FY 2021-22
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

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Utah Water Research Laboratory
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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 2021–22 (FY 22) 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. Due to drought, climate warming, and ongoing consumptive water use in river basins draining to the Great Salt Lake (GSL), the lake is presently at record low levels. UWRL researchers are part of a "strike team" formed in partnership with the University of Utah and State agencies to recommend policies and solutions to this crisis that threatens 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. The Logan River Observatory serves as a microcosm for understanding the watershed processes that produce the runoff to the GSL. Beyond the GSL, the entire western US remains in the grip of a severe and sustained drought. Colorado River reservoirs are also at record low levels. 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 $5.1 million in project funding from other sources in FY 22 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 22, budgeted expenditures for FY 23, and planned expenditures for FY 24. 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

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Section 1

Introduction

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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 research institute in every state. The Utah institute, known as the Utah Center for Water Resources Research (UCWRR), was established at the UWRL as part of a national network of water research institutes.

With 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 57 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.

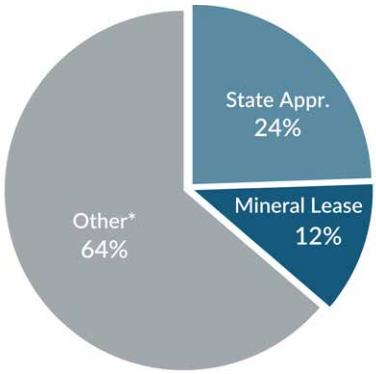
As students graduate and are hired by Utah employers, they become effective means of technology transfer from the UWRL to Utah's water and environmental organizations. Technology and information are also transferred through collaboration and partnerships with engineers, scientists, and managers of the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

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 22 of over $9.2 million makes it one of the largest university-based institutes in the nation.

UWRL Financial/Academic Summary FY 22	
Number of Active Projects	158
Total Expenditures	$9,279,383
Scholarly Publications in Peer-Reviewed Journals	72
Outreach Activities FY 22	
Short Courses and Field Training	31
UWRL Student Support FY 22	
Graduate Students Supported	48
Undergraduate Students Supported	63
Degrees Granted FY 22	
Doctor of Philosophy (PhD)	9
Master of Science (MS)	10
Master of Engineering (ME)	3

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 22, MLF funding of just under $1.1 million accounted for 12% 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 22 were over $9.27 million.



UWRL Expenditures FY 22

The UWRL's MLF projects 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)
- 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. We have hired three new faculty members in the areas of environmental engineering and groundwater studies. 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 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. UWRL faculty are also part of the recently created 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.

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 $133,770 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. Defining the geochemical cycling of arsenic along the shoreline of the declining Great Salt Lake in wetting and drying cycles, using automated robotic technologies for water and sediment samples across a range of moisture contents. This project will result in much needed information about how dynamic water levels of the GSL shoreline affect pollution concentrations in the sediment and water and will assess this risk in the context of the newly exposed sediments.
2. Developing high-resolution seasonal snow forecasts, up to nine months in advance, for Utah's watersheds in the face of ongoing drought. This project is using a novel set of climate modeling products, observations, machine-learning, and snow physics models to facilitate drought risk management, thus benefiting a wide spectrum of Utah stakeholders including water managers, hydropower planners, farmers, ranchers, ecologists, tourists, and the public.
3. Quantifying the effect of potential submerged control structures on density-driven exchange flows through the breach of the Great Salt Lake using CFD modeling and field measurements. This project will inform a State of Utah plan to modify the height of an existing berm to alter exchange flows due to ongoing drought conditions.
4. Developing an efficient, multi-pronged strategy cyanobacteria monitoring and laboratory analysis strategy for key Utah drinking water reservoirs that minimizes the costs without sacrificing accuracy. This project is working with state agencies to help water utilities and municipalities protect water consumers.

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, Water Operator's Certification Commission)
- Department of Natural Resources (Division of Water Resources, 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 Board)
- Logan Island Canal Company
- Logan River Task Force
- Logan River Water Users
- Salt Lake City Corporation
- OpenET Colorado River Basin Working Group

Other State and National Agencies and Organizations

- California Water Quality Monitoring Council, Environmental Flows Strategic Workgroup
- California Data Science Advisory Panel
- FEMA Guidelines for Best Design and Inspection Practices for Spillways
- FEMA Dam Intervention Initiative Advisory Board
- National Dam Safety Review Board
- NOAA National Water Center Community Advisory Committee for Water Prediction
- United States DOD, Industrial Wastewater Treatment of Federal Facilities and Integrated Solid Waste Management and Quality Recycling at Federal Facilities
- United Kingdom Natural Environmental Research Council
- USGS 104g proposal review

Professional Organizations

- Air and Waste Management Association – Industrial Wastewater Treatment Waste Management, Federal Facilities Committees
- American Geophysical Union (AGU)
- American Institute for Medical and Biomedical Engineering
- American Society of Civil Engineers (ASCE), Environmental Water Resources Institute (EWRI)
- 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 Inventory of Low-head Dams, Joint Task Committee
- National Onsite Wastewater Recycling Association
- National Society of Black Engineers
- Northeast Biotechnology Center and Consortium
- North American Plant Phenotyping Network
- United States Society on Dams, spillways committee
- Utah Onsite Wastewater Association
- Western States Water Council

Mineral Lease Fund Expenditures

The table below summarizes the actual, budgeted, and planned expenditures of ML funds allocated to the UWRL for FY 2022 through FY 2024 for research projects in the five major Program Areas. UWRL administration and technology transfer expenditures account for approximately 12% of total MLF budgeted and planned expenditures.

Mineral Lease Fund Expenditures: Research Program Area	Actual FY2022	Budgeted FY2023	Planned FY2024
Administration	$134,991	$139,041	$143,212
Environmental	$454,986	$805,904	$804,327
Hydraulics	$50,896	$97,869	$97,924
Measurement, Sensing and Information Systems	$92,563	$177,707	$177,800
Water Education, Outreach and Technology Transfer	$92,220	$146,787	$145,970
Water Resources	$269,830	$444,892	$442,967
TOTALS	**$1,095,486**	**$1,812,200**	**$1,812,200**

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 $1,095,486 expenditure was less than budgeted last year due to lower state deposits. The budgeted $1,812,000 for this and next year reflects what is budgeted for the UWRL from MLF in the Utah State Legislature higher education base budget. Recognizing that the state deposits received will be different from this budgeted amount, the project budget planning for each program area includes amounts for undesignated research projects, which are projects that 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.

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 biosolids, soils and crops, and the risks that these emerging contaminants pose to human health and the environment are also topics of active research. 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 PM2.5 and ozone associated winter inversions 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. Additionally, responding to the COVID pandemic, many UWRL faculty participated in cutting-edge collaborative research into mapping the SARS-CoV-19 virus in domestic wastewater distribution systems, survivability of the virus through municipal wastewater treatment plants, and the presence of the virus on short-range and long-range ambient aerosols. New faculty have brought expertise in nano particles and microplastics, topics of emerging interest in environmental water quality, treatment, and use.

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 developing 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 moneys are sometimes used to enhance the development of technologies, training modules or educational materials, and are often used to provide technical support to Utah's state and local agencies on water-related issues. 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 Grant Proposal Review	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 Great Salt Lake Strike Team Logan City Water Board Logan River Task Force Logan River Water Users NOAA National Water Center Community Advisory Committee for Water Prediction OpenET Colorado River Basin Working Group Water Environment Association of Utah – Biosolids Committee
Peer Review for Journal Articles	**Professional Leadership and Service**
Environmental Modelling & Software Journal, editorial board Frontiers in Control Engineering, editor Hydrological Processes, associate editor Journal of the American Water Resources Association Journal of Coastal and Hydraulic Structures, editor Journal of Biological Engineering, 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 Civil Engineering Committees Association for the Advancement of Artificial Intelligence European Working Group on Overflowing and Overtopping Erosion North American Plant Phenotyping Network Overtopping Protection at Dams and Levees Seminar Series, team leadership Society of PhotoOptical Instrumentation Engineers Conference Committee Technical Standards in Drone Technology (ASABE) United States Society on Dams Committees Utah Onsite Wastewater Association onference Planning Committee
Proposal/Program Review	
NASA Research Opportunities in Space and Earth Science program review panel National Science Foundation. Review panels and postdoctoral program	

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.

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Section 2

Administration, Advisory Support and Special Equipment

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Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds

Administration: Area	Actual FY2022	Budgeted FY2023	Planned FY2024
UWRL Administration	$28,273	$29,121	$29,994
Communications and Outreach Office	$29,294	$30,173	$31,078
Businss Services Office	$77,424	$79,747	$82,140
TOTALS	**$134,991**	**$139,041**	**$143,212**

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 22 administrative costs represented approximately 2.6% of total UWRL MLF expenditures.

Outreach and Business Support

Overall, annual research expenditures for the UWRL have generally fluctuated between $ 8 and $ 9 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 Office in the form of accounting and financial oversight. Further, 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 22 on these support activities accounted for 9.7% of total MLF funding.

Advisory Support on Water Problems

The UWRL receives many requests for advice and collaborative help on various water problems in the state. The UWRL provides support, sometimes from MLF sources, to defray travel costs so UWRL faculty can participate in meetings in the state to coordinate UWRL activities with ongoing water problems, to identify and seek funding for new applied research in the state, and to provide expert advice relative to current water issues faced by various state and local agencies. These activities are enumerated in the Project Summaries section of this document.

