may be used, with sound engineering judgement, to aid in the future design of arced labyrinth weirs.

Why this research?

As infrastructure continues to age and water resources demands continue to grow, the importance of appropriate and effective hydraulic structure designs is becoming more critical. Arced labyrinth weir design using computational methods is the focus of this study, however, the broader objective was to evaluate the challenges, consequences, limitations, etc. associated with two commercially available computational fluid dynamics (CFD) software packages (i.e., Star CCM+ and Flow3D).

Benefits to the State

The design of hydraulic structures using CFD tools is becoming more and more common in the profession by engineers with variable levels of CFD experience. The outcomes of this study, though not all encompassing and complete, are intended to better inform design engineers regarding CFD software choices.

What we did

We evaluated two CFD software packages in this study: one that is more complex and therefore possibly more challenging to utilize to its full capacity (Star CCM+) and one that is less complex but somewhat easier to learn and implement (Flow3D). This study commented on the ease-of-use and accuracy of output, measured against experimental data collected in the laboratory.

What we found

In general, Flow 3D reproduced the experimental data more accurately than the Star CCM+ for the conditions evaluated and the user-defined settings selected in the study. The user-defined parameters included the size of the computational meshing and various turbulence model alternatives. Note that the statement on modeling accuracy is not a general statement, but rather describes the results observed of this study. The Star CCM+ results were likely limited to the extent of the researcher's knowledge regarding how best to

PRINCIPAL INVESTIGATORS:

Blake Tullis (PI)
Zac Sharp (Co-PI)

STUDENTS:

Shelby Koldewyn (MS)

GEOGRAPHIC AREAS:

Study Areas: Laboratory evaluation project

Areas Benefited: Those considering designing arced labyrinth weirs

CONTACTS:

Blake Tullis
435.797.3194
blake.tullis@usu.edu

PUBLICATION:

Koldewyn, Shelby J. 2023. *Using Computational Fluid Dynamics for Predicting Hydraulic Performance of Arced Labyrinth Weirs*" (2023). All Graduate Theses and Dissertations, Spring 1920 to Summer 2023. 8899. https://digitalcommons.usu.edu/etd/8899

maximize the options/settings in that program. Flow 3D was found to be more user friendly and simpler to learn and implement.

Work plan FY 23–24

This project is complete.

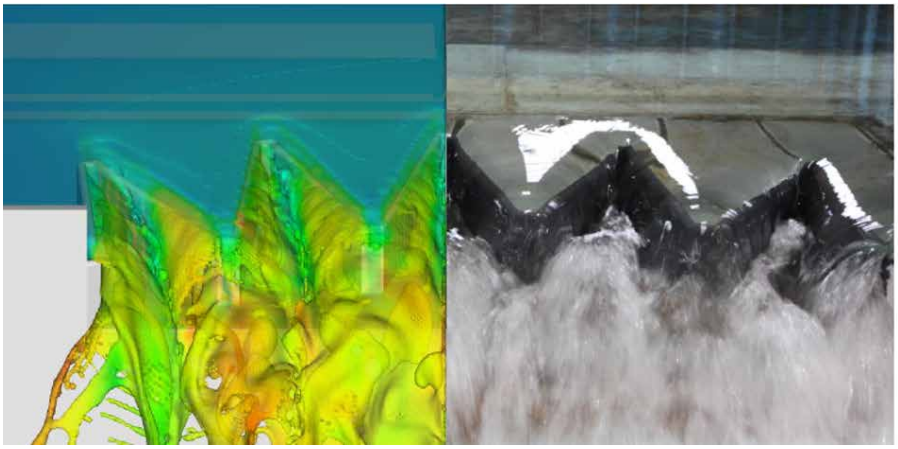


Figure 1: *α=16°: θ=30° H/P=0.4 comparison between numerical and physical nappe and tailwater aeration (Thompson, 2019).*

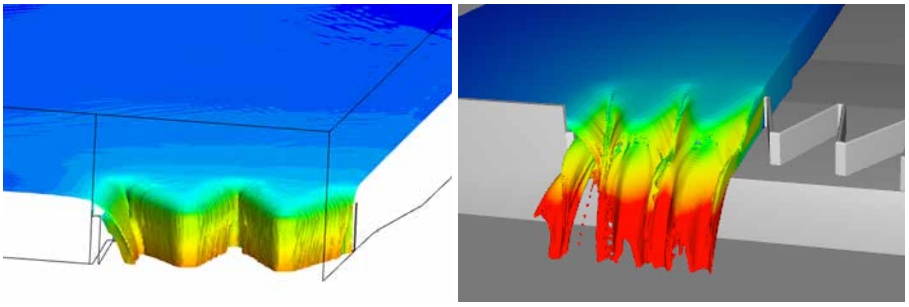


Figure 3. *Nappe aeration behavior observed on the 'distal half cycles' at H/P = 0.5 for the α=16°; θ=10° arced labyrinth weir using (a) Star CCM+ and (b) Flow-3D.*

Measurement, Sensing and Information Systems

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Measurement, Sensing and Information Systems: PI	Project Name	Actual FY2023	Budgeted FY2024	Planned FY2025
Barker, B.	Forage Crop Water Use under Subsurface Drip Irrigation in Utah	$2,237	$2,304	$2,373
Coopmans, C.	Development of Inexpensive UAV for Sensing Land Surface Hydro/Multispectral UAS Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment	$20,402	$21,013	$21,644
Coopmans, C.	Enabling the Use of Short-Wave Infrared (SWIR) for Aerial Drone-Based Water Use Studies Such As Canal Leakage	$20,401	$21,014	$21,644
Gowing, I.	High-Resolution Imagery Flood Mapping along the Logan River and Blacksmith Fork River in Cache County, UT, using UAS	$62,529	$64,405	$66,337
Horsburgh, J.	Hydroinformatics Gap Analysis for the State of Utah Division of Water Rights	$1,848	$1,904	$1,961
Horsburgh, J.	Modernized Standards and Tools for Sharing and Integrating Real-Time Hydrologic Observations Data	$882	$908	$935
Neilson, B.	Logan River Observatory	$110,479	$113,793	$117,207
Torres-Rua, A.	Water Use Assessment in Golf Courses and Urban Green Areas	$51,457	$53,001	---
	New projects		*$47,020*	*$332,482*
	TOTALS	**$270,235**	**$325,362**	**$564,583**

Forage Crop Water Use under Subsurface Drip Irrigation in Utah

Research Summary:

Subsurface drip irrigation (buried drip irrigation) has been considered as a technology to help reduce irrigation water use in Utah. However, there is no data on the water use of these systems for most crops grown in the state. We are measuring irrigation water application and crop water use for subsurface drip irrigation in producer fields in Northern Utah.

Why this research?

Consumptive irrigation water use includes transpiration from plants, evaporation of water from wet plant, soil, and other surfaces, and direct evaporation from irrigation water (for example, sprinkler droplet evaporation). Of these, only transpiration directly contributes to crop growth. Subsurface drip irrigation (SDI) can potentially reduce crop water use by reducing the amount of water evaporated from the soil in a field. However, plant productivity and transpiration may increase under SDI also. There is no data from Utah regarding SDI yield and water use for most crops including hay, pasture, and grain crops. We are collecting data, as we are able and as SDI systems are installed in alfalfa fields in Northern Utah.

Figure 1: *Subsurface drip irrigation tubing during installation. The tubing is fed from a mainline, which is partially buried in the foreground of the photo.*

Principal Investigators:

Burdette Barker (PI)

Justin Clawson (USU Extension, Co-PI)

Michael Pace (USU Extension, Co-PI)

Partners/Collaborators:

USU: Extension

Government: US Geological Survey (104b)

Geographic Areas:

Study Areas: Cache and Box Elder counties

Areas Benefited: Utah and the Intermountain West

Contacts:

Burdette Barker
435.797.3926
burdette.barker@usu.edu

Outreach:

We hosted four workshops on subsurface drip irrigation that indirectly relate to this project.

Benefits to the State

This data will enable growers and State agencies make decisions based on local data regarding the implementation of SDI in Utah.

What we did

We collected water use and yield data in production irrigation fields near Cove, Utah. Because there are very few fields with SDI in Utah, we were only able to arrange measurements in a single alfalfa field with SDI. We also instrumented one of the grower's center pivots for comparison. Measurements included soil moisture, irrigation application, and rainfall. Crop water use will be computed from these measurements.

What we found

To date, we have just completed our first season of data collection on a single field. We do not yet have results to share.

Work plan FY 23–24

In 2024, we will collect data in additional fields. The data will be summarized in Extension fact sheets and through a peer-reviewed journal manuscript.

Development of Inexpensive UAV for Sensing Land Surface Hydro/ Multispectral UAS Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment

Research Summary:

Scientific-quality data is essential in order to manage water and other environmental resources well. In this project, AggieAir, a highly capable aerial remote sensing group, works to provide high-quality information for hydrological and other natural resources management tasks, with development of specific aerospace and drone technology to collect this data, along with other applications.

Why this research?

Many current sources of remote sensing (e.g. crewed aircraft and satellite platforms) are too expensive, have low spatial resolution, or are not activated frequently enough to be practical for many applications. AggieAir is a low-cost, small uncrewed aerial system (sUAS) that fills the need for actionable aerial information by providing low-cost, multispectral aerial imagery and other scientific data quickly and frequently. The AggieAir platform design doesn't need a runway for takeoff and landing, so it can be launched almost anywhere. Although other 'drone' platforms are available on the market, AggieAir remains much more capable and accurate, allowing for better sensed data. Some examples of AggieAir applications include agriculture, riparian habitat mapping, road and highway surface monitoring, wetland mapping, and fish and wildlife tracking.

Benefits to the State

The data AggieAir produces have the potential to help save water in Utah by offering farmers and scientists a low-cost solution to mapping the soil moisture of their crops for more efficient irrigation and natural resource management. This data can also help canal operators to manage water more effectively or wetland managers to manage invasive plant species. If are left unchecked, they can take over native plant species, destroy bird habitat, and use excessive amounts of water. AggieAir can also provide new jobs and economic growth in the state. AggieAir's long-term goal is to eventually create a business in the State of Utah to market this technology. AggieAir brings a focus to Utah's place in aerospace, unmanned systems, and the civil uses for technologies such as remote sensing for agriculture. The AggieAir lab has been a resource at USU for more than a decade for STEM undergraduate recruiting, senior design projects, and student-driven research of all kinds. Via lab resources (students and employees, capabilities, etc.) AggieAir has supports STEM outreach and education programs such as NSF GearUP, Engineering State, Drone education at EAA AirVenture, National Intercollegiate Flying Association, Civil Air Patrol training, Women in Aviation, etc.

Principal Investigators:

Calvin Coopmans (PI)

Students:

Stockton Slack (MS), Mitchell Bailey (MS), Ryan Zaugg (MS), AJ Beckwith (MS), Nathan Scwemmer (UG), Emma Montgomery (UG), Richard Snyder (UG), Connor Roberts (UG), Stephen Cox (UG), Ezri Brimhall (UG), Ethan Payne (UG), Austin Washke (UG)

Partners/Collaborators:

Local/USU: Scott Budge (*USU Electrical and Computer Engineering*), Baron Wesemann (*USU Aviation Technology*), Steve Petruzza (*USU Computer Science*), USU Space Dynamics Laboratory

Commercial: DeseretUAS, ElectraFly, Fortem Inc., Northrop Grumman, Almond Board of California, E & J Gallo Winery,

Geographic Areas:

Study Areas: Test site flights near Cache Junction, UT under FAA Form 7711-1 2013-WSA-63). Sites across Utah and in California (partnered with Gallo Wineries and the Almond Board of CA).

Areas Benefited: All counties in the state could benefit.

Contacts:

Calvin Coopmans
435.764.4579
cal.coopmans@usu.edu

Website:

https://aggieair.usu.edu/

Publications:

- Gao, R, AF Torres-Rua, H Nieto, E Zahn, L Hipps, WP Kustas, M Mar Alsina, N Bambach, SJ Castro, JH Prueger, et al. 2023. *ET Partitioning Assessment Using the TSEB Model and sUAS Information across California Central Valley Vineyards*. Remote Sensing 15(3): 756. https://doi.org/10.3390/rs15030756
- Meza-Capcha, K, AF Torres-Rua, R Gao, O Hargreaves, K Osorio, LE Hipps, K Kopp, L Christiansen, I Gowing, C Coopmans. 2022. *Estimation of leaf area index in urban turfgrass using high resolution multispectral imagery for the two-source energy balance model*. Poster at American Geophysical Union Fall Meeting.
- Aboutalebi, M, AF Torres-Rua, M McKee, et al. *Downscaling UAV land surface temperature using a coupled wavelet-machine learning-optimization algorithm and its impact on evapotranspiration*. Irrig Sci 40, 553–574 (2022). https://doi.org/10.1007/s00271-022-00801-2
- Coopmans, C, S Slack, DJ Robinson, N Schwemmer. *A 55-pound Vertical-Takeoff-and-Landing Fixed-Wing sUAS for Science: Systems, Payload, Safety Authorization, and High-Altitude Flight Performance*, 2022 International Conference on Unmanned Aircraft Systems (ICUAS), Dubrovnik, Croatia, pp. 1256-1263, https://ieeexplore.ieee.org/document/9836128

What we did

AggieAir has continued aerial remote sensing and aerial platform development. Deploying multiple highly capable aerial platforms, AggieAir has mapped and made data available from various Utah sites, as well as for Gallo Vineyards and Almond Board of CA, NASA, and USDA in California for the 8th successive year. AggieAir continues to research and develop real-time data collection and processing solutions, including a new grant from the USU Institute for Land, Water, and Air (ILWA) to collect and process short-wave infrared (SWIR) aerial data. AggieAir supported the work of multiple graduate and undergraduate students and a Senior Design student group from the USU Department of Mechanical and Aerospace Engineering focused on designing and implementing an even lower-cost remote sensing vehicle called 'BabyBlue.'

What we found

AggieAir results are valid and wanted by the scientific community, and AggieAir leads in the remote sensing, aerial flight, and data delivery spaces.

Work Plan FY 23–24

AggieAir will continue to supply remote sensing, data processing and aerial information to the scientific community as well as partners in Utah and beyond, allowing researchers, students, and partners access to this world-class technology and research services. Built on now established large-scale, stable flight, AggieAir will continue streamline and improve the aerial data processing pipeline, allowing for near-real-time data delivery (mapping), which will lead to new applications and opportunities for research, aircrafts, and student experiences. Possible research paths include working with more federal agencies, developing aircraft technology for private industry, etc.