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 FY2022	Budgeted FY2023	Planned FY2024
Dupont, R.	Evaluation of the Presence, Fate, and Exposure Pathways of PFAS Compounds in Northern Utah Communities	$67,485	$89,509	$92,194
Dupont, R.	Field Sampling of COVID-19 in Wastewater to Manage Outbreaks and Disease Transmission	$20,596	-	-
Martin, R.	Airborne/Wastewater COVID Studies and Development of Area Source Emission Methodologies	$50,916	$52,444	$54,017
McFarland, M.	Mitigating Soil Salinity Effects on Crop Yield through Biochar Land Application	$55,727	$57,399	$59,121
McLean, J.	Advanced analytical support for research efforts in environmental quality	$54,492	$56,127	$57,811
McLean, J.	Impact of Metals and Metal Ions on Soils and Plants	$45,358	-	-
Moor, K.	Assessing the Sources, Transport, and Fate of Microplastic in the Logan River Watershed	$34,321	$45,351	$46,711
Moor, K.	Wildfire impacts on surface water photochemistry	$22,928	$33,615	$34,624
Sims, J.	Mitigation of Methane Emissions from Anthropogenic Sources	$32,094	$33,057	$34,048
Sims, R.	Wastewater Treatment: Nutrient Removal Using Biofilm Microalgae	$22,910	$23,598	$24,306
Stevens, D.	Assessment and Modeling of Cyanotoxin Presence and Occurrence Risk in Utah Surface Waters	$48,160	$57,605	$59,333
	New projects		*$191,405*	*$176,367*
	Undesignated		*$165,795*	*$165,795*
	TOTALS	**$454,987**	**$805,904**	**$804,327**

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

Project Description:

Need and Purpose

PFAS compounds represent a wide range of polyflourinated alkyl substances that have been used in consumer products and firefighting foams since the 1940s because of their heat and water-resistant properties. These chemicals are persistent in the environment and in the human body and have recently been associated with significant adverse human health effects, including increased cholesterol levels, low infant birth rates, cancer, and adverse effects on the immune system and on thyroid hormone production. Significant PFAS levels detected in surface and groundwater in Michigan and growing health effects evidence have resulted in lifetime health advisory levels in drinking water proposed in June 2022 by the US EPA for four of the commonly detected PFAS compounds ranging from 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) to limit human exposure to these hazardous materials. This project is designed to generate PFAS concentration data for various potential exposure routes (municipal wastewater treatment plant effluent used for secondary irrigation, municipal biosolids, municipal landfill leachate, wet deposition, etc.) in northern Utah. Potential human risks via direct exposure to secondary water, via recreational contact, and via ingestion of plants irrigated with treated effluent and contaminated rainwater or grown in contaminated biosolids are being evaluated.

Benefits to the State

Findings from this study will provide the first data from northern Utah describing PFAS fate and transformation in wastewater treatment plants and lagoons and documenting the potential risks of PFAS compounds in reclaimed wastewater, recreational settings impacted by precipitation and landfill leachate influences, produce grown in urban gardens with reuse water, and biosolids generated from municipal wastewater treatment plants. Treatment and reuse options limiting PFAS risks will be identified if necessary, providing essential information to those communities considering developing water reuse projects in the future. The results generated in this study can be broadly applied to other semi-rural regions in the State with water scarcity issues driving the development of treated wastewater for secondary water reuse and considering beneficial use of biosolids generated in their wastewater treatment plants.

Findings/Results

Sample processing and extraction as well as analytical methods have been developed in the UWRL Environmental Quality Laboratory for the identification and quantification of 24 different PFAS compounds in a wide

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Randal Martin (Co-PI)

Technicians:

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R. Chen

Students:

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Victoria Krull (MS)

Partners/Collaborators:

Local: Hyrum Wastewater Treatment Plant

Geographic Areas:

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

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

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variety of environmentally relevant samples. Quantitation in field samples has focused on C4-C10 carboxylic and sulfonic acids because of their relatively low method reporting limits (MRLs) below 0.04 ng/L, and because they have been routinely detected in samples analyzed in this study. Compounds > C10 rarely appear and tend to have higher MRLs. A range of PFAS compounds have been identified in both wastewater influent and treated effluent samples, in vegetables irrigated with secondary water, in municipal biosolids and forage crops grown in biosolids amended fields, in some rainwater samples, as well as in landfill leachate and leachate pond sediment samples collected from throughout Cache Valley. Figure 1 indicates the concentration of ten commonly detected PFAS isomers in local wastewater effluent samples compared to those quantified in the San Francisco municipal treatment plant serving a much larger urban population. This figure clearly indicates that wastewater PFAS concentrations are comparable in both highly urban and rural/peri-urban areas, making risks of exposure by this route universal.

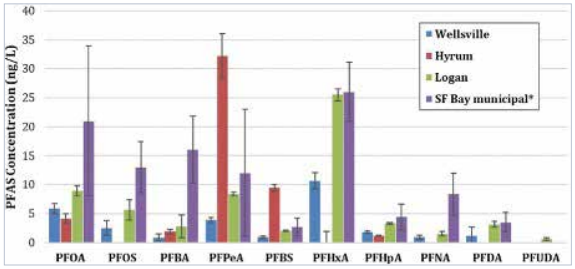

Figure 1: *PFAS concentrations in local systems compared to San Francisco Bay wastewater treatment plant effluent.*

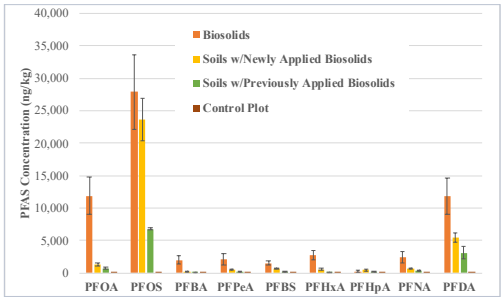

Figure 2: *Concentrations of PFAS compounds in Hyrum biosolids, biosolids amended soils, and control plot.*

Figure 2 indicates significant levels of some PFAS compounds (esp. PFOS and PFDA) in soils amended with Hyrum biosolids compared to the unamended control plot, with the concentrations subsequently decreasing in the soil over time for all of the PFAS compounds quantified in this study.

Work Plan FY 22–23

This project will continue into FY 22–23, completing wastewater reuse system sampling to include biosolids from both the Hyrum and Logan wastewater treatment plants; continued sampling of the fate of PFAS compounds in the soils and forage crops at the Hyrum biosolids application field sites; sampling of pore water at the Hyrum biosolids application field sites to assess PFAS mobility below the biosolids application areas; and sampling of the Logan biosolids composting system to assess PFAS fate and transformation during this common biosolids stabilization step.

Field Sampling of COVID-19 in Wastewater to Manage Outbreaks and Disease Transmission

Project Description:

Need and Purpose

The COVID-19 pandemic has taken a significant toll on human life and has been a significant economic burden throughout the world. Utah and Utah State University in particular have not been immune to this pandemic's effects, which caused disruption of learning and academic life on campus throughout 2020 and early 2021. This project was initiated to develop and validate methods for the sampling of student housing units on the USU residential campuses to provide early warning of asymptomatic or pre-symptomatic individuals in USU housing so that residents in those units could be screened, isolated, and quarantined as necessary to contain the spread of the virus on USU residential campuses. The purpose of the sampling effort during FY 21–22 was to continue the sampling effort from throughout the main campus student housing to monitor the decline in COVID transmission and provide supporting data from individual testing and caseload counts.

Benefits to the State

Sampling methods developed in this project have been used and validated at USU's main campus, as well as USU campuses in Price and Blanding, and COVID monitoring of the collected samples by USU's Biological Engineering Department have provided the necessary sample quantitation to detect and contain the spread of COVID-19 on these campuses and throughout the

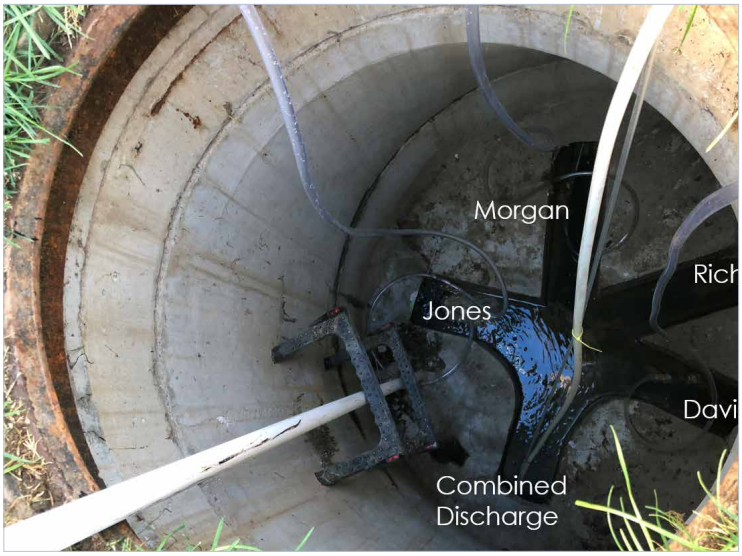

Figure 1: *COVID sampling manhole, Student Living Center, USU Main Campus*

Principal Investigators:

R. Ryan Dupont (PI)

Students:

Kyndall Bair (BS)
Megan Speechly (BS)

Partners/Collaborators:

Local: USU Facilities, Risk Management, Department of Biological Engineering, USU Eastern, USU Blanding; Logan City Environmental Department

Geographic Areas:

Study Areas: USU Main Campus, USU Eastern in Price, USU Blanding and adjacent communities

Areas Benefited: Other areas throughout the state that can benefit from early detection for containment of the spread of COVID-19 or other potentially highly transmittable human diseases.

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communities that host these institutions, and more recently to track the declining case and transmission rates through FY 21–22. The methods are applicable at other locations throughout the State where concentrated housing units or housing areas can benefit from early detection of infected individuals before symptoms of an infection might appear. Early detection and prevention of the spread of these disease-causing agents is critical to containing disease transmission and the mitigating the potentially high costs of treatment and severe health and economic consequences to affected communities.