Figure 2: *AggieAir's Student Senior Design team test flying their new aircraft, "BabyBlue."*

Figure 1: *AggieAir's Static display and participation at the 2nd Annual Utah Aeronautics Conference.*

Media Coverage:

"Peak river flow, and a drone, brought a unique chance for study of Logan floodplain" KSLTV (https://ksltv.com/572909/peak-river-flow-and-a-drone-brought-a-unique-chance-for-study-of-logan-floodplain/)

Enabling the Use of Short-Wave Infrared (SWIR) for Aerial Drone-Based Water Use Studies Such As Canal Leakage

Research Summary:

For new water resources applications, shortwave infrared (SWIR) data can be used to 'see' moisture in, for example, surface soil. By monitoring surface soil moisture via drones, SWIR data can be used to evaluate conditions in agriculture lands and water infrastructure such as canals. In this project, we attempt to create a system that will allow us to collect and process SWIR data to check for leaks in canals in order to conserve water.

Why this research?

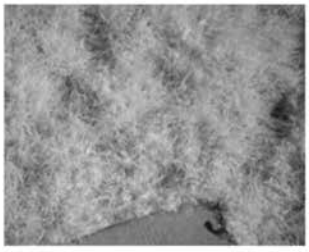
Water infrastructure such as canals often leaks as it ages, and easy and effective ways to inspect for leaks are lacking. Leaks can lead to lost water which, as a limited resource, is of utmost importance to conserve for stakeholders downstream.

Benefits to the State

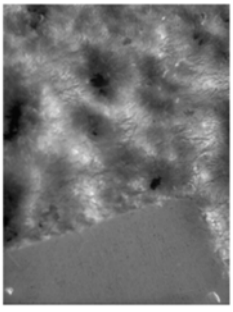
Utah has many miles of water infrastructure (canals), and all exposed of these aging parts of the water system can be inspected by air for leaks.

(a) Color (RGB)

(b) Monochrome



(c) Short-wave Infrared (SWIR)



(d) Thermal Infrared (TIR)

Figure 1: *Example AggieAir payload data (concrete, grass, snow) with multispectral sensors and SWIR.*

Principal Investigators:

Calvin Coopmans (PI)
Alfonso Torres-Rua (Co-PI)
Steve Petruzza (Co-PI)

Students:

Emma Montgomery (UG)

Geographic Areas:

Study Areas: Cache County, UT.

Areas Benefited: All counties in the state could benefit.

Contacts:

Calvin Coopmans
435.764.4579
cal.coopmans@usu.edu

Website:

https://aggieair.usu.edu/

What we did

This project is in beginning stages, so we have set up the work plan and hired a student to execute the work. As part of AggieAir's efforts, a custom multispectral camera payload system has been previously assembled, along with a new software platform 'Scientific Timely Actionable Robotic Data Operating System' (STARDOS), which allows multiple vehicles, sensors, and data processing chains to be configured and operated in concert. The AggieAir multispectral payload includes multiple sensors: RGB (visible) camera, NIR (near-infrared) camera, TIR (thermal infrared) camera, and now a new SWIR (shortwave infrared) camera.

What we found

The project has only just started, so results have not been generated yet.

Work plan FY 23–24

Since the SWIR camera is a new addition, we will create or modify software modules in STARDOS to interface with this camera and to convert the data into useable information (e.g., mapping, geolocation) so practitioners can spot trouble, plug leaks, and make better choices about infrastructure. In this project, undergraduate student researchers managed by Dr. Calvin Coopmans will extend existing code and implement new software functionality to handle the SWIR data so it can be used to map soil moisture levels from aerial drone surveys. During the project, the multispectral SWIR camera payload will be flown with a drone over a section of a canal to inspect for leaks and demonstrate how this technology can be used for other agriculture-related tasks.

High-Resolution Imagery Flood Mapping along the Logan River and Blacksmith Fork River in Cache County, UT, using UAS

Research Summary:

This project illustrates the effectiveness of using high resolution aerial imagery to capture the extent of regional river flooding, especially in and around urban areas. It gives local authorities the ability to update their regional flood maps, provides critical information regarding the effectiveness of flooding mitigation measures which can all be time sensitive issues. This project also highlights the creative use of drones and how they can be used in a variety of water resource applications, especially in time sensitive applications.

Why this research?

During exceptionally high flows, cities such as Logan, UT, have a critical need for timely information about the effectiveness of their flood mitigation efforts. Uncrewed aerial systems can provide such information quickly and safely. In this project, we anticipated that the analysis of the imagery gathered over the Logan and Blacksmith Fork rivers in Logan and Nibley, UT, will provide both cities with accurate flood extent maps. These current flood maps can be used to compare historical predicted flood estimates and to assess the accuracy. Additional analysis at Utah state University will also provide water surface profiles that will be used in computational fluid dynamics (CFD) modeling.

Benefits to the State

The purpose of this research was to capture high-resolution multi-spectral aerial imagery of the extent of any potential flooding along both the Blacksmith Fork River, and the Logan River, Cache County, Utah, during exceptionally high flows in spring 2023.

What we did

The high-resolution aerial imagery was captured using an DJI M-300 UAS and an AgEagle Altum-PT camera sensor, which together comprises 7 spectral bands, including a thermal and a Near Infrared band. Five flights

Figure 1: *A drone flying over Browns Pond capturing high-resolution multi-spectral imagery.*

Principal Investigators:

Ian Gowing (PI)
Beth Neilson (PI)
Shannon Syrstad (PI)

Partners/Collaborators:

State/National: Darren Farrar, Logan City Engineer; Tom Dickerson, Nibley City Engineer

Geographic Areas:

Study Areas: Blacksmith Fork River from the mouth of Blacksmith Fork canyon to the confluence with Logan River, and Logan River from the mouth of Logan Canyon downstream for 14 miles, Cache County, Utah

Areas Benefited: Logan City and Nibley City, Cache County, and other cities within the State of Utah that are affected by river flooding.

Contacts:

Ian Gowing
435.797.3159
ian.gowing@usu.edu

Website:

https://uwrl.usu.edu/lro/data

were flown along approximately 19 miles of the Logan River, and two flights flown along the Blacksmith Fork River. All flights were flown at 200m above ground level in accordance with the AggieAir Certificate of Waiver (C.O.A) 2023-WSA-12075-COA provided by the Federal Aviation Administration..

What we found

This project has shown the effectiveness of using drones in time sensitive applications where other sources of aerial imagery may not be available. It has highlighted the effectiveness of using drones to map flooding, an extremely time-sensitive event. The imagery captured has identified regions along both the Logan River and the Blacksmith Fork River, where localized flooding has occurred. The use of thermal imagery enabled researchers to identify flooding where tree canopy cover may have hidden these issues. It has been used to highlight the effectiveness of flood mitigation approaches that were implemented prior to high flows. The final orthorectified maps will be used by both Logan and Nibley city to update flood maps. Additional research at USU is being conducted to use the imagery to assist with computational fluid dynamics modelling.

Work plan FY 23–24

Analysis of the imagery is on-going. The imagery for both rivers is being fully orthorectified and an accurate water surface profile is being calculated for the entire flight paths along both rivers. This data will be used to assist with Utah State University student research into CFD modeling. The city of Logan is planning to use the imagery to update their current flood modeling maps.

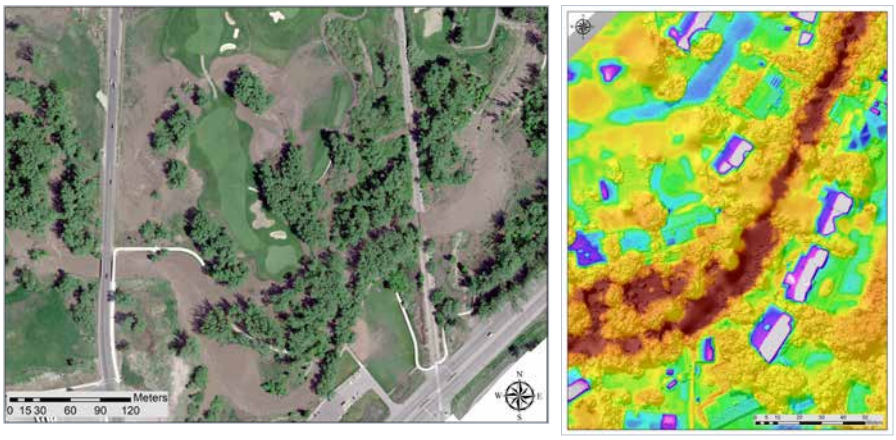


Figure 2: *Aerial imagery illustrating flooding along the Logan River, Utah..*

Hydroinformatics Gap Analysis for the State of Utah Division of Water Rights

Research Summary:

Utah State University (USU) has partnered with the State of Utah Division of Water Rights (DWRi) to perform a Hydroinformatics gap analysis focused on DWRi's distribution accounting activities and recent work related to their Water Rights Network data products.

Why this research?

Utah DWRi recognizes that they require modern data collection, management, and distribution systems in order to meet their statutory mandate. Water in Utah is "the property of the public" (Utah Code 73-1-1), and the division is an office of public record (Utah Code 73-2-11). The director of DWRi is responsible for the general administrative supervision of the waters of the state and the measurement, appropriation, apportionment, and distribution of those waters (Utah Code 73-2-1(3)(a)). DWRi currently makes a variety of water data available online but faces challenges in ensuring that data are well documented, consistent, accessible, and easily understandable.

In this project researchers at the Utah Water Research Laboratory are directly assisting DWRi in identifying and adopting modern standards and technologies that will improve the consistency, accessibility, and ultimately the general utility of DWRi's data and related systems. The project is working to meet this goal by completing a hydroinformatics technology and data gap analysis related to DWRI's water distribution accounting activities and their efforts to establish an openly available "Water Rights Network," which is a data product that will link water rights information with physical locations, points of diversion, points of use, and outputs of accounting models. The gap analysis is enabling DWRi to evaluate their existing systems, identify and formalize operational goals (e.g., timely and accessible data), identify desired best practices for data workflows, and document DWRi's operational data use cases, processes, and workflows. Once the gap analysis is complete, USU will assist DWRi in developing a technology modernization roadmap that helps position DWRi to procure or develop the necessary technology systems they require to fully support their operations now and into the future.

Benefits to the State

Utah DWRi is the state agency that regulates the appropriation and distribution of water in the state of Utah. It is an office of public record for information pertaining to water rights, including large volumes of

Principal Investigators:

Jeffery S. Horsburgh (PI)

Software Engineers:

Ken Lippold
Daniel Slaugh

Partners/Collaborators:

State: Utah Division of Water Rights—Jim Reese, David Jones, Jared Manning, and others.

Geographic Areas:

Study Areas: State of Utah

Areas Benefited: State of Utah

Contacts:

Jeffery S. Horsburgh
435.797.2946
jeff.horsburgh@usu.edu

data measured and recorded to assist DWRi in tracking and accounting for water use within Utah. The timeliness, accuracy, quality, and availability of DWRi's data along with the reliability of DWRi's data systems are critical to ensuring that Utah's valuable water resources are managed appropriately and in accordance with state law.

What we did

USU researchers have met weekly with DWRi personnel to learn in depth about DWRi's existing data collection activities, database systems, data management workflows, internal data use needs, and external data sharing requirements. This information is being compiled into a Hydroinformatics and data gap analysis report that will provide specific recommendations for how DWRi can build, maintain, and support robust operational data systems to assist DWRi in meeting their statutory requirements and operational goals.

What we found

We have identified specific opportunities for DWRi to update legacy data systems and will be documenting them in the hydroinformatics and data gap analysis report.

Work plan FY 23–24

We will continue meeting regularly with DWRi personnel through the beginning of 2024 to develop the hydroinformatics and data gap analysis report. The report will then be reviewed and prioritized to develop a technology modernization roadmap to guide DWRi's development and operations into the future.

Figure 1: *Farr West canal.*

Modernization Standards and Tools for Sharing and Integrating Real-Time Hydrologic Observations Data

Research Summary:

UWRL researchers are building on years of experience with Hydrologic Information Systems (HIS) development to build and advance software tools that enable the day-to-day operational work of running stream monitoring sites to collect data, managing the data they produce, and producing data products that can be used for modeling and decision making.

Why this research?

While the United States Geological Survey (USGS) operates a national network of real-time streamflow gages via the National Water Information System (NWIS)/Water Data for the Nation, hydrologic modeling efforts such as the continental-scale National Water Model could benefit from the availability of a much larger observations network—e.g., data from states, public utilities, water management agencies, researchers, watershed groups, and others. USGS generally does not support addition of these types of data to NWIS, and no current cyberinfrastructure allows organizations operating monitoring sites to stream data into an integrated, national network of real-time monitoring sites that could augment USGS real-time streamflow gages. Furthermore, most organizations that operate stream monitoring sites struggle with the day-to-day data management required to produce high-quality data products. This project aims to meet two major sets of needs: (1) the needs of data collectors for effective software and systems that will enable them to manage data and produce data products that can be shared and (2) needs analogous to programs created by the National Weather Service (NWS) to standardize access to national networks of weather stations (e.g., the NWS Cooperative Observer Program (COOP) that augments the Automated Surface/Weather Observing Systems with data from over 4300 observing sites contributed by COOP participants).

While many organizations collect stream monitoring data—no current cyberinfrastructure exists that enables data submission, integration, management, curation, and access capabilities as cyberinfrastructure that will enable creation of a national-scale, operational Hydrological Information System (HIS) for cooperator contributed data. UWRL researchers are developing new software and cyberinfrastructure to meet these needs.

Benefits to the State

Multiple Utah agencies, including the Division of Water Rights, Division of Water Resources, and Division of Water Quality, operate or collaborate in the

Principal Investigators:

Jeffery S. Horsburgh (PI)

Students:

Amber Jones (PhD)
Ehsan Kahrizi (PhD)
Sajan Neopane (MS)

Partners/Collaborators:

National: Cooperative Institute for Research to Operations in Hydrology (CIROH).