Findings/Results

A total of 22 sampling locations in manholes servicing student housing units throughout the USU campus, established early in the COVID pandemic, along with five additional sampling locations at the Blanding and Price campuses, continued to be sampled through the end of April 2022. Composite wastewater samples were collected one to two times per week from each location for processing and detection of COVID-19 viral levels in the sampled wastewater. Samples collected prior to students returning to the Logan campus in the Fall of 2022 showed low levels of viral load in the wastewater from family housing units of the "permanent" campus residents (graduate students and families in Aggie Village). Upon the return of students to campus, viral levels did not increase significantly until several weeks after the start of Spring 2022 semester, likely in response to new, more transmissible COVID strains. COVID count data decreased significantly by February 2022 and remained low through the termination of sampling at the end of April 2022.

Early in the pandemic, the use of wastewater screening for the collection of composite samples from potentially infected individuals in USU housing units was able to detect viral load from pre- or asymptomatic individuals allowing the directed and strategic screening and isolation of individuals to limit the spread of COVID-19 during a time of high national and statewide viral transmission rates. Highly variable viral responses in samples collected early in the pandemic suggest that viral loadings from individuals at various stages of infection and recovery in the sample populations make this a screening method at best. Sampling in FY 21–22 provided confirmatory information tracking the dissipation of COVID transmission on USU's campuses.

Work Plan FY 22–23

This project ended in April 2022.

Airborne/Wastewater COVID Studies and Development of Area Source Emission Methodologies

Project Description:

Need and Purpose

The continued prevalence of the COVID-19 pandemic throughout the country and Utah underscores the need to understand the long-range and local transmission modes. As a part of this effort, Dr. Martin became involved in several studies examining the potential for long-range transport of the SARS-Co-2 virus via attachment to air-borne particles, the potential for virus-laden aerosols associated with municipal wastewater treatment, and by extension, the success of typical wastewater treatment (WWT) at eliminating the virus before the effluent is reintroduced to the atmosphere. Additionally, cooperative work was initiated to develop a Relaxed Eddy Accumulation (REA) area source sampling system with initial target source likely to include local landfills and the drying playa of the Great Salt Lake This summary combines two projects funded via Mineral Lease funds and monies obtained from the Mariner Eccles Foundation.

Benefits to the State

Successful tracking of the airborne SARS-CoV-2 virus would help establish source attributions and could lead to mitigation scenarios, while understanding the efficacy of traditional wastewater treatment for SAR-Co-2 virus destruction would directly relate to local and state public health protections.

Findings/Results

Nationwide aerosol and precipitation samples were obtained through cooperative agreements with the National Atmospheric Deposition Program (NADP) and other related networks, and source-related aerosol and aqueous samples were collected from a northern Utah membrane wastewater treatment facility. To date, USU has undertaken REA system development.

Some of the ambient depositions (NADP and other samples) were found to contain SARS-Cov-2 RNA, but the spatial detection seemed locationally inconsistent. Air parcel back trajectory analysis is being conducted to see if any patterns can be identified when viral RNA was detected. Several aerosol and in situ (process stream) samples were collected from the target treatment WWT facility and replicate samples were collected throughout the year. Aqueous-borne SARS-CoV-2 RNA was found at several location throughout the WWTP process, including the effluent, but no RNA was detected in the aerosol collected from within the plant facilities. Note that the presence of RNA does not necessarily imply active virus, just the presence of virus bodies.

Principal Investigators:

Randal Martin (PI)
Janice Brahney (Co-PI)
Keith Roper (Co-PI)
Sierra Young (Co-PI)

Students:

Motasem Abualquboz (MS)

Partners/Collaborators:

Local: Logan, UT
Cache County

State/National: Utah Division of Air Quality, UT Air Monitoring Center

Geographic Areas:

Study Areas: Northern Utah and nationwide

Areas Benefited: The COVID studies will not only benefit all of Utah but will also have national implications. Once completed, the REA emissions measurement system will primarily target the state of Utah but may also have national implication.

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Work Plan FY 22–23

The COVID-related data collection has likely come to an end, but analysis and manuscript preparation will continue. Studies have also been initiated associated with the WWT-related and ambient concentrations of an important emerging pollutant class known as PFAS (per- and polyfluoroalkyl substances). Work will continue on the development and deployment of the REA system for area source emission determinations, especially as related to the desiccating Great Salt Lake.

Mitigating Soil Salinity Effects on Crop Yield through Biochar Land Application

Project Description:

Need and Purpose

Saline soils are of particular concern in Utah and other semi-arid areas where moisture evaporation, together with consumptive use of irrigation water, results in soils with excessively high salt concentrations. High soil salt concentrations can reduce both the soil's water transmission potential and crop growth. Maintenance of a favorable salt balance is necessary for sustained agricultural production in Utah as well as in other arid areas of the world that are subjected to periodic drought conditions. Quantifying the impact of salinity on crop yield is important to computation of the potential economic benefits from salt leaching practices and/or installation of drainage systems.

Figure 1: *Photograph of University of Utah, Utah State University and University of Alabama Research Colleagues at a Northern Utah Farm Inspecting Corn Yields on Organically Amended Fields (Corrine, Utah).*

Biochar application to saline soils has been touted as a promising strategy for enhancing agricultural crop production. In a recent collaborative research study conducted between Utah State University, the University of Utah and the University of Alabama, the use of saline groundwater in combination with soil amendments was evaluated to determine its impact on wheat production. Spring wheat was grown under the combinations of two water treatments that included freshwater (307.2 ppm, Total Dissolved Solids) and saline water (3000 ppm, Total Dissolved Solids) by drip irrigation. Two mass loadings of biochar were also studied including 0.0 ton of biochar per hectare (0 ton/ha) and 4.8 ton/ha as a soil amendment. The results indicated that saline water reduced the wheat production yield by 11.0% compared to the use of fresh water. Alternatively, biochar addition enhanced the grain yield by 5.6% and 13.8% compared to non-biochar addition under fresh and saline irrigation water conditions, respectively. These preliminary results indicated and led to the recommendation that saline groundwater is a viable source of irrigation water and that biochar seemed to alleviate salinity stress on wheat production.

Principal Investigators:

Michael McFarland (PI)

Partners/Collaborators:

Academia: Steve Burian, University of Utah/University of Alabama

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Publications:

- El-Sayed, M.A. E., Hazman, M., El-Rady, A. G. A., Almas, L., McFarland, M., El-Din, A. S. and S. Burian (2021). *Biochar Reduces the Adverse Effect of Saline Water on Soil Properties and Wheat Production Profitability*. AGRICULTURE 2021, 11(11), 1112; https://doi.org/10.3390/agriculture11111112
- Mohamed Y. Hazman, Mohamed E. A. El-Sayed, Farida F. Kabil, Nourhan A. Helmy, Lal Almas, Mike McFarland, Ali Shams El Din and Steven Burian (2022). *Biochar application to fertile soil on tomato crop production under saline irrigation regime*. Agronomy 2022, https://doi.org/10.3390/agronomy12071596
- Shin, S., Aziz, D, El-Sayed, M., Hazman, M., Almas, L., McFarland, M., Shams El-Din, A. and S.J. Burian (2022). *Systems Thinking for Planning Sustainable Desert Agriculture Systems with Saline Groundwater Irrigation: A Review*" Water, vol. 14 water-1961646; doi: 10.3390/w14203343. https://www.mdpi.com/2073-4441/14/20/3343

A similar follow-up study used a second agricultural crop. In this second study, Utah State University and the University of Utah tested the hypothesis that the application of biochar at a rate of up to 4.8 dry tons per hectare could ameliorate the negative effects associated with the use of saline irrigation water (salt content of 3,000 ppm Total Dissolved Solids) in the growth of tomato. Results demonstrated that saline irrigation water significantly reduced crop yield by an average of 51%, and biochar addition was not able to reverse this deleterious effect. Furthermore, biochar addition did not reduce the amount of accumulated sodium found in the tomato fruit nor in its plant roots. However, the tomato fruit grown in biochar-amended soil were found to be lower in total suspended solids (TSS) levels (41.7% reduction) than fruit grown in unamended soil. In addition, tomato fruit grown in biochar amended soils were observed to have a large diameter (50% increase in fruit size).

Benefits to the State

- Biochar research has the potential to increase agricultural crop yields in areas impacted by drought or other adverse climate conditions.
- Recycling agricultural residues in the production of biochar can be a source of economic revenue for rural communities in Utah.
- The ability to utilize saline irrigation water for agricultural crop production can protect valuable Utah drinking water supplies.
- Land application of biochar reduces soil erosion and increases drainage capacity of sodic soils in Utah.

Findings/Results

This research, which is focused on the effects of biochar land application for mitigating salinity effects on agricultural crop production, represents a new and fascinating line of research (Figure 1). Since the beginning of this research program in 2020, we have published a number of peer-reviewed publications.

Work Plan FY 22–23

Plans for the next fiscal year include the following:

1. Given the conflicting results associated with the use of biochar land application to improve crop yields under saline conditions, additional research is planned focused on investigating the effects of specific pyrolytic conditions (i.e., time and temperature) on final biochar chemical and physical properties.
2. Utah State University, University of Utah and University of Alabama researchers will be identifying farmers, ranchers, and other large landowners in Utah as potential research sites to conduct a full-scale biochar testing program under normal agricultural crop production procedures.

Advanced Analytical Support for Research Efforts in Environmental Quality

Project Description:

Need and Purpose

The Environmental Quality Laboratory'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 innumerable interactions between humans and water. These pressing challenges include: monitoring and preventing harmful algal blooms and cyanotoxin production; presence of pharmaceuticals, personal care products, and fluorinated substances in reused wastewater, through secondary water systems, and into soils and crops; monitoring pesticides and adjuvants in water, soil, plants, and pollen; airborne fluorinated substances, especially those arising from landfills; investigating the breakdown of plastics and microplastics in the environment; monitoring pollutant loading from stormwater; monitoring wastewater for COVID-19 DNA; and other urgent matters that arise.