Geographic Areas:

Study Areas: Computer based research

Areas Benefited: Any agencies or managers needing Hydrologic Information System (HIS) cyberinfrastructure capabilities to better enable collection, storage, management, and sharing of time series of hydrologic observations. This important class of data is collected by research groups, local, state, and federal agencies, and many other organizations nationwide.

Contacts:

Jeffery S. Horsburgh
435.797.2946
jeff.horsburgh@usu.edu

Website:

https://hydroserver.geoglows.org/

Media Coverage:

- Utah State TODAY (Article): *USU Engineering Researchers Launch First Project Under New Water Institute*. October 25, 2022. https://www.usu.edu/today/story/usu-engineering-researchers-launch-first-project-under-new-water-institute
- Utah State Magazine (Article): *Measure to Manage—with Better Water Data*. December 6, 2022. https://utahstatemagazine.usu.edu/scitech/measure-to-manage-water-solutions-begin-with-better-data/

Work plan FY 23–24

We will continue software development this year, and we are nearing our first public releases of the developed software and systems and will be migrating all of the continuous monitoring data from the Logan River Observatory into the systems we have developed as an example use case for testing the new capabilities. We are also meeting with Utah agencies (Division of Water Rights and Division of Water Quality) to learn more about their data management needs and to align our development efforts.

operation of continuous stream monitoring stations that produce large volumes of hydrologic monitoring data. The systems developed by this project can either be used directly by state agencies or serve as a model that can be used by those agencies to develop their own data management and sharing systems.

What we did

We (1) Developed a synthesis paper of existing HIS technologies and systems with plans to submit for publication in Fall 2023, (2) Developed architectural design and functional specifications for operational HIS components to be built, (3) Explored modernized standards for web service interfaces and data encodings for data ingress and egress from HIS, including the Open Geospatial Consortium's SensorThings API specification, (4) Mapped legacy HIS functionality and the Observations Data Model (ODM) for hydrologic time series data to the modernized SensorThings API and data model; (5) Prototyped initial versions of operational HIS software components as part of the "HydroServer" software stack, including Python/Django implementation of SensorThings REST API and a backend database using SensorThings data model implemented in Timescale Cloud, data management REST web service API, data management console web application/web user interface, streaming data loader app for automated data loading, and cloud deployment and hosting using Amazon Web Services; and (6) Established GitHub repositories for open-source development of the HydroServer software stack.

What we found

The initial prototypes of our systems are deployable in the commercial cloud (e.g., using Amazon Web Services), which makes them more scalable. The systems we are developing meet significant data management needs of State of Utah agencies, including the Division of Water Rights and Division of Water Quality. We continue to work with both agencies to explore their data use cases and ways the modernized HIS systems could meet their data management needs.

HydroServer HIS website.

Logan River Observatory (LRO)

Research Summary:

The LRO provides long-term, comprehensive hydrologic data to inform local and statewide water management decisions based on Utah-specific hydrologic research. The LRO is also an outdoor laboratory and classroom for training the next generation of engineers and scientists who will be Utah's future water managers. Detailed watershed data (discharge, water quality, climate) combined with this increase in expertise allow us to: (1) address existing water issues in the state, (2) support new research to advance understanding of Utah's watersheds, and (3) focus on future challenges associated with limited water supplies.

Why this research?

In 2012, $20 million in National Science Foundation (NSF) funds were awarded to Utah State University and other Utah Universities in an infrastructure grant that established a monitoring network in the Logan River and two other watersheds in Utah. Ongoing support for maintenance and operations of these stations by NSF was discontinued when the state of Utah became ineligible for NSF's EPSCoR funding. At that point, the Logan River Observatory (LRO) was established and expanded the Logan River monitoring network to include 16 discharge stations, 8 full water quality stations, 8 partial water quality stations, 3 full climate stations, and 2 partial climate stations, making it one of the most highly instrumented watersheds in the US. This infrastructure and the associated data provide an opportunity for Utah to lead the country in water-related research and development of innovative water management approaches in water scarce regions. Through integration of research, teaching, and involvement of community members and local and state government entities, this infrastructure can support the critical water management decision making that we are now facing across Utah.

Benefits to the State

The ongoing operation and maintenance of these stations and the data that they provide are critical for understanding water supply and water quality monitoring in the northern part of the State of Utah and throughout the Great Salt Lake basin. Given that the Logan River Watershed spans wilderness areas, Forest Service land, and urban and agricultural areas, the lessons learned and methods developed for integrating efforts by various levels of government, citizen led organizations, and management entities are highly transferrable to watersheds spanning pristine to rural to urban areas throughout Utah and the western US.

Principal Investigators:

Bethany Neilson (PI)
Jeffery S. Horsburgh (Co-PI)
Patrick Strong (Co-PI)

Students:

PhD—Hyrum Tennant, Michael Lasswell.
MS—Devon Hill, Braedon Dority,
BS—Abby Johnson, Abby Englund, Chelsey Cowburn, Missy White,
Other Students—listed at: https:/LRO.usu.edu

Partners/Collaborators:

Local: Logan City, Cache Water District
State: Utah Division of Water Resources
Federal: USGS Utah Water Science Center

Geographic Areas:

Study Areas: Logan River Watershed

Areas Benefited: The information gained and methods developed are applicable to the entire State of Utah and similar watersheds in the western US.

Contacts:

Bethany Neilson
435.797.2772
bethany.neilson@usu.edu

Jeffery Horsburgh
435.797.2946
jeff.horsburgh@usu.edu

Website:
https://lro.usu.edu

Publications:

4 publications in scientific journals. See the LRO website at https://uwrl.usu.edu/lro/research/publications

Conference presentations:

13 oral and poster presentations at local, state, and national conferences. See the LRO website at https://uwrl.usu.edu/lro/research/publications

Report:

Logan River Observatory Annual Report. https://uwrl.usu.edu/files/pdf/2022-23-lro-annual-report.pdf

Media Coverage:

Multiple written and video news articles, about Logan River Observatory work are available at: https://uwrl.usu.edu/lro/news/

Work plan FY 23–24

During the coming year, we will continue data collection to support ongoing research, including refining methods of data collection and dissemination. We will also continue supporting new proposals that are being developed that will focus research efforts in the Logan River watershed and will utilize the Logan River Observatory data.

The Utah Division of Water Resources plans to use the flow and water quality data collected by these stations for water management and potential water development projects within the Logan River basin. These data are also critical for quantifying the water entering the Bear River and eventually the Great Salt Lake. Utah Division of Water Quality plans to use the data to assess compliance with state water quality standards, determine the need for additional stream restoration project funds, and identify and address other water quality related problems. Cache County Water Conservancy District and Logan City use LRO data to gather information about drinking water source status and protection and to inform Logan City's stormwater management efforts. LRO data also help the Cache County Water Conservancy District to protect and manage water resources in Cache County.

What we did

Long-term funding from the Utah Legislature and funds from Logan City and the Cache County Water Conservancy District have allowed the LRO to establish strong relationships with many local entities and organizations. New opportunities from these connections include the following: **(1)** Three CEE Senior Design groups to determine the feasibility of a future Cache County Water Conservancy District water development project in a Logan River tributary, investigate another potential project in a different tributary, and investigate alternative diversion structure strategies in Logan City; **(2)** supporting Logan City and the greater Great Salt Lake basin in anticipating water availability changes in the Logan River and similar watersheds in the region from changing snow patterns via a related NSF-funded research grant that uses LRO monitoring infrastructure; **(3)** working with the Logan River Task Force to determine scientifically informed methods for riparian zone management; **(4)** working with various Logan River stakeholders to determine appropriate minimum instream flowrates needed to maintain instream temperatures when redesigning a primary diversion structure and addressing fish passage concerns; **(5)** facilitating collaborations between Division of Wildlife Resources, Trout Unlimited, and a local canal company to redesign diversion structures that address instream flow and fish passage issues in the Blacksmith Fork, **(6)** assisting different canal companies in understanding flow rates throughout canal systems and groundwater exchanges between canals and other nearby streams and rivers when considering piping options; **(7)** facilitating the investigation of groundwater recharge across all of Cache Valley; and **(8)** working with the Division of Water Rights to further understand the challenges associated with shepherding leased water through distribution systems to the Great Salt Lake. Additionally, many funded research projects used LRO data.

Water Use Assessment in Golf Courses and Urban Green Areas

Research Summary:

The importance of the TURFEX project is the innovation in science, methodologies, and tools (drones and satellites) to directly monitor water use by the major urban vegetation (turfgrass) across Utah cities. A major goal by TURFEX is generating new knowledge for tracking water use that can be extended to other cities across the Western US.

Why this research?

Water management in urban green areas (such as golf courses, parks) is continuously challenged by water shortages and larger plant transpiration as climate change results in hotter summers and reduced water availability. Efforts to improve urban water management (like USU WaterMAPS https://extension.usu.edu/cwel/watermaps) are becoming more relevant in Utah and across Western States. Exploring innovations in science, information, and tools to further adapt recommendations for urban water management are necessary as climate change and water shortages continue. The Turfgrass tree Urban Remote sensing and energy Fluxes Experiment (TURFEX) is using remote sensing sources such as information from drones (USU's AggieAir: https://uwrl.usu.edu/aggieair/) and satellites (OpenET https://openetdata.org/) to quantify water use and turfgrass quality, quantify the relationship between water use and turfgrass quality, and develop recommendations for aesthetic urban turfgrass landscape and water use/irrigation needs.

Benefits to the State

Severe drought conditions such as the 2021 water year imposed severe limitations on water availability to maintain urban green areas across Utah, especially for large city parks and golf courses, impairing turfgrass regrowth and risking replanting costs, in addition to rother negative

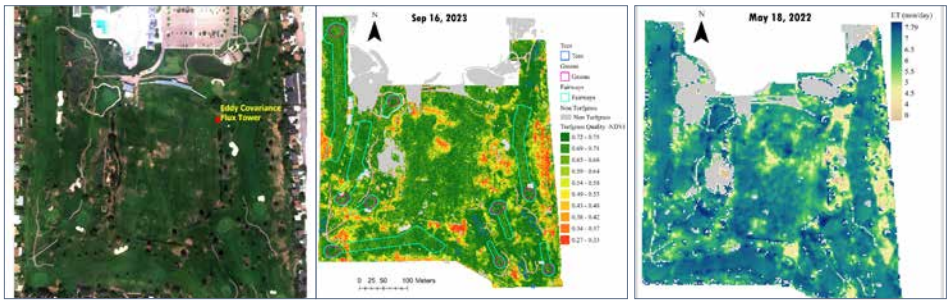


Figure 1: *Eagles Lake Golf Course (left) and example maps of turfgrass quality (middle) and turfgrass water use (evapotranspiration) (right) using drone imagery in 2023.*

Principal Investigators:

Alfonso Torres-Rua (PI)

Lawrence Hipps (College of Agriculture, Co-PI)

Students:

Karem Meza (PhD)

Partners/Collaborators:

Local: Eagles Lake Golf Course, Roy, UT
USU: Kelly Kopps, USU WaterMAPS, College of Agriculture
Federal: Bill Kustas, Agricultural Research Service - USDA
International: Hector Nieto, Spanish National Research Council, CSIC - Institute of Agricultural Sciences, Spain

Geographic Areas:

Study Areas: Roy, UT

Areas Benefited: Utah and the western US.

Contacts:

Alfonso Torres-Rua
435.797.0397
alfonso.torres@usu.edu

Lawrence Hipps
435.797.0209
lawrence.hipps@usu.edu

impacts to human, urban, environmental, and water management services. The work by TURFEX aims to generate information such as: (1) the additional irrigation needed to recover brown or yellow turfgrass to a healthy green condition, (2) the locations across the golf course (or park) needing additional irrigation, and (3) the water usage in such areas. With that information, golf course/park managers and city planners can identify opportunities for water conservation or prioritize water application.

What we did

In early 2021, we installed multiple instruments (eddy covariance system) at the Eagles Golf Course, in Roy, UT, which was selected for its size and project fit. The eddy covariance system is considered the gold standard for plant water use quantification. Several Utah State University students quantified turfgrass quality, obtained drone imagery, developed a collaboration with the OpenET team, and developed models and protocols, which helped us to ensure drone and satellite results are adequate to quantify water use and map turfgrass quality across the golf course area.

What we found

Based on information from 2021, 2022 and 2023, we found that drone information can adequately describe turfgrass water use and its variability across the golf course. This was more visible in 2022 (an extreme drought year), when certain golf areas were no longer irrigated and priority was given to others based on the water availability. Similarly, we found that turfgrass quality conditions and changes can be adequately quantified by the same drone imagery. These findings open an opportunity to relate water use and turfgrass quality and quantify irrigation needs to maintain and recover healthy green turfgrass conditions.

Work plan FY 23–24

The TURFEX project will focus on summarizing findings regarding the turfgrass quality and water needs with remote sensing information, as well as continue the analysis of OpenET products to continuously monitor urban green areas. This work will be published in peer-reviewed journals as the analysis is completed.

Figure 2: *High (a), intermediate (b), and low (c) turfgrass quality, team preparing AggieAir drone for flight at Eagles Lake Golf Course (d), and eddy covariance surface energy balance system (e,f).*

Figure 3: *TURFEX logo.*

Publications:

Meza-Capcha, K et al. *Spatial Estimation of Actual Evapotranspiration over Irrigated Turfgrass Using sUAS Thermal and Multispectral Imagery and TSEB Model*. Irrigation Science (peer review publication submitted for review).

Conference presentations:

- Meza, K, AF Torres-Rua, L Hipps. *Estimation of Evapotranspiration over Urban Turfgrass Using Eddy Covariance Flux Measurements and OpenET Platform.* In Linking Optical and Energy Fluxes Workshop, Ameriflux. July 2023. (Oral presentation)
- Meza, K, AF Torres-Rua, L Hipps, WP Kustas, K Kopp, R Gao, L Christiansen, V Burchard-Levine, P Martin, S Alvarez, I Gowing, and C Coopmans. *Spatial Estimation of Actual Evapotranspiration and Turfgrass Quality on Golf Courses Using UAS-TSEB and Machine Learning.* In Water Smart Innovation Conference, October 2023. (Poster presentation)
- and 6 other oral and poster presentations at local, state, and national conferences.