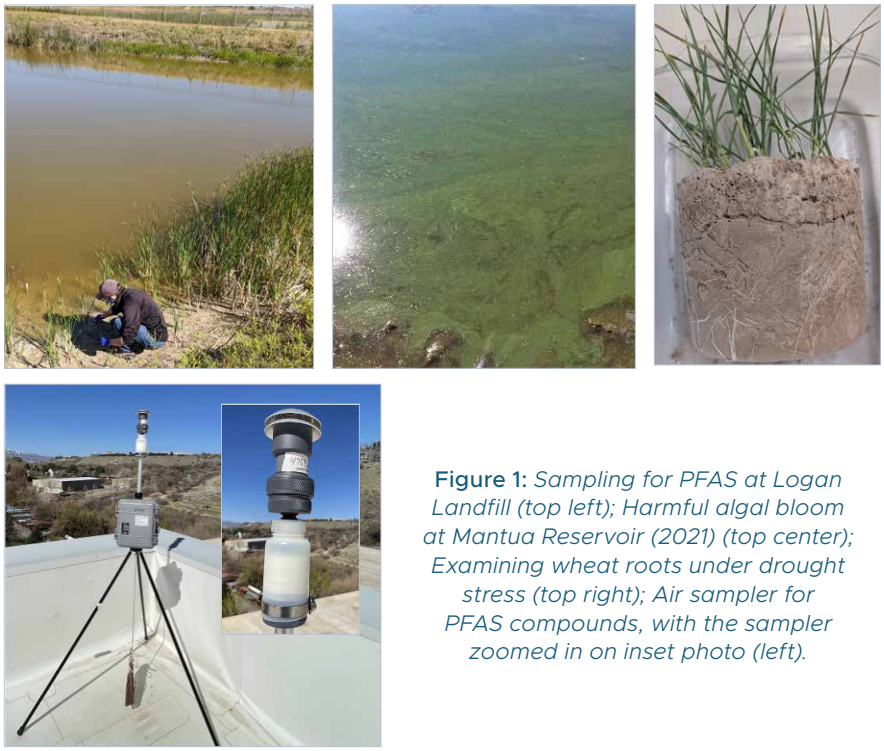

Figure 1: *Sampling for PFAS at Logan Landfill (top left); Harmful algal bloom at Mantua Reservoir (2021) (top center); Examining wheat roots under drought stress (top right); Air sampler for PFAS compounds, with the sampler zoomed in on inset photo (left).*

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

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Benefits to the State

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

Findings/Results

Methods under development include nano- and micro-plastic analysis in environmental samples, single particle analysis of nano materials in plant-soil systems, and selenium and arsenic analysis in Great Salt Lake sediments.

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

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.

Work Plan FY 22–23

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.

Figure 2: *Examples of UWRL Environmental Quality Laboratory advanced analytical equipment*

Impact of Metals and Metal Ions on Soils and Plants

Project Description:

Need and Purpose

Copper oxide nanoparticles (CuO NPs) may be used in agriculture as an antifungal or antimicrobial, a fertilizer, or as a drought resistance treatment. However, application of CuO NPs in or near soils for any purpose may have unintended consequences to plant and microbial life as the NPs dissolve, transform, or move. Plants need copper (Cu) as a micronutrient, but elevated levels of bioavailable Cu are highly toxic to plants and their associated microbes. Soils are complex and many properties influence the behavior of Cu in the soil. Plant roots and soil microbes add to the complexity as they release chemicals (exudates), which frequently bind to Cu in solution, promoting dissolution of the CuO NPs and altering plant uptake of Cu. The focus of this year's effort was to evaluate how soil properties, in particular pH and soil organic matter versus exudates contributed by plants and microbes, alter the solubility of CuO NPs.

Benefits to the State

Results directly benefit Utah counties with current metal contamination from abandoned and active hard rock mining and related industrial operations by protecting environmental quality and human health related to metal exposure. CuO NPs may benefit counties with agricultural operations as more research is conducted on the pesticidal and drought resistance-stimulating properties of the NPs, particularly as drought and opportunistic pathogens increase.

Findings/Results

Findings indicate that plant and root exudates control CuO NP solubility, overriding baseline soil properties. Wheat was grown in sand with the addition of pore waters from three Utah soils in the presence or absence of the native microbes extracted from the soils. The soils varied in SOM concentration and composition, and pH. CuO NPs were dosed at 30 mg Cu/kg sand. The wheat grew for 10 days, and pore water was extracted and analyzed for exudates and CuO dissolution.

Principal component analysis shows a clear distinction in soil properties (separation of blue, red, and green data from left to right) and in the contribution of the plant microbial systems tested (separation of triangles and circles top to bottom) (Figure 1, left). Principal component 1 describes soil-based parameters such as pH and SOM concentration and composition displaying the unique characteristics of the soils tested (Figure 1, right). Principal component 2 defines microbial and plant exudates in the different soils. Without microbes, Cu is associated with the plant produced organic acids, citrate (21%) and gluconate (8%), the siderophore DMA (18%), and

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Joan E. McLean (PI)
David Britt (Co-PI)
Astrid Jacobson (Co-PI)
Joshua Hortin (Co-PI)

Students:

Dakota Sparks (MS)

Partners/Collaborators:

National: In support of National Science Foundation funding

Geographic Areas:

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

Areas Benefited: All counties in Utah

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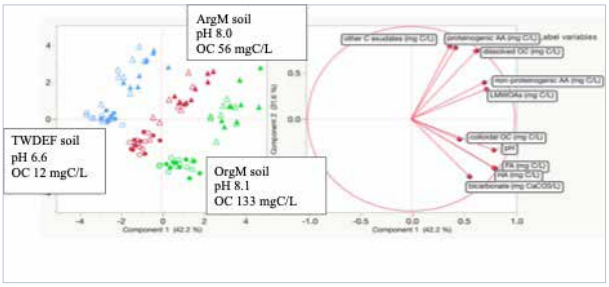

Figure 1: *Statistical analysis of pore water parameters after wheat growth to evaluate the factors, soil properties or plant-bacteria exudates, that contribute to CuO solubility. Triangles are without native microbes and circles are with microbes.*

the amino acid, arginine (9%). DMA is produced by wheat as a strong binder of iron and copper to enhance bioavailability of these required nutrients (Figure 2A). Organic acids, amino acids and DMA are consumed in the presence of soil microbes. Soil properties, fulvic acid and carbonates control Cu solubility (Figure 2B). Despite differences in properties of the tested systems (Figure 1) and the distribution of soluble Cu (Figure 2), the soil-plant system limits the concentration of Cu in solution (Figure 3A), and the plant controls uptake and movement of Cu in the shoot tissue regardless of solution Cu concentrations (Figure 3B).

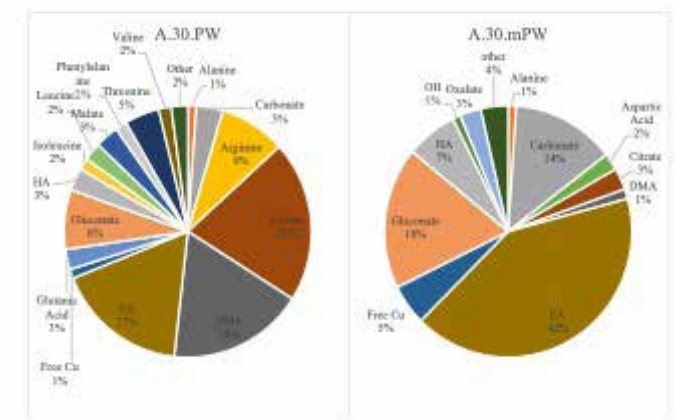

Figure 2: *Distribution of solubilized Cu with soil and plant derived metal chelators in the ArgM soil. PW: pore water; mPW: pore water with native microbes.*

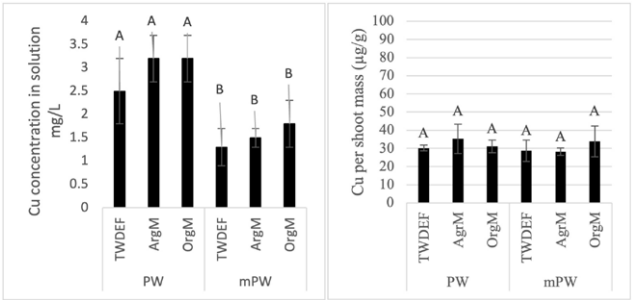

Figure 3: *Dissolved copper concentration is not affected by soil properties without (PW) or with (mPW) soil microbes (A). Wheat uptake of Cu is independent of copper solution concentration (B).*

Work Plan FY 22–23

Dakota Sparks completed his thesis work in July 2022 and will publish the results in a peer-reviewed journal. To further this work, the research team will seek additional funding.

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

PROJECT DESCRIPTION:

Need and Purpose

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 mediated by 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 aim 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.

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.

Findings/Results

We have performed a microplastic sampling campaign in the Logan River watershed along a transect that spans remote headwaters to a semi-urban population center. 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

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Janice Brahney (Co-PI)
Bethany T. Neilson (Co-PI)

Geographic Areas:

Study Areas: Logan, UT; Northern Utah

Areas Benefited: Remote Environments in Utah

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metric to assess the extent of degradation. We are currently investigating how plastic chemistry—e.g., polyethylene (polymer in plastic bags) vs. polyethylene terephthalate (polymer in water bottles)—changes photodegradation rates.

Work Plan FY 22–23

We are currently concluding the project and are continuing to measure photodegradation rates for different plastic chemistries.