Media Coverage:

Fairways Magazine (Article). *USU Turfgrass Studies Helping Utah's Golf Course Sustainability* 2022 June Issue, p. 49. https://indd.adobe.com/view/849081b4-fb0c-4c1d-8e33-78524cf15555

Water Education, Outreach and Technology Transfer

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Water Education, Outreach and Technology Transfer: PI	Project Name	Actual FY2023	Budgeted FY2024	Planned FY2025
Dupont, R.	Logan City Renewable Energy and Sustainability Advisory Board (RESAB)	$22,826	$23,511	$24,216
McFarland, M.	Biosolids Land Applier Certification Training	$35,134	$36,188	$37,274
Sims, J.	Development of an On-Site Demonstration Site at the Ash Creek Special Service District	$7,646	$7,875	---
Sims, J.	Utah On-Site Wastewater Treatment Training Program	$7,646	$7,875	$8,111
Stevens, D.	Center of Excellence for Water	$16,899	$17,406	$17,928
Stevens, D.	State of Utah Operators Certification Commission	$39,724	$40,916	---
Tullis, B.	State of Utah Drinking Water Board	$5,000	---	---
	New projects			
	TOTALS	**$134,875**	**133,771**	**$87,529**

Logan City Renewable Energy and Sustainability Advisory Board (RESAB)

Research Summary:

The mission of the Logan City Renewable Energy and Sustainability Advisory Board (RESAB) is to provide advice and technical assistance related to the conservation and efficient use of resources, to assist the City of Logan in transitioning toward a renewable energy portfolio that is secure, diverse, and cost-effective; promotes security of the environment; and addresses climate change action.

Why this research?

The mission of the Logan City Renewable Energy and Sustainability Advisory Board (RESAB) is to provide advice and technical assistance related to the conservation and efficient use of resources, to assist the City of Logan in transitioning toward a renewable energy portfolio that is secure, diverse, and cost-effective; promotes security of the environment; and addresses climate change action.

RECAB's goals include the following:

1. Reduce residential energy consumption (per capita) over the next 10 years.
2. Improve energy efficiency of commercial and public customers.
3. Implement 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 Logan City with carbon emission study.

Benefits to the State

The RESAB mission is to provide Logan City with technical expertise and experience on the potential of new renewable energy sources, carbon emission estimates, carbon emission reductions, and public education. The PI attends monthly meetings of the Logan RESAB, provides comments and input on renewable energy and waste management issues that arise, and has responded to special requests from RESAB regarding technical issues related to alternative renewable energy sources and Logan City's greenhouse gas emission

Principal Investigators:

R. Ryan Dupont (PI)

Partners/Collaborators:

Local: Emily Malik, Logan City Environmental Department

Amy Anderson, Holly Daines, Tom Jensen, Logan City Council

Geographic Areas:

Study Areas: Logan City and Cache County

Areas Benefited: Logan City and Cache County

Contacts:

R. Ryan Dupont
435.797.3227
ryan.dupont@usu.edu

Websites:

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

Work plan FY 23–24

Involvement of the PI with the Logan RESAB will continue, as will his response to special project requests as they arise, to support Logan City RESAB's mission and goals. Planning for future renewable energy options, enhancement of Logan City's EV charging network, and greenhouse gas emission inventory review and reduction prioritization are the main activities planned for FY 23–24.

inventory. The PI is a member of the Community Solar subcommittee of RECAB that is evaluating program options for increasing participation in the existing Logan City solar farm and considering options for expansion of the current program and facilities to include a commercial customer base. The Sustainability name change occurred in February 2021 to reflect the expanded membership and mission of the Board regarding climate change concerns, the City's greenhouse gas emission inventory, and steps necessary for greenhouse gas emission reductions to address climate change.

What we did

The PI attended all regularly scheduled remote RESAB meetings throughout FY22–23 and provided review and comment on all RESAB items relevant to his area of expertise. Topics included the following:

1. Analysis of current and future resource mix to meet a 50% renewables component in Logan City's power portfolio by 2030,
2. Input on the long-term renewable energy Road Map and 50% renewable resolution for Logan City that was passed by the Logan City Council in 2018,
3. Participation on the Community Solar program analysis RESAB subcommittee,
4. Input on greenhouse gas emission reduction strategies and programs and policies to support climate action and on updating of Logan City's greenhouse gas emission inventory, and
5. Input on EV charging station expansion within Logan City.

Figure 1: *Community solar array installed adjacent to the Logan City Wastewater Treatment Lagoons*

Biosolids Land Applier Certification Training

Research Summary:

The State of Utah Division of Water Quality, together with several professional engineers who had received biosolids management training at Utah State University proposed development of an operator certification training course to meet the training needs of the Water Environment Association of Utah (WEAU). The PI developed, offered, and taught the certification training course over a two-day period (March 22, 2023 and March 29, 2023) at the Jordan Basin Water Reclamation Facility (Draper, Utah). The PI authored, taught from, and provided each course attendee with a new professional biosolids workbook.

Why this research?

Under the State of Utah Administrative Code R317-10 (Rule for Certification of Wastewater Works Operators), State of Utah operators of municipal wastewater treatment facilities must be certified. The Water Environmental Association of Utah (WEAU) is primarily responsible for providing training opportunities for wastewater operators who seek to pass specific wastewater certification examinations and/or to gain continuing education unit (CEU) credits required to maintain their professional certification.

Recent federal proposals to change the environmental compliance regulations affecting how sewage sludge from municipal wastewater treatment can be legally managed has created interest in Utah to develop an operator certification training course specifically focused on sewage sludge beneficial use. In 2023, WEAU reached out to members of the professional engineering community to formulate a new sewage sludge/biosolids course specifically tailored for the wastewater operator.

Benefits to the State

This project benefits the State of Utah by:

- Increasing the number of wastewater treatment professionals certified to develop and implement biosolids land application programs.
- Increasing financial revenue for landowners who choose to recycle biosolids on their property.
- Increasing the sewage sludge management options for Utah wastewater treatment facilities.
- Reducing the risk of regulatory non-compliance of the US Clean Water Act sewage sludge provisions.

Principal Investigators:

Michael J. McFarland (PI)

Partners/Collaborators:

State: Dan Griffin, Utah Division of Water Quality

Industry: James Goldhardt, Coombs Hopkins Company

Geographic Areas:

Study Areas: State of Utah.

Areas Benefited: State of Utah

Contacts:

Michael J. McFarland
435.994.0905
farlandm1@outlook.com

Other Resources:

Dan Griffin, Biosolids Coordinator, State of Utah Division of Water Quality
dgriffin@utah.gov

Judy Etherington, Director Utah Wastewater Operator Certification Council
jetherington@utah.gov

What we did

- In accordance with the Utah Administrative Code (R317-8-1.10 (11), sewage sludge from the treatment of municipal wastewater may be beneficially recycled as a fertilizer and/or soil conditioner if it meets the biosolids quality standards as defined by Title 40 US Code of Federal Regulation Part 503 (US Clean Water Act). To legally address this regulatory requirement, sewage sludge managers as well as landowners within the State of Utah must be cognizant of the federal and state regulations governing the beneficial use of sewage sludge.

- The only biosolids/sewage sludge operator certification training course offered within the State of Utah was made available in the Spring of 2023 through the Water Environmental Association of Utah (WEAU). Approximately twenty-five (25) students registered for the course that included wastewater treatment operators, consulting engineers, landowners and state regulators.

- The need for a wastewater operator certification course in sewage sludge/biosolids beneficial use required the development of technical materials that would enable attendees to take and pass the national biosolids land applier certification examination. To address that need, the Biosolids Land Applier Certification Workbook was developed (book cover shown as follows) and was the primary reference used in the new certification course.

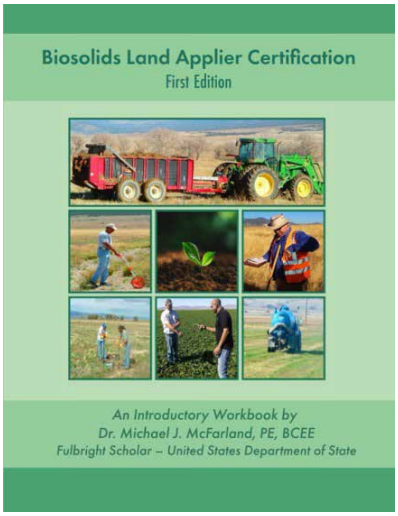


Figure 1: *Biosolids Land Applier Certification Workbook (Author, Dr. Michael J. McFarland)*

Work plan FY 23–24

Plans for the next fiscal year include the following:

1. Collaborating with the US Environmental Protection Agency (USEPA) in developing scientifically defensible methodologies for evaluating the risk of emerging contaminants in land applied biosolids to public health and the environment.
2. Developing a new wastewater operator certification workbook to support a training course focused on industrial pretreatment approaches to ensure biosolids quality satisfies regulatory requirements defined in the US Clean Water Act.

Development of an On-Site Demonstration Site at the Ash Creek Special Service District

Research Summary:

An on-site wastewater (also referred to as septic systems) demonstration site is being constructed at the Ash Creek Special Service District (Ash Creek) site in Hurricane, Utah. Ash Creek also has classroom facilities for on-site certification workshops that will utilize the demonstration site. This southern demonstration site at Ash Creek will facilitate having instructors and regulatory staff from the area being able to participate in the State of Utah certification training program for on-site wastewater certification professionals as well as provide tours and other educational activities concerning septic systems and non-point source pollution (NPS) to homeowners and users of septic systems, real estate developers, consulting engineers, students, and the public.

Why this research?

The Huntsman On-Site Wastewater Treatment Training and Demonstration Site on the campus on Utah State University (USU) in northern Utah is used for State of Utah certification workshops for on-site wastewater professionals as well as occasional tours for outside groups and for university classes. The site is an integral part of the USU On-Site Wastewater Treatment Training Program (https://uwrl.usu.edu/research/owt). However, because the USU demonstration site is located in northern Utah, there is a need to have a similar demonstration site in the southern part of the state to serve on-site professionals in that area. Therefore, a second demonstration site is being constructed at the Ash Creek Special Service District (Ash Creek) site in Hurricane, Utah. Ash Creek also has classroom facilities for on-site certification workshops that will utilize the demonstration site. This southern demonstration site at Ash Creek will facilitate having instructors and regulatory staff from the area being able to participate in the certification training program as well as provide tours and other educational activities concerning septic systems and non-point source pollution (NPS) to homeowners and users of septic systems, real estate developers, consulting engineers, students, and the public.

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. Enhanced educational opportunities available at the Ash Creek demonstration site

Principal Investigators:

Judith L. Sims (PI)

Research Assistant:

McKayla Beauchamp

Partners/Collaborators:

Local: Mike Chandler, Ash Creek Special Service District

Utah's 13 Local Health Departments

State: Division of Water Quality, Utah Department of Environmental Quality

Utah On-Site Wastewater Association (UOWA)

Council of Local Environmental Health Directors (CLEHA)

CLEHA Onsite Wastewater Partnership (COWP)

Geographic Areas:

Study Areas: Entire State of Utah

Areas Benefited: The development of the on-site wastewater demonstration site at Ash Creek will be especially beneficial to persons in southern and central Utah, but use of the site will be open to all on-site professionals and other interested parties from all parts of Utah.

Contacts:

Judith L. Sims
435.797.3230
judith.sims@usu.edu

Websites:

https://uwrl.usu.edu/research/owt/

Work plan FY 23–24

We will finalize procurement of materials and demonstration materials, complete displays, and finish installation of the educational models at the Ash Creek demonstration site. A "grand opening celebration" is planned for the spring of 2024, sponsored by the USU's Utah On-Site Wastewater Treatment Training Program, the Utah Division of Water Quality, Utah Local Health Departments, and the Utah On-Site Wastewater Association.

will benefit Utah on-site professionals active in the oversight of septic system siting, design, inspection, and monitoring and maintenance, and especially professionals located in central and southern Utah.

What we did

The approach to the development of the project is design/build. Demonstration displays include: (a) septic tanks displays; (b) display of distribution devices for septic tank effluents in absorption systems; (c) displays of absorption systems: standard trenches (pipe and gravel, chambers, bundled synthetic aggregates), deep wall trenches, pressurized drain fields, and absorption beds; (d) alternative systems: at-grade systems, mound systems, sand-lined trenches, and packed bed systems (including intermittent sand filter, recirculating sand and gravel filters, textile filter, peat filter, synthetic open cell foam media filter, and synthetic polystyrene media filter), and membrane bioreactors; (e) pump systems, tanks, and vaults; (f) control panels; (g) effluent filters for septic tanks; (h) valves for alternating drain fields; (i) dosing tanks; (j) drip irrigation systems, and (k) grease traps.

During FY 21–22 we continued to design and build various demonstration displays. We revised the wording for signs and continued to edit videos illustrating percolation testing, soil texturing procedures, field soil pit evaluation techniques, conventional on-site wastewater treatment system design, and operation and maintenance (O&M) procedures for alternative on-site wastewater treatment systems. Because of the continuing COVID pandemic, we were not yet able to complete installation of the displays at Ash Creek Special Service District. The project was extended one more year so the demonstration site could be completed.

Figure 1: *The new demonstration site will be located at the Ash Creek Special Service District in Hurricane, Utah.*

Utah On-Site Wastewater Treatment Training Program

Research Summary:

The Utah On-Site Wastewater Treatment Training Program, established in January 1998 in cooperation with the Utah Department of Environmental Quality (DEQ) and the thirteen Utah local health departments, provides classroom and field (hands-on) training in on-site wastewater treatment systems to Utah homeowners, regulators, designers, installers, pumpers, and other stakeholders in on-site wastewater treatment systems. The Training Program also provides the mandatory training required by the Utah Division of Water Quality for the certification of on-site wastewater professionals involved in siting, designing, operating, and maintaining both conventional and alternative on-site systems.

Why this research?

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

Benefits to the State

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 ten 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.

What we did

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

Principal Investigators:

Judith L Sims (PI)
Margaret Cashell
Brian Cowan
Richard Jex

Program Support:

Ashton Decker
Brittanie Carter

Partners/Collaborators:

Local: Utah's 13 Local Health Departments

State: Division of Water Quality, Utah Department of Environmental Quality

Council of Local Environmental Health Directors (CLEHA)

CLEHA Onsite Wastewater Partnership (COWP)

Utah On-Site Wastewater Association (UOWA)

Geographic Areas:

Study Areas: The entire State of Utah

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

Website:

https://uwrl.usu.edu/research/owt/

Contacts:

Judith L. Sims
435.797.3230
judith.sims@usu.edu

Ashton Decker
435.797.3168
onsitewastewater@usu.edu

Publications:

Sims, JL, M Cashell, B Cowan, and R Jex. 2022, 2023. *Course Manuals for Levels 1, 2, and 3 Original Certification and Recertification Workshops*. Utah Water Research Laboratory, Utah State University, Logan, UT.