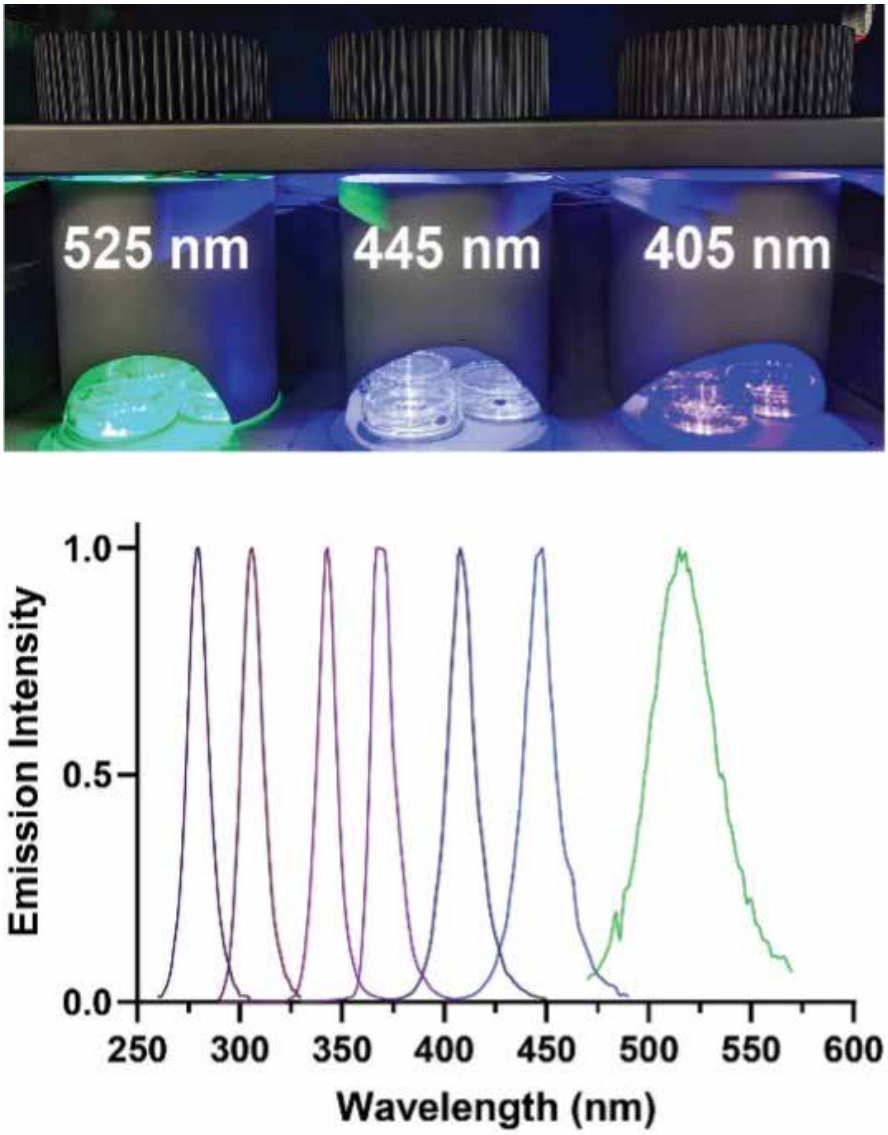

Figure 1: *Laboratory LED photoreactors used for again plastic. Corresponding emission spectra with peaks that span 275 to 525 nm..*

Wildfire Impacts on Surface Water Photochemistry

Project Description:

Need and Purpose

Wildfires increasingly threaten water quality in the Intermountain West. One of the major impacts on water quality is the input of various inorganic and organic chemicals from burn-scarred lands into rivers and streams. An important input is organic carbon. The burning process in wildfires changes the elemental composition of biomass (trees, grasses), forming black carbon and chars. These forms of carbon, collectively termed pyrogenic carbon, have very different chemical properties than the organic carbon that typically exists in rivers and streams. Wildfires thus change the composition of organic carbon in rivers and streams. This will impact many biogeochemical processes and possibly the fate of pollutants that reside in surface waters.

As a first step toward understanding the impacts of pyrogenic carbon on biogeochemical processes, we are investigating the photochemistry of pyrogenic carbon. Photochemistry is an important degradation pathway for many pollutants in the environment and is mediated by sunlight. This loss of a pollutant due to solar exposure is referred to as photodegradation. The organic carbon in surface waters plays a critical role in the photodegradation of pollutants. However, because pyrogenic carbon has a different chemical composition compared to organic carbon in streams and rivers, we do not know the potential for pyrogenic carbon to mediate photodegradation processes. Through this project, we aim to determine the ability of pyrogenic carbon to degrade pollutants in surface waters. We are investigating the capabilities of pyrogenic carbon to form singlet oxygen, a critical reactive intermediate that drives pollutant degradation in rivers and streams. Through this project, we will more fully understand the impacts of wildfires on pollutant degradation pathways in sunlit surface waters.

Benefits to the State

Utah has largely avoided major wildfires compared to other states in the Western US. However, due to climate change and drought, wildfires are expected to become more intense and widespread. In the future, Utah will likely be impacted by larger, more intense wildfires. These wildfires will impact water quality, not only locally near the burn sites, but also throughout the watershed. This project reveals the role of pyrogenic carbon inputs from wildfires on pollutant photodegradation pathways. This impacts the fate and persistence of pollutants in Utah's waterways.

Principal Investigators:

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Students:

Monika Madhiyan (PhD)

Geographic Areas:

Areas Benefited: Fire-impacted areas of Utah

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Findings/Results

Our overall approach to determining the capabilities of pyrogenic carbon to photodegrade pollutants focuses on singlet oxygen, a reactive intermediate formed in surface waters by organic carbon, and we are measuring the quantity of singlet oxygen produced. We have studied a series of lab-prepared chars by combusting wood in a furnace at different temperatures (150 to 350 °C) to simulate the different burn severities experienced in real wildfires. We have determined the quantity of singlet oxygen produced by measuring singlet oxygen with a laser driven time-resolved phosphorescence system. Lab-prepared pyrogenic carbon was shown to produce similar levels of singlet oxygen to other organic carbon found in surface waters. This is in stark contrast to past studies that have concluded that pyrogenic carbon exhibits significantly higher singlet oxygen generation capabilities, with authors suggesting that it will better photodegrade pollutants.

Figure 1: *Sample processing to generate dissolved fractions of pyrogenic carbon samples collected from a real wildfire and lab-prepared chars.*

Work Plan FY 22–23

This project will continue in FY 22–23. We are currently concluding the study of singlet oxygen generation of pyrogenic carbon. Our next step is to focus on triplet-excited state organic matter, another important reactive intermediate in surface waters that is generated by organic carbon. We will investigate this reactive intermediate with time-resolved singlet oxygen phosphorescence. Similar to the singlet oxygen work, we will compare triplet-excited state organic matter formed from pyrogenic carbon and other organic carbon from surface waters, focusing on their ability to degrade aquatic pollutants.

Mitigation of Methane Emissions from Anthropogenic Sources

Project Description:

Need and Purpose

Increasing atmospheric greenhouse gas (GHG) concentrations have necessitated development of methods to not only reduce GHG emissions, but also to increase GHG treatment. Carbon dioxide (CO_2) emissions receive the majority of attention given to GHGs, but 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. In agriculture, the production of CH_4 emissions is largely tied to enteric fermentation by domestic livestock, which includes animals that produce CH_4 as part of their digestive process. In the energy industry natural gas and petroleum are large sources of CH_4 emissions. Methane is the primary constituent of natural gas and is emitted during many phases of natural gas production processes. Oil and coal production are also industry sectors that produce large quantities of CH_4 emissions. 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 for the decade 2008–2017 were estimated to have increased nearly 10% from the previous decade.

In addition, methane contributes to the formation of NH_4NO_3, which is a major component of particulate matter less than 2.5 microns ($PM_{2.5}$). $PM_{2.5}$ is an important air contaminant that contributes to poor air quality in Cache Valley and in other areas of Utah during winter inversions. In this project, we investigate the efficacy of a potential method to mitigate the impacts of methane produced from anthropogenic sources such as landfills, wastewater treatment sites, mining, and agriculture (Figure 1).

Benefits to the State

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

Principal Investigators:

Judith L. Sims (PI)
Charles Miller (Co-PI)
Ronald Sims (Co-PI)

Students:

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

Geographic Areas:

Study Areas: Cache County

Areas Benefited: Areas of Utah where air quality problems or large amounts of methane are generated

Contacts:

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Reports:

- Parkinson, Jace, (2021). *Methane Emission Treatment and Potential Upcycling using Methylomicrobium alcaliphilum* All Graduate Plan B and other Reports. 1573. https://digitalcommons.usu.edu/gradreports/1573

Poster Presentations:

- Storrer, Jaden; Parkinson, Jace C; and Miller, Charles. 2021. *Producing Valuable Bioproducts Through Methane Mitigation*. Intermountain Biological Engineering Conference, Logan, UT, October 30.
- Storrer, Jaden; Parkinson, Jace C; Sims, Judy; and Miller, Charles. 2022. *Upscaling the Valorization of Methane into Ectoine, a High-Value Bioproduct*. Annual Conference, Institute of Biological Engineering, Athens, GA, April 7-9.

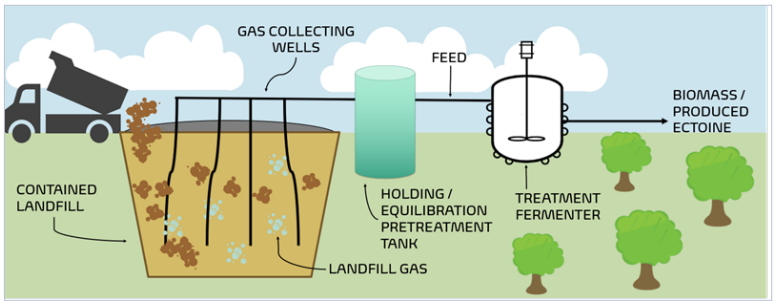

Figure 1: *Preliminary design visual for a M. alcaliphilum based method of landfill gas treatment.*

Findings/Results

Anthropogenic methane emissions are harmful to the environment and can be difficult to treat. Use of M. alcaliphilum for bioremediation of methane looks to be one of the most promising methods for reducing the negative environmental impacts of methane emissions while simultaneously providing an economic incentive through the production of ectoine, a high value by-product. A successful bioreactor design for M. alcaliphilum based methane treatment requires biokinetic constants and microbial growth information. Methods were established for determining biokinetic constants, including growth rate, biomass yield, specific methane consumption rate, and a correlation between methane oxidation and carbon dioxide production for M. alcaliphilum. Values determined for these constants were used to provide a preliminary engineering design for treating methane emissions from the North Valley Landfill in Cache County, Utah.

M. alcaliphilum, an obligate methanotroph, was evaluated for use in bioreactors for oxidizing anthropogenic methane emissions. Bench scale culture of M. alcaliphilum yielded biological constants including growth rate, biomass yield on substrate, apparent yield on substrate, and specific methane degradation rate. Using the EPA LandGEM tool to generate emission predictions for the North Valley Landfill, in Cache County, Utah, a preliminary engineering design model for treatment of methane emissions was developed. The model estimated treatment of over 800,000 m^3 methane emitted from approximately 280,000 Mg of waste using 250 kg of M. alcaliphilum contained in reactors sized at a total liquid phase volume of 50,000 L.

Work Plan FY 22–23

We will continue to investigate the capability of M. alcaliphilum to grow and degrade methane in dilute methane environments, as is common in most anthropogenic methane emission sources such as landfills (less than 20% methane by volume in gas phase) and calculate the methane degradation rate and ectoine production rate by M. alcaliphilum under batch conditions.

Wastewater Treatment: Nutrient Removal using Biofilm Microalgae

Project Description:

Need and Purpose

Nutrient management in water resource recovery facilities (WRRF) in Utah has been mandated by the Utah Department of Environmental Quality in response to national legislation to improve the water quality of receiver systems including rivers, lakes, and reservoirs, mitigate eutrophication, and recycle nutrients. This project is assisting in achieving these goals using a new technology developed by the Sustainable Waste to Bioproducts Engineering Center (SWBEC), which is a rotating algae biofilm reactor (RABR) that removes phosphorus from wastewater through cultivation of biofilm microalgae that can be harvested and recycled into value bioproducts. Specifically, this project will test a process for phosphorus uptake using the RABR technology for treatment to reduce the phosphorus concentration in the reclaimed water from 3.5 mg/L to 0.3 mg/L at the largest WRRF in Utah, which treats approximately 60 million gallons per day at the Central Valley Water Reclamation Facility (CVWRF) in South Salt Lake City.

Benefits to the State

SWBEC at USU is currently working with WesTech, a major environmental technology firm, and the Central Valley Water Reclamation Facility (CVWRF), the largest water reclamation facility in the State of Utah, to test the RABR technology at both laboratory and pilot scales at the CVWRF to treat wastewater while also producing value bioproducts through recycling nutrients out of the water that can cause eutrophication in Utah Lake and other water bodies in Utah. The phosphorus enriched algae biomass can be used to produce value bioproducts to enhance the Utah economy, including high-phosphorus fertilizer and feedstock for biocrude and bioplastic production, as well as fire-retardant. Results will also be a direct benefit to the CVWRF and to other water reclamation facilities in the State of Utah by meeting Utah environmental standards while supporting the growth of Utah bio-based industries.

Findings/Results

Results include the following:

1. Phosphorus concentration in the wastewater was reduced from 9.5 mg/L to 1.7 mg/L for a removal of 82% of total phosphorus. The goal is to treat the wastewater to a phosphorus concentration of 1 mg/L, and further testing will be conducted at a wastewater treatment time longer than 3 days to attain this goal.

Principal Investigators:

Ronald C. Sims (PI)

Students:

Dylan Ellis (MS)

Partners/Collaborators:

Local: Logan City

State/National: Utah Department of Environmental Quality

Business/Industry: WesTech Engineering SLC and Central Valley Water Reclamation Facility SLC

Geographic Areas:

Study Areas: Salt Lake City water resource recovery facilities, specifically the Central Valley Water Reclamation Facility (CVWRF)

Areas Benefited: Both rural and urban areas would benefit from the results of this project because municipal wastewater from all areas of the State of Utah could be improved with the technology being tested and bio-based industries would be supported.

Contacts:

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Presentations:

- Dylan Ellis and Ronald Sims, 2022. *Phosphorus Uptake in Rotating Algae Biofilm Reactors Treating Municipal Wastewater Anaerobic Digester Pressate*. Poster presentation at the Institute of Biological Engineering National Conference, April 7–9, 2022. Athens, GA.

2. Microalgae that remove phosphorus from the wastewater were characterized and are shown in the table. Microalgae included green algae and blue green (cyanobacteria) cells.
3. Presentation at national conferences (Institute of Biological Engineering)

The model RABR for testing wastewater from the Central Valley Water Reclamation Facility is shown below.

Identified Algae and Cyanobacteria

Appearance	Name
Single	Chlorella
Single	Chloroccum
Filamentous	Ulothrix
Filamentous	Lyngbya
Filamentous	Odogonium
Diatom	Gomphonema

Work Plan FY 22–23

In FY 22–23, the project will address composting of bioplastic materials derived from wastewater treatment microalgae. Mineralization and reduction in the mass of plastic will be evaluated. Treatment of the wastewater for phosphorus removal will also continue.

Figure 1: *Testing unit for phosphorus removal from wastewater at the Central Valley Water Reclamation Facility in South Salt Lake City.*

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

Project Description:

Need and Purpose

Cyanotoxins are chemicals and chemical classes that are produced by cyanobacteria, phototrophic bacteria of the phylum Cyanophyta that contain chlorophyll and a blue pigment that is found primarily in lakes, oceans, and reservoirs. Many cyanobacteria are capable of obtaining the nitrogen they need directly from the atmosphere, and 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.

Historically, the presence of microcystins in Utah water supplies is rare, though not absent. A well-publicized cyanobacteria bloom in Utah Lake in fall 2014 resulted in the death of a swimming dog, creating a stir on social media and in traditional news outlets and prompting a response by the State of Utah Department of Environmental Quality. Cyanobacteria blooms have been reported in several Utah reservoirs used for drinking water supplies (e.g., Scofield Reservoir in Carbon County, Mantua Reservoir in Box Elder County, and Pineview Reservoir in Weber County). 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 samples from 8 out of 28 Utah reservoirs showed a moderate to high risk for exposure to cyanotoxins.

This project will proceed in four stages:

1. Extensive literature review of cyanobacteria and cyanotoxin modeling.
2. Coordination with drinking water utilities to determine the need for and to set up programs for monitoring and assessing cyanotoxin risk and to determine data needs.
3. Monitoring and assessment activities for key selected Utah drinking water utilities.
4. Initial laboratory and kinetic modeling work for cyanobacterial growth and toxin release under a variety of environmental conditions.

Benefits to the State

Specific benefits of the UWRL cyanotoxin risk assessment to the State of Utah include (1) guidance for development of long-term monitoring programs for

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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: Cache, Box Elder, Carbon, Weber, Morgan, and Washington counties

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

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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

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.

Figure 1: *Site in Mantua, UT subject to cyanobacteria blooms*

Findings/Results

We are 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: Aphanizomenon flos aquae (neurotoxin, hepatotoxin), Dolichospermum (Anabaena. neurotoxin), and Microcystis (neurotoxins and hepatotoxins). In samples from the Bear River Health Department, we measured the toxins anatoxin-a, microsystins, and cylindrospermopsin from May–September in 6 lakes and reservoirs.

Work Plan FY 22–23

The literature review portion of the study was completed in January 2021, and a review publication for a peer reviewed journal is being prepared and will be submitted from that report. Monitoring at Mantua and other lakes and rivers in Cache, Box Elder, and Rich counties continued through October 2021 and resumed in spring 2022 (after lake thaw). Laboratory studies began in June 2021 and will continue through the duration of the project. We have been culturing cyanobacteria native to Pineview, Scofield, and Mantua, Utah, to prepare stock cultures for kinetics experiments. The end result of those studies will be an improved kinetic model for growth and toxin production from at least one of the three types of cyanobacteria.

Hydraulics

ACTUAL, BUDGETED AND PLANNED EXPENDITURES OF MINERAL LEASE FUNDS

HYDRAULICS: PI	Project Name	Actual FY2022	Budgeted FY2023	Planned FY2024
Crookston, B.	Hydraulic Design Guidance for Stepped Spillways	$750	$15,000	$15,450
Crookston, B.	Predicting Density-driven Exchange Flows through the Great Salt Lake West Crack Breach	$843	$15,000	$15,450
Phillips, C.	Collaborative Research: Separating the Climate and Weather of River Channels: Characterizing Dynamics of Coarse-Grained River Channel Response to Perturbations across Scales	$18,808	$19,372	$19,953
Phillips, C.	High-Resolution River Physical Water Quality Dynamics	$18,000	$18,540	$19,096
Sharp, Z.	Improving the Hydraulics of Urban Flooding	$12,495	-	-
	New projects		*$21,411*	*$19,729*
	Undesignated		*$18,546*	*$8,546*
	TOTALS	**$50,896**	**$97,869**	**$97,924**

Hydraulic Design Guidance for Stepped Spillways

Project Description:

Need and Purpose

Spillway rehabilitation is needed in Utah and in the USA as existing infrastructure ages and design standards are modernized. A stepped chute, with and without a labyrinth crest, provides a spillway rehabilitation alternative that is economical and does not require a large footprint. Due to limited research, however, the exact implications of a stepped chute with a labyrinth crest or with inclined steps are unknown. Labyrinth weirs and stepped chutes are known to dissipate energy, introduce aeration, and increase turbulence within the flow. Combinations of stepped chutes with labyrinth crests present challenging design needs. Furthermore, modern construction techniques of stepped chutes often include inclined steps. This research seeks to identify design guidance for such spillways for parameters such as sidewall height, length to flow uniformity, and energy dissipation.