Videos:

- Percolation Test https://www.youtube.com/watch?v=YooMuqStE90
- Soil Characterization https://www.youtube.com/watch?v=XTkS_uFt_tM
- In Situ Soil Evaluation https://www.youtube.com/watch?v=Y28W74IrdaI
- Level 2 Tour—USU Demonstration Site https://www.youtube.com/watch?v=0fMxSxHegbk
- Level 3 Tour—USU Demonstration Site https://www.youtube.com/watch?v=XPbuayDNEzk

3: Design, Inspection, 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.

Workshops held during FY 22–23:

- **Level 1**: 4 workshops at Ogden, Richfield, Park City, and Price, Utah locations—93 total participants
- **Level 2**: 4 workshops at Logan, Utah location—87 total participants
- **Level 3**: 2 workshops at Logan, Utah location—35 total participants
- **Level 1 & 2 Renewal**: 4 workshops at Richfield, Logan, Coalville, and Price, Utah locations—92 total participants
- **Level 3 Renewal**: 3 workshops at Richfield, Coalville and Price, Utah locations—40 participants

FY 21–22 Total: 347 participants

A re-test option at local health departments is an alternative to attending a Level 1 & 2 certification renewal classes. Professionals wishing to certify can waive attendance at Level 1 & 2 by taking these examinations.

- Level 1 & 2 re-testing: 2 test dates in FY 22-23—10 total participants
- Level 1 & 2 classes waived: 3 waivers for Level 1 & 2 workshops for 3 professional engineers

Work plan FY 23–24

We will continue to provide workshops in support of the mandatory State of Utah certification program for on-site wastewater professionals through FY 2025.

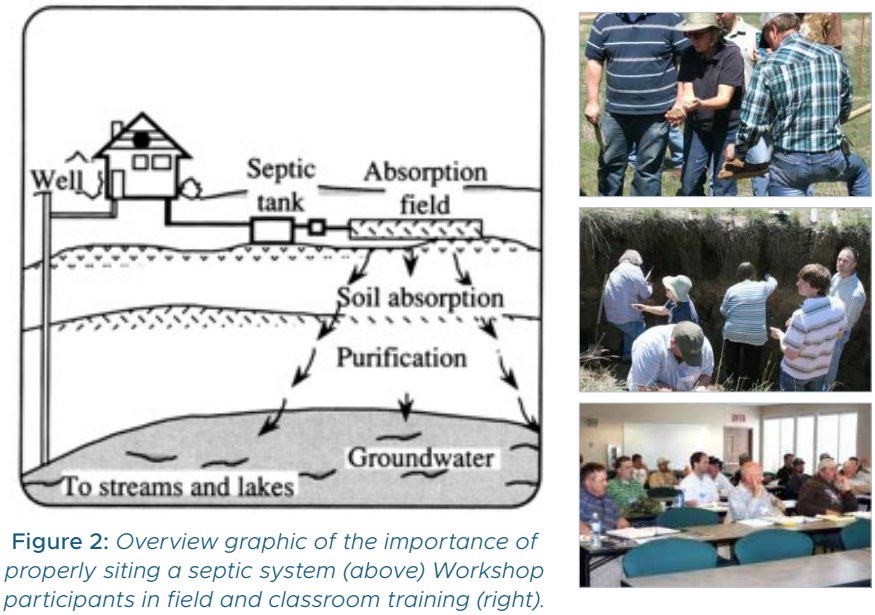


Figure 2: *Overview graphic of the importance of properly siting a septic system (above) Workshop participants in field and classroom training (right).*

Center of Excellence for Water

Research Summary:

This ongoing project at USU has resulted in the development of 17 undergraduate courses for improving water education at Egyptian National Universities, the ongoing presentation of four major workshops, preparation for 18 postgraduate courses to support MS programs in Sustainable Water Resources Management, and support for exchange programs between USU and five Egyptian universities, Center of Excellence Governance and Sustainability efforts, and water-related research.

Why this research?

Egypt critically needs to improve its ability to meet current and projected water demands. Our goal is to catalyze long-term improvement in Egyptian water resources management by improving its innovative applied research and education enterprise through the creation of the Alexandria Water Resilience Center of Excellence (AWR-COE). The AWR-COE will serve the needs of the Egyptian people and economy, including industry, and support the government to face water challenges, develop policy, and prepare a next generation of graduates and entrepreneurs to be change agents that stimulate economic growth. Inclusion of women, disabled persons, and talented yet financially needy faculty and students, is central to all aspects of our design and implementation.

Based on our theory of change, if research needs are identified for the private and public sectors, and the required profile for graduates is drawn based on labor market's need, and if the expertise of the US partners is transferred such that it builds on the capacity of Egypt's higher education institutions through their faculty, students, and research administrators by providing the right infrastructure and environment, then the AWR-COE will be a sustainable model to generate innovative, modern, and competitive solutions to develop the Egyptian economy, strengthen government policy, and equip future graduates to be change agents, thus achieving Egypt 2030 goals and contributing to global Sustainable Development Goals.

Benefits to the State

This project provides opportunities for faculty and students at USU to exchange ideas with our Egyptian partners, travel to Egypt for collaboration in water related research, study at Egyptian Universities, and have Egyptian partners travel to USU for the same purpose. This will result in a deeper understanding of water management in arid lands that will benefit Utah directly and provide opportunities for future collaboration internationally.

Principal Investigators:

David Stevens (PI)
Ryan Dupont (Co-PI)
Kurt Becker (Engineering Education Co-PI)

Partners/Collaborators:

National: UD AID
Brent Haddad, University of California-Santa Cruz

Jonathan Yoder, Washington State University

Rominder Suri, Temple Univ.

Essam Shaaban Mohammed, American University in Cairo

Geographic Areas:

Study Areas: Logan, UT

Areas Benefited: Statewide and Universities in Egypt

Contacts:

David K. Stevens
435.797.3229
david.stevens@usu.edu

Publications:

- Quarterly reports to American University in Cairo.
- 10 monthly meetings (via Zoom) with USU Project Partners.

Workshop Presentations:

- Participation in Cairo Water Week Conference. October 2022.
- *Learning Management Systems (Phase V)* and *Innovative Teaching Strategies (Phase VI)*. Workshops at Cairo, Beni Suef, Alexandria, and Egypt. July and October 2022, February 2023.
- *State of the Art Curriculum*. Workshops at Alexandria/ Aswan and Egypt. October 2022 and February 2023
- *Remote Sensing for Improving Irrigation Efficiency*. Workshop at USU. June 2023.

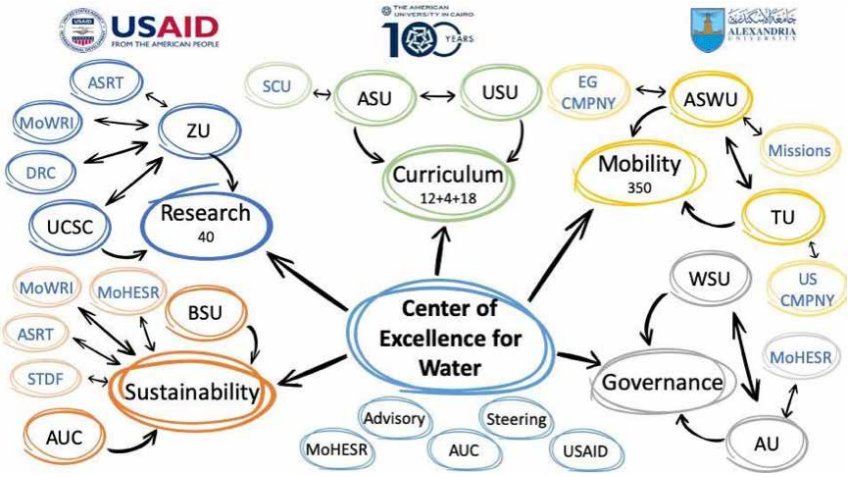


Figure 2: *A "mind map" of the overall project.*

What we did

This international collaborative project funded by USAID continued our partnerships between 5 US universities (Utah State, Washington State, California-Santa Cruz, Temple, and the American U. of Cairo (Egypt), 5 Egyptian Partner Universities (EPUs): (Alexandria, Ain Shams, Zagazig, Beni Suef, and Aswan), and a number of agency, public, and industrial partners in Egypt. This fiscal year, we presented multiple workshops and hosted a large number of Egyptian students and faculty at USU for semesters abroad and research collaboration.

Work plan FY 23–24

We will finalize development of the 17 undergraduate courses, issue a call for proposals and develop 18 graduate level courses in water resources sustainability for implementation at the 5 EPUs, hold Phase VI of the Learning Management Systems workshop and Phase V of the Innovative Teaching Strategies workshop in Egypt. We present workshops at conferences in addition to individual faculty efforts in course development. We will be hosting two visiting faculty members at the UWRL, welcome 4 undergraduate and 4 graduate students for a semester abroad. The overall project has been extended through 2027 with a small budget increase due to delays and increased costs post-pandemic.

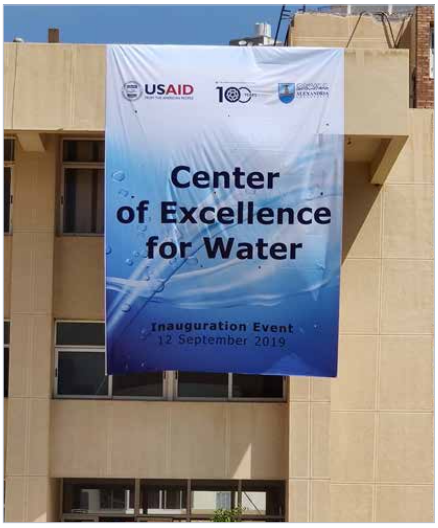


Figure 1: *UWRL researchers are helping to find solutions to the challenges Egypt faces related to water sources, wastewater services, and irrigation and are designing new courses and degrees for Egyptian universities in fields related to water issues.*

State of Utah Operators Certification Commission

Research Summary:

The Operators Certification Commission established by the Utah Drinking Water Board manages training for water treatment plant operators. 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.

Why this research?

Under the Utah Drinking Water Act (the Act), responsibility for overseeing drinking water treatment and distribution rests with The Utah Department of Environmental Quality 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 David Stevens has been a member of that commission since 1987.

Figure 1: *Little Cottonwood treatment plant ponds.*

Principal Investigators:

David K. Stevens (PI)

Partners/Collaborators:

State: **Tim Davis**, Director, Division of Drinking Water

Michael Grange, Operator Certification Commission Secretary, at Division of Drinking Water

Geographic Areas:

Study Areas: State of Utah

Areas Benefited: State of Utah

Contacts:

David K. Stevens
435.797.3229
david.stevens@usu.edu

Websites:

https://deq.utah.gov/drinking-water/operator-certification

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.

What we did

The PI attended all scheduled Operators Certification Commission meetings July 1, 2022, to June 30, 2023, and provided review and comment on all Commission items relevant to his area of expertise.

Work plan FY 23–24

PI involvement on the Board will end in 2024.

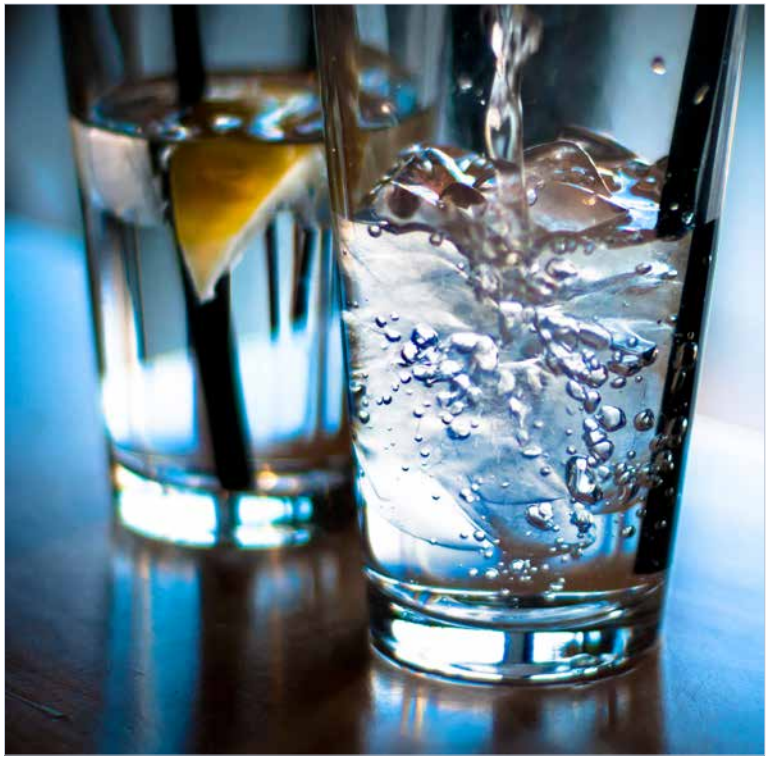
State of Utah Drinking Water Board

Research Summary:

The Utah Drinking Water Board, administered by Uta's Division of Drinking Water, adopts and enforces rules related to public drinking water systems. The PI attends yearly meetings of the Board held in Salt Lake City and provides comments and inputs policies and procedures in accordance with Federal and State drinking water laws.

Why this research?

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. Utah Water Research Laboratory faculty member Dr. Blake Tullis has served on the State of Utah Drinking Water Board from FY 2020 to the present.



Principal Investigators:

Blake Tullis (PI)

Partners/Collaborators:

State: Marie Owens, Director, Division of Drinking Water

Geographic Areas:

Study Areas: State of Utah

Areas Benefited: State of Utah

Contacts:

Blake Tullis
435.797.3194
blake.tullis@usu.edu

Websites:

https://deq.utah.gov/boards/utah-drinking-water-board

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. Dr. Tullis attends approximately quarterly meetings of the Drinking Water Board held throughout the State or virtually 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.

What we did

The PI attended all regularly scheduled Drinking Water Board meetings and facility tours from July 1, 2022, to June 30, 2023, with the exception of one due to a conflict in schedule, and provided review and comment on all Board items relevant to his area of expertise.