Benefits to the State

This research is of benefit to the State of Utah and others as it provides important design guidelines for this specific spillway type. To date, Utah, the US Army Corps of Engineers, USDA, US Bureau of Reclamation, and private consultancies and universities have all shown interest in such guidance.

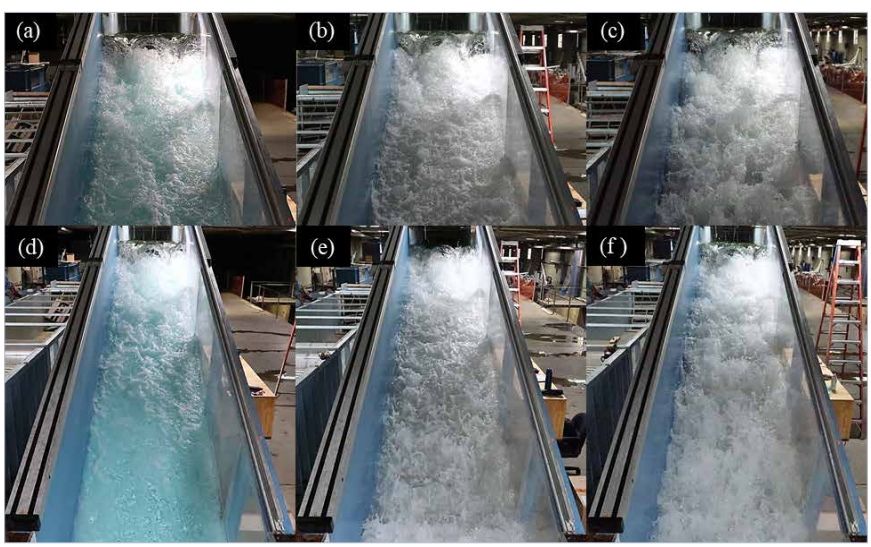

Figure 1: *Flow pattern comparison for Q=285.0 l/s between (a and d) h=0.0 mm, (b and e) h=101.6 mm, and (c and f) h=203.2 mm.*

Principal Investigators:

Brian Crookston PhD, PE

Students:

Meg Raj KC (PhD),

Partners/Collaborators:

Academia: Stephan Felder, University of New South Wales

State/National: Sherry Hunt, USDS Agricultural Research Service

Geographic Areas:

Study Areas: All work was conducted in the Hydraulics Laboratory of the Utah Water Research Laboratory at Utah State University

Areas Benefited: Flood control infrastructure, water supply storage in reservoirs, etc.

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Websites:

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

Findings/Results

We produced detailed documentation of the two-phase flow and air-water properties in the stepped chute. The results thus far have demonstrated that the sidewall height can be appropriately sized using existing methods when the maximum flow depth, occurring at the chute entrance, is used. Aeration, initiated by the labyrinth weir plays a critical role in achieving uniform flow farther upstream. A stepped spillway with a labyrinth crest appears to dissipate less energy compared to a stepped spillway with a linear crest.

Work Plan FY 22–23

Work in the coming year will focus on inclined steps with and without a labyrinth crest.

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

Project Description:

Need and Purpose

The Great Salt Lake is of environmental and economic value yet is threatened by various factors including drought and water diversion for irrigation purposes. Management efforts are required to preserve this saline lake; such efforts include accurately estimating the exchange flow through an opening in a railroad causeway that divides the lake. This study investigated two modeling approaches for predicting these discharges, a physics-based computational fluid dynamics model and a data-driven artificial neural network model. 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.

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.

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

Principal Investigators:

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

Students:

Michael Rasmussen (MS)
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: All work was conducted at the Hydraulics Laboratory at Utah State University and at the West Crack Breach

Areas Benefited: Northern Utah

Contacts:

Brian M. Crookston
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Publications:

- Rasmussen, M. (2022). *Using computational fluid dynamics to predict flow through the West Crack Breach of the Great Salt Lake railroad causeway*. MS. Thesis. Utah State University, Logan, Utah.
- Rasmussen, M., S. Dutta, B. T. Neilson and B. M. Crookston, (2021), *CFD Model of the Density-Driven Bidirectional Flows through the West Crack Breach in the Great Salt Lake Causeway*, Water, 13(17): 2423, http://doi.org/10.3390/w13172423

Presentation:

- Crookston, B.M., Rasmussen, M., Larsen, E., Kartchner, H., and S. Dutta. (2022). *Predicting density-driven exchange flows through the west crack breach of the Great Salt Lake Causeway with CFD and ANN*. 2022 International Symposium on Hydraulic Structures. Roorkee, India.

Findings/Results

A submerged berm is situated within the WC Breach and north of the railroad. The berm is intended for management efforts in that it serves as a control structure for buoyancy-driven flows moving north-to-south. Depending on current or anticipated conditions, the berm could be modified with construction equipment by removing submerged causeway materials or by incorporating additional materials, thus increasing or lowering the crest elevation of the berm. The CFD model results indicate that, indeed, the north-to-south flows are influenced by this submerged berm and that either a lower lake elevations or increased berm height 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 conditions in July 2021.

Work Plan FY 22–23

The work will focus on the relationship between weather patterns, the new berm height, and discharge.

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

Project Description:

Need and Purpose

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 physical model to assess the sensitivity of mountain river channels to shifting changes in climate, water, and associated compound hazards.

Benefits to the State

The scientific and engineering aim for this project is the development of a model to predict what rivers are susceptible to changes in climate and land use. This model will represent a foundation from which predictive models for assessing river stability will be developed. The state of Utah is facing an uncertain water future as drought results in diminishing water resources and increasing 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.

Findings/Results

The development of this research project resulted in the creation of a computer program to extract high-resolution river geometry from high-resolution lidar topography, thus allowing for an unprecedented view of river features. These measurements provide the foundation for changing single site field surveys into large data assemblages that encompass the full width variability within 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. This analysis is being automated to allow for the rapid extraction of results to be paired with physical experiments to determine the mechanisms that lead to river instability and increased flooding.

Principal Investigators:

Colin Phillips (PI)

Partners/Collaborators:

Local: Logan River Observatory, Native American Summer Mentorship Program

State/National: Claire Masteller, University of Washington in St. Louis; Open Topography

Geographic Areas:

Study Areas: Logan watershed, Utah; Eel River watershed, California; Colorado front range streams and rivers.

Areas Benefited: Strawberry River watershed, Utah.

Contacts:

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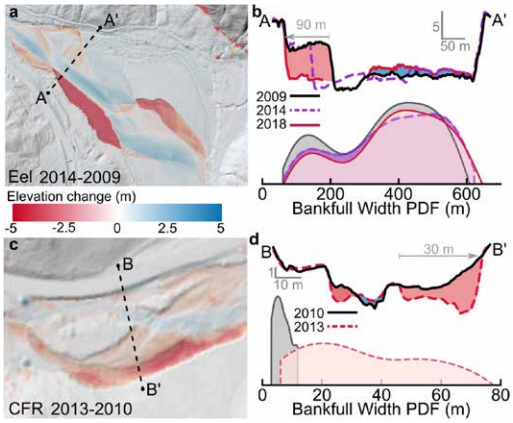

Figure 1: *Data analysis output for the Eel River (a) showing how 90 meters of bank erosion (red) over five years is well within the variability (b) experienced by the river over the river reach. The erosion experienced during the Colorado Front Range floods resulted in complete destabilization of the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

Work Plan FY 22–23

This project is in its first of three funded years of work. Within the first year, we will conduct field work in Utah and Northern California to understand how variability within river system geometry extracted from remotely sensed metrics compares to physical ground-based measurements. Field work in Utah will focus on the Logan River and the section of the Strawberry River within the Dollar Ridge Fire burn scar. We will begin physical experimental modeling at the Utah Water Research Laboratory to assess how laboratory rivers respond to large scale flooding and sediment perturbations.

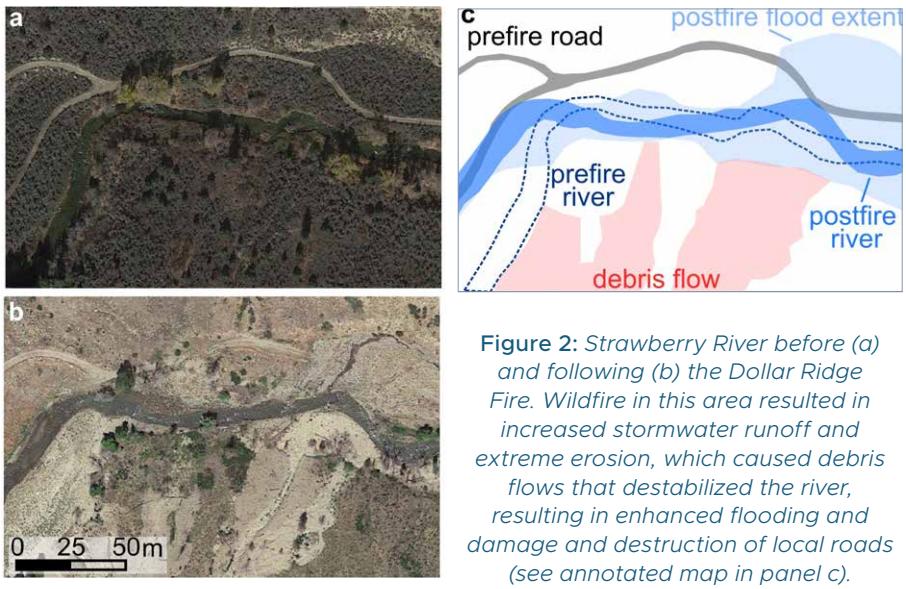

Figure 2: *Strawberry River before (a) and following (b) the Dollar Ridge Fire. Wildfire in this area resulted in increased stormwater runoff and extreme erosion, which caused debris flows that destabilized the river, resulting in enhanced flooding and damage and destruction of local roads (see annotated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

High-Resolution River Physical Water Quality Dynamics

Project Description:

Need and Purpose

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 freshwater.