Work plan FY 23–24

Blake Tullis from the UWRL will continue this board service through 2023.

Water Resources

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Water Resources: PI	Project Name	Actual FY2023	Budgeted FY2024	Planned FY2025
Neilson, B.	Logan City Stormwater Monitoring	$84,508	$87,043	---
Rosenberg, D	Adapting to Low Colorado River Flows and Storage	$27,417	$28,239	$29,086
Rosenberg, D.	Increasing the Impact of Utah State University's Extension Water Check Program with 5-Second Metering	$74,224	$76,451	$78,745
Rosenberg, D.	Making Water Research Results More Reproducible	$27,407	$28,229	$29,076
Shuai, P.	ExaSheds: Advancing Watershed System Science using Machine Learning-Assisted Simulation	$22,735	---	
Tarboton, D.	Great Salt Lake Strike Team	$50,890	$52,417	$53,989
Tarboton, D.	Hydrology Scenarios in the Colorado River Basin	$51,033	$52,564	$54,141
	New projects		*$54650*	*$20,000*
	TOTALS	**$338,214**	**$379,593**	**$265,037**

Logan City Stormwater Monitoring

Research Summary:

As part of Logan City's regular stormwater sampling program and USU's ongoing water quality research in urban stormwater systems within Logan City, USU is assisting Logan City in collecting and interpreting flow and water quality monitoring data within the Logan River and related stormwater conveyances.

Why this research?

Because of the historical role of agriculture in this area and the availability of agricultural water conveyances within the city, Logan City's stormwater collection system was designed to collect stormwater within irrigation canals throughout Logan City, which then convey stormwater downstream to Cutler Reservoir. This combined use system in relatively common in the State of Utah and intermountain west and requires monitoring of combined irrigation and stormwater to assess the impacts that stormwater may be having on the quality of delivered irrigation water and downstream waterbodies.

Benefits to the State

This project provides continued expansion of Logan River Observatory monitoring efforts into urban and agricultural environments. It provides a demonstration of how continuous monitoring and stormwater sampling data can provide increased understanding of the functioning of combined urban/agricultural water systems. The cyberinfrastructure and data dissemination protocols we have developed can be adapted as needed to ensure these approaches can be transferred to other small cities across Utah.

What we did

In prior years we assisted Logan City in the design, purchase, and installation of continuous flow and water quality monitoring stations in the Northwest Field and South Benson Canals. We coordinated with Logan City's flow structure installation at these locations and have installed continuous monitoring equipment and telemetry. We have also installed storm monitoring equipment at these locations and at the Utah Water Research Laboratory (UWRL) Logan River Observatory station. In 2021, we moved a sampling location upstream to South Benson Canal along 600 West to avoid issues encountered at the original sampling location.

In 2022–2023, we collected continuous sensor data and discrete water quality samples (baseline and storm event sampling) for one storm during

Principal Investigators:

Bethany T. Neilson (PI)
Jeffery S. Horsburgh (Co-PI)

Partners/Collaborators:

Local: Paul Lindhardt and Bill Young, Logan City

Geographic Areas:

Study Areas: Canals within Logan City

Areas Benefited: Logan City, Cache County, and other areas of the state with similar stormwater systems

Contacts:

Bethany T. Neilson
435.797.7369
bethany.neilson@usu.edu

Datasets:

Data are available for this work at the following links:

- Logan River at UWRL, http://lrodata.usu.edu/site/LR_WaterLab_AA
- Northwest Field Canal, http://lrodata.usu.edu/site/NWF_1600N_CNL
- South Benson Canal, http://lrodata.usu.edu/site/SLB_600W_CNL

the irrigation season. We additionally sampled during a significant snow melt period to understand the chemical loads in early spring before the canals are turned on.

We continue to work with Logan City to analyze monitoring results and determine future monitoring efforts that will develop advanced understanding of hydrologic and water quality processes within Logan City and assist Logan City with their stormwater management efforts.

What we found

Grab samples from storm events continue to show varied responses, with the highest concentrations of biochemical oxygen demand (BOD), total phosphorus, and E. Coli often occurring at the Northwest Field (NWF) Canal site. BOD at the UWRL is typically below the detection limit, and can be below detection limit at the other sampling locations.

Work plan FY 23–24

We plan to write a summary report of our findings from the last 5 years of data.

Figure 1: *Canal sampling.*

Adapting to Low Colorado River Flows and Storage

Research Summary:

This work developed real-time, online open source participatory modeling environment(s) to engage Colorado River water managers and experts and discuss more adaptive reservoir operations such as basin water accounts. Twenty-six Colorado River managers and experts participated.

Why this research?

As Colorado River flows and reservoir levels decline, we face a new era of aridity where we live with what the river offers. This project explored three ways to manage the river based on flow and storage rather than storage alone. Adaptations to low flow can contribute towards more sustainable and equitable river management. There is also a need to reduce stress and conflict around, for example, Glen Canyon Dam releases to generate hydropower and increase insect diversity and productivity.

Benefits to the State

Key benefits of the combined management developed here include the following:

- Gave each party more flexibility to make their individual water consumption, conservation, and reservoir storage decisions independent of other parties.
- Adapted reservoir releases to inflow to give parties more flexibility to conserve water, slow draw down to protection volumes, and reduce sudden, unanticipated draw down, and managing Lake Powell and Lake Mead as a combined system rather than as separate reservoirs.
- Allowed parties to manage all available water rather than just prior conserved water.
- Gave parties more flexibility to store water in Lake Powell and release colder water through the hydropower penstocks to advantage endangered, native Grand Canyon fish.

What we did

The PI created real-time, online modeling environments by using an interactive web spreadsheet (Google Sheet) during video conference sessions. Twenty-six Colorado River managers and experts participated, including participants from a Utah Water Conservancy District and the Utah Colorado River Authority. Participants constructively improved basin water accounts rather than separately developing and testing competing alternatives. This fiscal year, we (1) provided open source, real-time interactive spreadsheet and

Principal Investigators:

David E. Rosenberg (PI)

Students:

Jian Wang (postdoc)
Mozzam Rind (MS)

Partners/Collaborators:

Federal: Clayton Palmer, Brent Oseik, Western Area Power Administration

Theodore Kennedy, U.S. Geological Survey

Federal/State/Local: 26 managers and experts from across the basin

Geographic Areas:

Study Areas: All areas of Utah that are within the Colorado River basin. Also portions of Wyoming, Colorado, New Mexico, Arizona, California, Nevada, and northern Mexico

Areas Benefited: Municipal and agricultural water districts throughout Utah

Contacts:

David E. Rosenberg
435.797.8689
david.rosenberg@usu.edu

Datasets:

Rosenberg, DE. 2021. *Colorado River Coding*. https://doi.org/10.5281/zenodo.5522835

Publications:

- Rind, M, and D Rosenberg. 2023. *Bugs Pay for Days of Steady Reservoir Releases to Reduce Costs to Hydropower Customers and Sustain Funds to Maintain Infrastructure*." Hydroshare.org. https://doi.org/10.4211/hs.b5c65e50679f48dfaf0d5e86dafd9815
- Rosenberg, DE. 2022a. *Colorado River Basin Water Accounts: Provoke discussion about more adaptive operations*. Hydroshare.org. https://doi.org/10.4211/hs.dd17d7bdf25d4da0abeaf381c9fa2df0
- Rosenberg, DE. 2022b. *Input for pre-scoping for National Environmental Protection Act effort to update operations for Lake Powell and Lake Mead by 2026*. Reclamation, Summary of the Federal Register Notice Input Received (September 22, 2022).
- Rosenberg, DE. 2022c. *Lessons from real-time, online collaborative modeling to discuss more adaptive reservoir operations*. https://doi.org/10.4211/hs.eb2ae94405324fe7818e8404ad855afa
- Wang, J, and DE Rosenberg. 2023. *Adapting Colorado River Basin Depletions to Available Water to Live within Our Means*. Journal of Water Resources Planning and Management, 149(7), 04023026. https://doi.org/10.1061/JWRMD5.WRENG-5555

simulation models so parties can explore adaptive strategies under different basin inflows; (2) synthesized 10 lessons to improve model process, build trust, increase operational flexibility, and generate more actionable suggestions for reservoir management; (3) shared "Bugs pay for days of steady reservoir releases to reduce costs to hydropower customers and sustain funds to maintain infrastructure" at April 2023 meeting of the Technical Work Group of the Glen Canyon Dam Adaptive Management Program.

What we found

Key findings presented were the following:

1. Shift experimental steady low releases that allow downstream aquatic invertebrates to lay and hatch eggs from Summer to Spring/Fall months. Shift reduces costs of bug flows and associated hydropower-bug conflicts (Table 1).

Table 1: *Shift Days of Steady Releases to Spring/Fall Months to reduce costs of bug flows (Revenue loss in $ million per month)*

Season	Days of steady releases per month			
	4	8	9	15
May, June, July, August	$0.3	$1.9	$2.7	$5.0
March, April, September, October	$0.5	$1.5	$1.6	$2.6

2. To further reduce conflict, create and fund an ecosystem budget—~$2 million per year—to allow ecologists to pick months and number of days per month of steady low flows and compensate hydropower producers for lost value.

Work plan FY 23–24

We will develop and submit proposal with colleagues from University of California, Davis and The Ohio State University to the National Science Foundation program Humans, Disasters, and the Built Environment. Research on transitions from emergency reservoir operations to more adaptive basin water uses.

Increasing the Impact of Utah State University's Extension Water Check Program with 5-Second Metering

Research Summary:

The overarching goal of this project is to increase the volume of water saved by the Utah State University (USU) Extension Water Check program. We are collecting 5-second water use data to understand user behavior and offering recommendations to participants to reduce landscape water use.

Why this research?

Outdoor water is the largest component of residential water use, and it has the largest opportunity for reducing use. Since 1999, the Water Check program has visited thousands of households across Utah, measured landscape features, tested irrigation system performance, and recommended efficiency improvements and irrigation schedules to reduce landscape water use. We are now using Flume Inc. Smart Home Water Monitor devices (Figure 1) to collect 5-second water use data that will help us understand how much water households save, which Water Check recommendations participants implemented, why the participants implement some recommendations and not others, and how to further reduce landscape water use.

Benefits to the State

This project is helping Utah's Water Check program be more effective. The project can help Utah residents achieve statewide and regional conservation goals. This project can also help answer questions and meet recommendations of the Utah Governor's Recommended State Water Strategy such as what role water conservation plays, identify conservation potential, quantify water savings, adapt to changing weather, and look at the role of science, technology, and innovation in management. Additionally, the project can position Utah as a leader in collecting and disaggregating high-frequency (5-second) water use data into end-uses and targeting conservation messages to household motivations and specific end-use behaviors.

Figure 1: *Flume, Inc. Smart Home Water Monitoring device (grey) strapped around a water meter.*

Principal Investigators:

David E. Rosenberg (PI)
Jeffery S. Horsburgh (Co-PI)
Belize Lane (Co-PI)
Kelly Kopp (Co-PI)

Students:

Mahmuder Aveek (MS)
Camilo Bastidas (Post-doc)

Partners/Collaborators:

Local: Hyde Park, Logan City
Commercial: Flume, Inc. (San Luis Obispo, CA); WaterDM (Boulder, CO)

Geographic Areas:

Study Areas: Cities of Logan and Hyde Park, Utah; Cache County, Utah; and counties throughout Utah

Areas Benefited: Municipal water providers and residential users statewide in all counties

Contacts:

David E. Rosenberg
435.797.8689
david.rosenberg@usu.edu

Websites:

https://uwrl.usu.edu/water-check-study

Datasets/Code:

- https://www.hydroshare.org/resource/fe0377e960b741c4a52dc6ea49db7d80/
- https://github.com/cjbas22/HelpUSUExtensionP

Work plan FY 23–24

We plan to continue with monitoring in 2023. We will also produce 2-minute video, present findings at a national conference, and identify how weather conditions effect water savings—conduct follow-on controlled pre/post Water Check study where ~50% of participants *do not receive* a Water Check.

What we did

We installed 78 Flume devices, completed 74 Water Checks, collected 2+ weeks of data for 59 households, and conducted 9 follow-up interviews. Overall, we collected 561 weeks of data, 189/372 weeks before/after a Water Check.

We also implemented seven suggestions to improve the Water Check program (Box 1) and shared study results with contacts at City of Logan, Hyde Park City, and Utah Division of Water Resources.

What we found

Analysis of the data showed that:

- 59 Households collectively reduced water use by 626,000 gallons—1.9 acre-feet. Significantly different than no savings with 99.998% confidence (Table 1).
- Participants reduced their use by:
  - Reducing water application to more closely match their landscape water budget.
  - Reducing the duration of irrigation events and number of irrigation events per day.
  - Increasing days between irrigation events.
- Large water users reduced use closer to their budgets. Small users started below their budgets and further reduced use. Landscape water budgets also declined seasonally.
- Findings were similar across the two participating cities – Logan and Hyde Park, Utah.

We expect more reductions if Water Checks are completed earlier in the summer and targeted towards the largest water users.

Tabel 1: *Reductions in water use.*

Comparison	Volume (1,000 gal.)
Pre Use minus Post Use	626
Pre Use minus Pre budget	124
Post Use minus Post Budget	52
Pre budget minus Post Budget	554

Box 1.
Recommendations to improve Water Check Program

Include follow-up visit.
Assess drip irrigation zones.
Work with homeowner associations
Add a 1-pg summary to report
Share example water-wise landscapes
Share contact information for landscape contractors
Connect participants to city staff

Making Water Research Results More Reproducible

Research Summary:

Researchers who present their results in ways that allow other researchers to replicate or reproduce those results help to ensure the quality and accuracy of scientific research and open opportunities to build on prior research. In this project, we share practices that can help make research data, models, code, and directions more available and results more reproducible.

Why this research?

A broad interest exists to make science and engineering results reproducible even though few published results are currently reproducible. This contradiction exists because of several perceived and real challenges: (1) reproducing article figures, tables, and other results requires more author effort to prepare and share data, models, code, and directions; (2) authors must learn new skills to organize and share materials online; (3) authors may not share proprietary or sensitive materials; (4) some workflows use stochastic, high-performance computing, big data, or methods with long run times that are too big to share or reproduce bit for bit; (5) reproducing others' results requires time and expertise; (6) funders, universities, and institutions value publication of novel, peer-reviewed journal articles rather than datasets, documentation, or reproduction of others' efforts; and (7) Promoting and rewarding reproducibility may unintentionally encourage researchers to pursue easily reproduced methods rather than complex methods that offer bigger contributions but cannot be reproduced using currently available tools. The authors, journals, funders, and institutions that produce, publish, and support research must better coordinate to overcome these challenges. In this project we share community practices that can make research data, models, code, and directions more available and results more reproducible.

Benefits to the State

Making research results more reproducible will allow more Utahns to access research. Improved access will also allow Utah researchers and businesses to use and extend research produced in Utah, the US, and the world. Making research results more reproducible will also improve public trust in research, data, and models and will help organize materials in perpetuity for future users. Making research results more reproducible will also help narrow the gap between academics and professionals in practice.

Principal Investigators:

David E. Rosenberg (PI)

Partners/Collaborators:

Non-Profit: American Society of Civil Engineers, Environmental Water Resources Institute

Geographic Areas:

Study Areas: No specific study area is designated for this project. Reproducibility work is conducted across Utah, other US states, and internationally.

Areas Benefited: Areas throughout Utah and across the US.

Contacts:

David E. Rosenberg
435.797.8689
david.rosenberg@usu.edu

PUBLICATIONS:

Rosenberg, D. 2022. *Let's make our research more reproducible to accelerate science and increase impact*. EWRI World Congress: Atlanta, GA, June 2022. https://doi.org/10.4211/hs.21f7b428df14455788f4c7d03dfd1de0

WEBSITES:

- http://rosenberg.usu.edu/Research.html#Reproduce
- https://ascelibrary.org/reprod (Journal Result Reproducibility Hub)
- https://ascelibrary.org/jwrmd5/reproducibility_papers (Special Collection of Papers with Reproduced Results)

DATASETS:

Data, model, code, and directions for articles with reproduced results can be found in the Data Availability section of papers listed in the Journal Special Collection: https://ascelibrary.org/jwrmd5/reproducibility_papers

What we did

- Articles were published open access with no charge to authors as incentive to authors to make their results reproducible.
- Created a reproducible hub for the Journal with links to resources to make results more reproducible.
- Created a Special Collection of Papers with Reproduced Results.
- Created a program to award and commend (i) authors with outstanding effort to make their results reproducible, and (ii) reviewers for outstanding effort to reproduce results.

What we found

The number of articles published in the Journal of Water Resources Planning and Management with reproduced results are increasing over time (Table 1 and Figure 1). Five authors have received awards for their efforts in making research reproducible. To date, we have achieved the following three program goals:

- Encourage authors to make their results more reproducible.
- Allow scientists and practitioners to more easily find and use reproducible work.
- Recognize and reward authors who make their work more reproducible.

Table 1: *Articles in the reproducible results program.*

Article Status	Number since Dec. 2020
Published, Results reproduced	10
Published, Data/Code/Model/Directions available	3
In review or revision	11
Published, withdrew from program	7
Declined for review	31
TOTAL	**62**

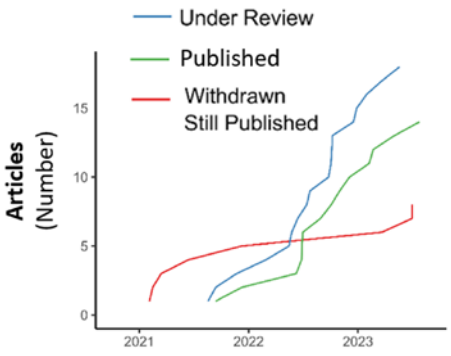


Figure 1: *Published articles with reproduced results by year.*

Work plan FY 23–24

As we continue the reproducible results program, we plan to recruit more Associate Editors for Reproducibility and Reproducibility Reviewers to reproduce results, add papers with reproduced results to the Special Collection of Papers with Reproduced Results, continue to award and recognize authors and reviewers with outstanding effort to reproduce results, hold training workshops to build reproducibility skills in potential reviewers and authors, and expand the program to other journals.

ExaSheds: Advancing Watershed System Science using Machine Learning-Assisted Simulation

Research Summary:

Watershed hydro-biogeochemical models involve many parameters that are uncertain and hard to observe directly in the field. Inverse modeling technique offers a way to infer the uncertain model parameters with observations like streamflow and temperature, but some challenges are high dimensionality, high computational cost, and model structural errors. Machine learning (ML) assisted inverse modeling provides new ways to reduce high dimensionality, improve computational efficiency, and minimize model structural errors. This project helped develop watershed hydro-thermal models for the Upper Neversink Watershed, which also provided training data for ML-assisted inverse modeling.

Why this research?

Water resources are critically important but are under increasing pressure from Earth system changes and the ever-increasing demand for clean water, food, and energy driven by human activity. Such stresses on our water supply and quality affect the nation's watersheds, which are the fundamental functional units of the Earth's surface, wherein vegetation, fluvial systems, soils, and the subsurface interact to govern water flows and many biogeochemical interactions. Watersheds also govern the success of energy and agricultural systems and the impacts of those systems on downstream water quality.

Quantitative modeling at the river basin scale and beyond is essential to address how, why, when, and where water quality and water availability will change in the face of wildfire, droughts, floods, land-use change, extreme weather, and climate change. However, current water quality modeling tools for river systems are challenged to simulate a single watershed, and predictive capabilities are needed for river basins that includes many smaller watersheds. In addition, these tools are largely empirical and do not fully incorporate current and emerging hydro-biogeochemical process understanding. Although advances in computational hardware and algorithms and the rapid growth of environmental data have led to powerful ML tools that offer significant improvements over traditional empirical approaches, the pure data-driven ML approaches are still plagued by large uncertainties when used to extrapolate from current environmental conditions to understand how climate and land-use change will influence future water quality and availability. These observations suggest that ML-assisted physics-based (hybrid) approaches have an important role in simulating hydrological and biogeochemical function in watersheds and river basins.

Principal Investigators:

Pin Shuai (PI)

Partners/Collaborators:

National: Xingyuan Chen, Pacific Northwest National Laboratory

Geographic Areas:

Study Areas: Neversink watershed in the Delaware River Basin, NY.

Areas Benefited: Headwater watersheds in Utah and beyond.

Contacts:

Pin Shuai
435.797.1531
pin.shuai@usu.edu

Publications:

Jiang, P, P Shuai, A Sun, MK Mudunuru, and X Chen. 2023. *Knowledge-Informed Deep Learning for Hydrological Model Calibration: An Application to Coal Creek Watershed in Colorado*. Hydrology and Earth System Sciences 27 (14): 2621–44. https://doi.org/10.5194/hess-27-2621-2023

Work plan FY 23–24

This project is complete.

Benefits to the State

This work enhances seasonal to decadal predictability of the watershed systems using state-of-the-art modeling and simulation. It has direct application for watersheds in Utah to predict the impact of climate, land use/cover change on hydrological processes including streamflow. The findings can be used by stakeholders to inform water management decisions.

What we did

We calibrated the Advanced Terrestrial Simulator (ATS) model at Upper Neversink River watershed within the Delaware River Basin, where streamflow observations are available at 11 gages with varying record lengths. We leveraged a recently proposed, knowledge-informed deep learning technique for model calibration. To assess the impact of calibration period and gage location, model calibration was performed using different streamflow observations, including: (1) outlet discharges from one to eight years; (2) different combinations of one/two/three years of outlet discharges; and (3) one year of discharge at each of the upstream gages. We then evaluated the calibrated model on a test period (Oct 1999 to Sep 2002), independent of the calibration period (Oct 1991 to Sep 1999).

What we found

The results show that estimating the outlet discharge mostly improved when using two- or three-year streamflow observations. The performance of the calibrated ATS run positively correlates with the entropy of the observed streamflow that ATS is calibrated against. This positive relation indicates that streamflow variability, measured by entropy, can be an indicator to select the calibration time range prior to the calibration. Finally, an informative nearby gage can be used to calibrate the model and estimate the outlet discharge. This would potentially lower the computational expense by reducing the watershed domain used in calibration. Our success underscores the importance of selecting observations in calibration and the potential of using a reduced calibration period to account for a limited computational budget.

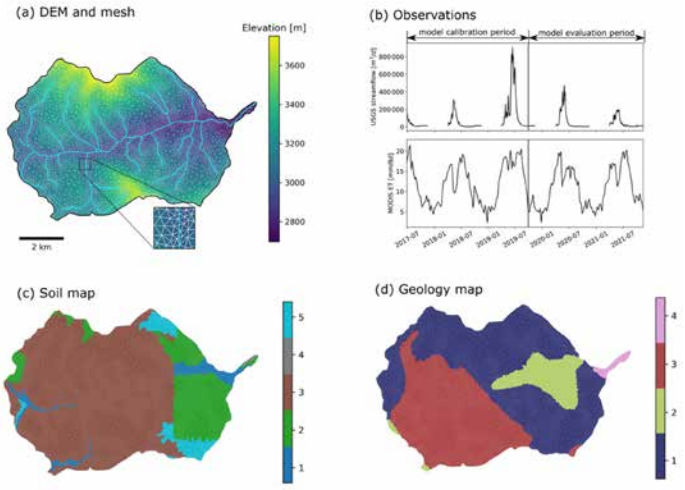


Figure 1: *Study site and soil/geology information.*

Great Salt Lake Strike Team

Research Summary:

The Great Salt Lake (GSL) is at critically low levels, threatening the economic, environmental and ecologic values derived from the lake. UWRL faculty members David Tarboton and Bethany Neilson participated in the GSL Strike Team, which provides impartial, data-informed, solution-oriented policy recommendations restoring the lake to more healthy conditions. Strike team recommendations addressed leveraging wet years, setting a lake elevation range goal, investing in conservation, investing in water monitoring and modeling, and developing a holistic water management plan.

Why this research?

The critically low level of the Great Salt Lake threatens the economic, environmental, and ecologic values of the lake. Research provides crucial perspective, understanding, information, and scenarios to help policy and decision makers chart a path forward.

Benefits to the State

Great Salt Lake (GSL) and the rivers that drain to the lake are important resources for Utah. Streamflow from snowfall and snowmelt in rivers drain to the lake and provide the majority of water used in the GSL basin and along the Wasatch Front. Infrastructure along the shore as well as the brine shrimp and mineral industries depend on the lake level. Ecologically, the lake supports important bird habitat. All of these benefit Utah.

What we did

Research we conducted for the GSL Strike team determined inflow requirements and the ranges of conservation needed to maintain the lake at healthy target levels and to fill to selected target levels in 5, 10 and 20 years. When inflows exceed evaporation, the lake volume and level increase, the area of the lake available for evaporation increases, and the actual evaporation increases. When inflows are less than evaporation, volume and level decline, area of the lake available for evaporation decreases, and the lake settles at a lower level. These processes, quantified in prior research, establish the sensitivity of lake level to changes in inflows. Streamflow inflow changes with climate fluctuations and lower streamflow when more water is uses in the basin. We calculated the inflow needed to fill and maintain lake levels then used these required inflows with historic drought and contemporary streamflow scenarios and historic average precipitation and evaporation to determine the additional inflow needed through conservation based on target levels in the GSL comprehensive management plan.

Principal Investigators:

David Tarboton (PI)
Bethany Neilson (Co-PI)

Partners/Collaborators:

Academic: Janet Quinney Lawson Institute for Land, Water, and Air (USU) and Kem C Gardner Policy Institute (Univ. of Utah)

State: Department of Agriculture and Food, Department of Natural Resources, Department of Environmental Quality

Geographic Areas:

Study Areas: The Great Salt Lake

Areas Benefited: The Great Salt Lake Basin

Contacts:

David Tarboton
435.797.3172
david.tarboton@usu.edu

Bethany Neilson
435.797.7369
bethany.neilson@usu.edu

Publications:

- The Great Salt Lake Strike Team. 2023. *Great Salt Lake Policy Assessment: A synthesized resource document for the 2023 General Legislative Session*, The University of Utah, Kem C Gardner Policy Institute, https://gardner.utah.edu/great-salt-lake-strike-team/

Conference Presentations:

- Tarboton, D and Great Salt Lake Strike Team. 2023. *How much water will it take to restore the Great Salt Lake and how to achieve it?*, Utah State University Spring Runoff Conference, Logan, UT, March 15.
- Neilson, BT. *Great Salt Lake Policy Assessment: A synthesized resource document for the 2023 General Legislative Session*. Presentation to the Cache Water District. March 2023

Media Coverage:

- YouTube Policy Assessment Release. https://www.youtube.com/live/NtZK2P1OAmA?feature=shared
- Utah State Today (article). https://www.usu.edu/today/story/research-universities-state-agencies-team-up-to-offer-solutions-for-great-salt-lake. February 8, 2023.
- Utah State Today (article). https://www.usu.edu/today/story/water-shepherding-usu-experts-discuss-how-to-ensure-conserved-water-gets-to-the-great-salt-lake February 2, 2023.

Work plan FY 23–24

The Great Salt Lake Strike Team is preparing an updated assessment and evaluation of potential solutions for the GSL to be presented to the legislature this year.

What we found

Our key findings are summarized in the tables and figure below. These updated tables account for lake level increases from the recent wet spring (2023). The results inform the effectiveness of the policy actions considered by the strike team towards the goal of maintaining the lake at a healthy level.

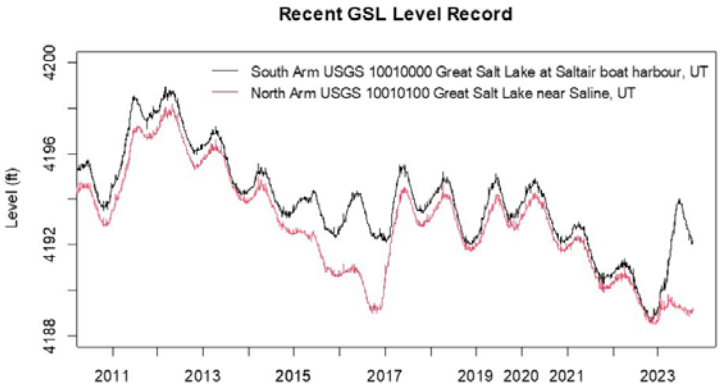


Figure 1: *Recent GSL North and South Arm levels. As of 10/1/23 the levels were 4192 ft in the South Arm and 4189 ft in the North Arm for a total volume of 8.23 million acre-ft.*

The N and S arm levels differ in 2023 because a causeway berm to manage salinity in the S Arm restricted flow. Normally, with the berm open, the typical difference is 0.5 ft. The optimal or healthy lake level is at or above 4198 ft (up to 4205 ft). Some adverse effects occur in the transitory zone from 4195 to 4198 ft, with adverse effects from 4192 to 4195 ft and serious adverse effect below 4192 ft (Utah Division of Forestry Fire and State Lands, 2013). Table 1 provides inflow requirements starting from the lake at 4191 ft.

Table 1: *Inflow requirements for target levels with the lake starting at 4191 ft.*

Target Elevation (ft)	Fill in 5 years (kaf/yr)	Fill in 10 years (kaf/yr)	Fill in 20 years (kaf/yr)	Maintain (kaf/yr)	Condition
4191				1414	Severe adverse effects
4192	1564	1504	1476	1463	Adverse effects
4195	2091	1849	1758	1738	Transitionary effects
4198	2807	2348	2174	2137	Optimal range

Two streamflow scenarios were considered to account for climate variations: Drought—1059 thousand acre-ft per year (kaf/yr) is the lowest 5-year inflow on record (1988 to 1992)—and Contemporary average—1643 kaf/yr is the average inflow for 2000–2022. At these inflows, the additional inflow through conservation required to fill the lake to the given target levels in 5 years is given in Table 2.

Table 2: *. Additional conservation inflow needed for drought and contemporary streamflow scenarios, to fill lake to target level in 5 years.*

Target Elevation (ft)	Drought (1059 kaf/yr inflow)	Contemporary Average (1643 kaf/yr)
4191	355	0
4192	505	0
4195	1032	448
4198	1748	1164

Hydrology Scenarios in the Colorado River Basin

Research Summary:

Many ensembles representing plausible future streamflow are available for the Colorado River Basin. This research has developed statistical metrics to provide an evidence-based framework for evaluating these streamflow ensembles and their suitability for use in future planning. In this research, we developed a classification approach as an analytical framework for grouping and assessing suitability of ensembles. We also identified and filled a knowledge gap in the current scenarios, creating a new streamflow scenario that combines observed and tree-ring-reconstructed flow data with a climate projection adjustment to simulate warming-driven decline in streamflow as an additional plausible option for Colorado River Basin planning / decision making.

Why this research?

Long-range planning of Colorado River water supply River requires an assessment of multiple potential future streamflow scenarios and includes evaluating the impacts of a continuation of the current drought that began in 2000, as well as potentially extreme future droughts and the long-term and progressive decline in watershed runoff caused by a warming climate. Hydrologic and water supply modeling, used by agencies such as the US Bureau of Reclamation and the Colorado River Authority of Utah, is dependent on and sensitive to estimates of future inflow scenarios. This study (1) developed an analytical framework for characterizing, categorizing, and establishing the suitability of scenarios to meet specific planning needs and (2) developed new scenarios to fill identified gaps in the coverage provided by existing scenarios.

Benefits to the State

The Colorado River Basin drains much of Utah, and Utah is one of the upper basin states apportioned a fraction of the Colorado River water under the Colorado River Compact and other elements of the Law of the Colorado River. This water is used in the Wasatch front via the Central Utah Project and elsewhere. The planning of secure water supplies for Utah requires understanding the availability and variability of future streamflow in the Colorado River.

What we did

Given the many ensembles representing plausible future streamflow in the Colorado River at Lees Ferry, we have assembled a broad set of metrics that provide an evidence-based characterization of streamflow ensembles. These indicate whether ensembles are statistically similar to and representative of the past or a changing future. We developed an approach to categorize

Principal Investigators:

David Tarboton (PI)
Jack Schmidt (PI - Center for Colorado River Studies and Watershed Sciences, Utah State University)

Students:

Homa Salehabadi (PhD)

Partners/Collaborators:

National: Rebecca Smith (U.S. Bureau of Reclamation), James Prairie (U.S. Bureau of Reclamation)

Business/Industry: Kevin Wheeler (Water Balance Consulting)

Geographic Areas:

Study Areas: The Colorado River Basin, which overlaps into Daggett, Duchesne, Uintah, Carbon, Emery, Grand, Wayne, Garfield, Kane and San Juan counties in Utah as well as portions of the nearby states of Wyoming, Colorado, New Mexico, Arizona, California and Nevada

Areas Benefited: The Colorado River Basin and regions adjacent to it that depend on Colorado River water.

Contacts:

David Tarboton
435.797.3172
david.tarboton@usu.edu

Media Coverage:

USU College of Engineering, news article: https://engineering.usu.edu/news/main-feed/2023/streaming-wars

Presentations (Selected):

- Salehabadi, H, DG Tarboton, and KG Wheeler. 2023. *New Ensemble Developed to Model Potential Warming-Driven Declining Streamflow*. Presented at US Bureau of Reclamation Integrated Technical Education Workgroup Session #4, August 2, 2023. https://www.usbr.gov/ColoradoRiverBasin/post2026/itew.html
- Salehabadi, H, DG Tarboton, KG Wheeler, R Smith, J Prairie, A Butler, S Baker, B Udall, J Schmidt. 2023. *Assessment of Future Streamflow in the Colorado River Basin with some Implications for Water Management*. Presented at Boase Hydrologic Sciences and Water Resources Engineering Seminar Series, University of Colorado Boulder, October 18, 2023.
- Salehabadi, H, DG Tarboton, KG Wheeler, and R Smith. 2023. *Characterizing Streamflow Ensembles Using Metrics and Storylines and Generating a New Warming-Driven Ensemble*. Presented at Colorado River Climate and Hydrology Work Group, Salt Lake City, UT, November 29, 2023.

Work plan FY 23–24

We will further test the metrics and new scenarios and deliver the results to our US Bureau of Reclamation partners for inclusion in their tools used for Colorado River Basin planning and will continue to publish our results.

both ensembles and metrics. This approach, even in the face of a changing climate and changing streamflow, provides a way to visualize and interpret the changes being simulated. We then assessed the characteristics of existing streamflow scenarios to associate them with plausible future conditions. The results indicated that existing streamflow scenarios in the Colorado River Basin do not sufficiently characterize the plausible condition of warming-driven declining streamflow with modestly increasing variability and high-flow year frequency similar to the past. To fill this gap, we created a new streamflow scenario using a stochastic nonparametric approach that combines observed and tree-ring-reconstructed flow data and then adjusted the marginal distribution of the streamflow sequences to incorporate estimated decline in future flow.

What we found

The presented metrics and their classification of ensembles provides an analytical framework for characterizing and assessing the suitability of future streamflow ensembles for water resources system planning. They provide information to inform decisions on which streamflow scenarios should be used for planning purposes. Recognizing that changes occur over time, comprehensive metrics on each scenario contribute to better planning in river basins, such as the Colorado, facing critical water shortages. The new scenario developed to address the gap in existing ensembles (Figure 1) is expected to help researchers, engineers, and managers at various agencies involved in Colorado River Management, such as the U.S. Bureau of Reclamation, in planning for future Colorado River System operations. This ensemble was constructed to provide a lower mean than the full observed record, and has a decadal mean that decreases over time, consistent with current understanding from climate projections. It provides low and high flows not limited to the historical record and increases variability, also as projected. Despite its declining trend, the ensemble retains occasional high-flow years, a characteristic missing in most prior climate projection-related ensembles.

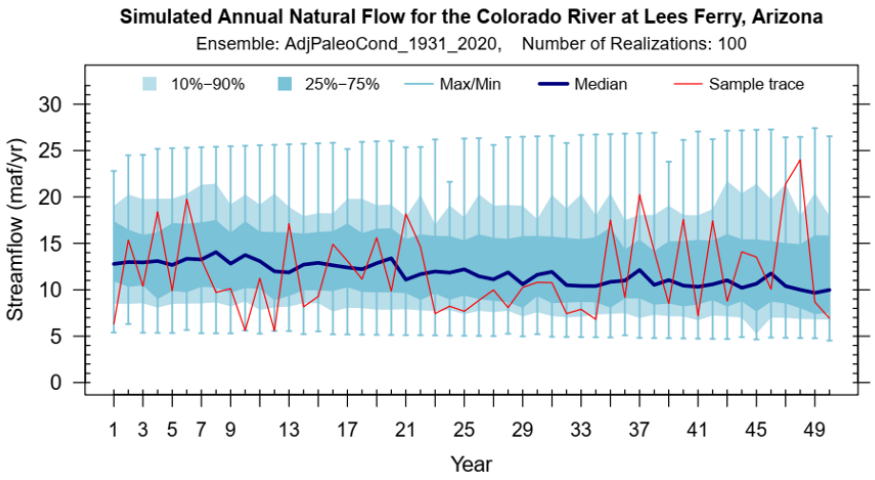


Figure 1: *Simulated water year natural flow for the Colorado River at Lees Ferry from the new warming adjusted paleo conditioned ensemble developed to fill a gap in prior ensembles.*

Section 4

Research Faculty, Professional and Support Staff

Utah Water Research Laboratory

David G. Tarboton, Director
Steven L. Barfuss, Associate Director
Jeffery S. Horsburgh, Associate Director
Randal S. Martin, Head of Environmental Engineering Program
Bethany T. Neilson, Head of Water Engineering Program
Cathi Allen, Business Services Office Manager
Carri Richards, Public Relations Specialist
Jan S. Urroz, Administrative Supervisor

Utah Water Research Laboratory Faculty

David G. Tarboton, PhD, Director UWRL; Sant Endowed Professor of Water Resources Engineering, CEE/UWRL
Steven L. Barfuss, MS, Associate Director, UWRL, Research Professor, CEE/UWRL
Burdette Barker, PhD, Assistant Professor, Extension Irrigation Specialist, Extension/CEE/UWRL
Cal Coopmans, PhD, Research Assistant Professor, AggieAir Director ECE/UWRL
Brian Crookston, PhD, Associate Professor, CEE/UWRL
R. Ryan Dupont, PhD, Cazier Endowed Professor, CEE/UWRL
Jeffery S. Horsburgh, PhD, Associate Director, UWRL, Associate Professor, CEE/UWRL
Joanna (Liyuan) Hou, PhD, Assistant Professor, CEE/UWRL
Michael C. Johnson, PhD, Research Professor, CEE/UWRL
Jagath J. Kaluarachchi, PhD, Professor, CEE/UWRL; Dean, College of Engineering
Belize Lane, PhD, Associate Professor, CEE/UWRL
Randal S. Martin, PhD, Research Associate Professor, CEE/UWRL; Head of Environmental Engineering Program, CEE/UWRL
Michael J. McFarland, PhD, Associate Professor, CEE/UWRL
Joan E. McLean, MS, Research Professor, CEE/UWRL
Kyle Moor, PhD, Assistant Professor, CEE/UWRL
Bethany T. Neilson, PhD, Professor, CEE/UWRL, Head of Water Engineering Program
Colin Phillips, PhD, Assistant Professor, CEE/UWRL
David E. Rosenberg, Ph.D., Professor, CEE/UWRL
Zac Sharp, PhD, Research Assistant Professor, CEE/UWRL
Pin Shuai, PhD, Assistant Professor, CEE/UWRL
Ronald C. Sims, PhD, Professor, BE/UWRL
David K. Stevens, PhD, Professor, CEE/UWRL
Yiming Su, PhD, Assistant Professor, CEE/UWRL
Alfonso Torres-Rua, PhD, Assistant Professor, CEE/UWRL
Blake P. Tullis, PhD, Professor, CEE/UWRL, Associate Vice President of Research, USU
Sierra Young, PhD, Assistant Professor, CEE/UWRL

Utah Water Research Laboratory Staff

Cathi Allen, BS, Business Services Office Manager Sr.
Camilo Bastidas, PhD, Postdoctoral Scholar
Marianne Brown, Staff Assistant I
Tracy Brown, MS, Business Manager
Mark Cannon, BS, Research Engineer II
Andrea Carroll, Business Assistant III
Brittanie Carter, MS, Marketing and Public Relations Coordinator
Pabitra Dash, PhD, Programmer/Analyst Sr.
Ashton Decker, BS, Staff Assistant/Receptionist
Maria Gates, BS, Business Manager
Ian Gowing, BS, Research Engineer III, AggieAir Service Center Manager
Andrew Lee, Engineering Technician II
Anzy Lee, PhD, Postdoctoral Scholar
Marissa Li, MS, Researcher II
Ken Lippold, MS, Research Engineer
Eileen Lukens, MS, Research Engineer
Ayman Nassar, PhD, Postdoctoral Scholar
Bryson Parker, Maintenance Technician
Ken Provard, BS, Research Engineer I
Maurier Ramirez, MS, Programmer/Analyst Sr.
Alyssa Regis, BA, Communications and Outreach Specialist
Katie Reynolds, MS, Business Assistant II
Carri Richards, BS, Public Relations Specialist
Britlie Sharp, Office Assistant
Judy Sims, MS, Coordinator, Utah On-Site Wastewater Treatment Training Program
Daniel Slaugh, BS, Software Engineer
Patrick Strong, BS, Research Engineer I
Jamie Stubbs, BS, Business Assistant III
Shannon Syrstad, MS, Research Engineer II
Chad Taylor, Engineering Technician III
Jan Urroz, BS, Supervisor of Administrative Services and Infrastructure
NeCole Walton, BS, Business Manager
Jian Wang, PhD, Postdoctoral Scholar

Emeriti Faculty

A. Bruce Bishop, PhD, Professor Emeritus, CEE/UWRL
David S. Bowles, PhD, Professor Emeritus, CEE/UWRL
William J. Doucette, PhD, Professor Emeritus, CEE/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
Mac McKee, PhD, Professor Emeritus, CEE/UWRL
Richard Peralta, PhD, Professor Emeritus, CEE/UWRL
William J. Rahmeyer, PhD, Professor Emeritus, CEE/UWRL
Judy Sims, MS, Research Associate Professor Emeritus, BE/UWRL
Darwin L. Sorensen, PhD, Research Professor Emeritus, BE/CEE/UWRL
J. Paul Tullis, PhD, Professor Emeritus, USU Foundation, CEE/UWRL

Utah Water Research Laboratory
UtahStateUniversity

1600 Canyon Road, Logan, UT 84322-8200 | 453.797.3550 | https://uwrl.usu.edu