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.

Findings/Results

Utilizing over 400,000 records of fine sediment we have developed a simple physically based model that demonstrates that the 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 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 flux scales with the size of the watershed; however, at the watershed scale, catchment properties do not explain the concentration of suspended sediment. Geospatial catchment features such as land use, lithology, and

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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).

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average rainfall or aridity provide no additional explanatory power for the suspended sediment pattern at the point scale (near the sampling site). We've begun investigating the river network scale at increasing distances upstream of a reduced selection of sites to determine if watershed characteristics can be used to predict concentration (the color pattern 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 concentrations 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. Currently our results indicate that, for timespans greater than one year, the model provides a strong prediction of the total yield and provides an overprediction for timescales less than a year. The statistical model can be calibrated based on a limited number of physical samples and can therefore be applied in a wide variety of settings across Utah and the United States.

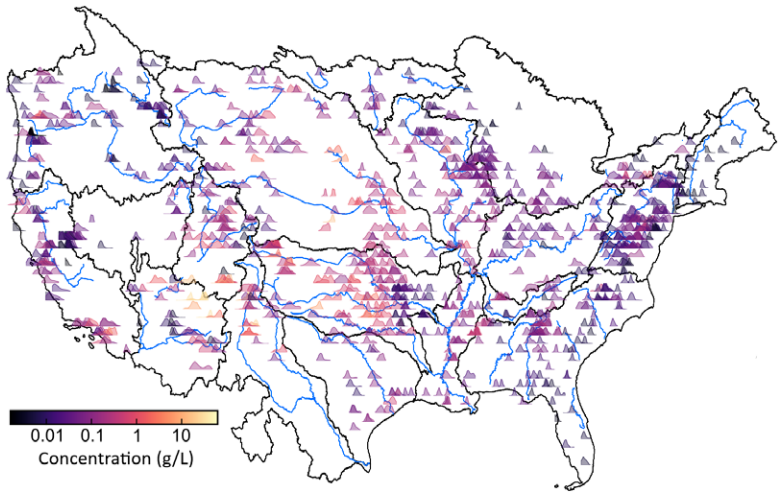

Figure 1: *Suspended sediment database for the United States. Color represents the concentration in grams per liter. The highest concentrations in the nation are located in southern Utah and northern Arizona.*

Work Plan FY 22–23

During the coming year, we will complete the assessment of watershed factors (rainfall, flood recurrence, lithology, and land use) for determining the average concentration of suspended sediment at the USGS sampling stations. This geospatial assessment will pair with the validation of the suspended sediment yield model utilizing the highest resolution data available to date, primarily within the Green and Colorado rivers within Colorado, Utah, and Arizona.

Improving the Hydraulics of Urban Flooding

Project Description:

Need and Purpose

In most river systems, the initial flooding location is the same with every flood event. Flooding occurs when water flows over the riverbanks and can cause property damage or injury and death to people and animals. Flood prediction improvements can help eliminate flood damage in multiple ways. First, with a proper warning, flood mitigation efforts can be implemented to keep flow in the riverbanks. Second, with proper warning, people and animals can be evacuated and kept safe. Third, and a large focus of this research, if the portion of the river (or structure, culvert, bridge, etc.) that causes the flooding can be identified, it potentially can be fixed to prevent flooding in that area.

Current methods for determining flood boundaries in urban areas involves using topography and bathymetry data sets for an urban river and its flood zone. With that data set, a 1D HEC-RAS model can be set up and run, making a number of assumptions. The 1D HEC-RAS models are very accurate and efficient for long river reaches; however, the weakness of the 1D model is predicting the performance of control structures and other choke points in the river that may cause flooding. To accurately model control structures or other choke points in urban rivers with a 1D model, the modeler must know a rating curve for that choke point. If that information is not available, then the modeler is left to guess. The 2D HEC-RAS model is an improvement over the 1D model in that it allows the user to let the model calculate the rating curve at control structures. The 2D model is also efficient and, in some instances, accurate for predicting rating curves of choke points. An improvement over the 2D model is a full 3D computational fluid dynamics (CFD) model, which can offer accurate rating curve information for various structures and choke points in urban rivers.

This research explored a site-specific location within Logan City limits that is the first place to flood and compared the results of 1D, 2D, and 3D models for predicting that flood event. The research also investigated the cause of the flooding and recommended economic fixes the city can implement to prevent the flood event from occurring.

Benefits to the State

Every city in Utah could implement this new approach to investigate their flood boundaries and be better prepared for future flooding. Logan City will receive all site-specific data and reporting that is completed in this project for the location of their most sensitive flood zone.

Principal Investigators:

Zachary Sharp, PhD, PE (PI)

Students:

Taylor Kesler (MS)

Partners/Collaborators:

Local: Logan, UT

Geographic Areas:

Study Areas: All modeling work was completed at the Utah Water Research Laboratory at Utah State University

Areas Benefited: Potentially any city at risk of flooding

Contacts:

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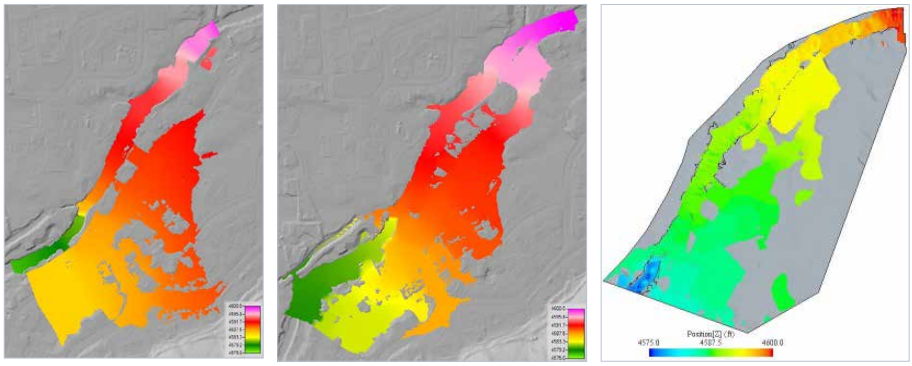
Findings/Results

The 1D HEC-RAS model was not ideal for the river reach studied. Lateral flows do not perform well in 1D models and are better suited for 2D modeling. The 2D HEC-RAS models gave better results. The 2D model showed water leaving the channel upstream of the diversion structure. The flooding began far enough upstream that the diversion structure was not indicated as the cause of the flooding. Hydraulic grade lines and water surface elevations do not show significant water accumulating behind the weir. If the weir were the primary flooding factor, the water surface would rise behind the weir and flow over the banks. The 1000 cfs condition provided additional evidence. The weir profiles show water in the floodplain while the water level is below the top of the weir walls. In higher flow cases, the water does top the weir walls. Water that flowed around the diversion structure primarily came from upstream, not immediately before the structure. The 3D Star-CCM+ model showed the water leaving the channel at the same locations. The 3D model also gave detailed results of the weir itself. Water can be seen flowing around the weir at a low point in the topography. This inconsistency was not visible in the less detailed models. The 3D model provided valuable insight to the performance of the structure, beyond the capability of the 1D and 2D models.

Work Plan FY 22–23

This project is complete.



Flood extents from 1D and 2D HEC-RAS and 3D CFD modeling at 2500 cfs

Measurement, Sensing and Information Systems

Actual, Budgeted and Planned Expenditures of Mineral Lease Funds

Measurement, Sensing and Information Systems: PI	Project Name	Actual FY2022	Budgeted FY2023	Planned FY2024
Coopmans, C.	Development of Inexpensive UAV for sensing land surface hydro/Multispectral UAV Collaborative Remote Sensing System for Irrigation Water Management and Ecological Assessment	$11,454	$25,000	$25,750
Gowing, I.	Mapping Invasive Aquatic Weed (Eurasian Watermilfoil) in Browns Pond, Utah, Using an Unmanned Aerial Vehicle	$7,147	-	-
Horsburgh, J.	Cyberinfrastructure for Intelligent Water Supply	$18,100	-	-
Rosenberg, D.	Increasing the Impact of Utah State University's Extension Water Check Program with 5-Second Metering	$55,862	$80,038	$82,439
	New projects		*$38,939*	*$35,881*
	Undesignated		*$33,730*	*$33,730*
	TOTALS	**$92,563**	**$177,707**	**$177,800**

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

Project Description:

Need and Purpose

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

Benefits to the State

The data produced by AggieAir have the potential to help save water in Utah by offering farmers 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 these invasive plant species are left unchecked, they can take over native plant species, destroy bird habitat, and use excessive amounts of water. AggieAir can also provide new jobs and economic growth to the state of Utah. The long-term goal of the AggieAir system is to eventually create a business within the state of Utah and market this technology. AggieAir's technology also brings a focus to the State's place in aerospace, unmanned systems, and the civil uses for technologies such as remote sensing for agriculture. In addition, the AggieAir lab has served for more than a decade as a resource at Utah State University, providing a home for STEM undergraduate recruiting, senior design projects, and student-driven research of all kinds. In addition, via the lab resources (students and employees, capabilities, etc.) AggieAir has supported 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.

Findings/Results

In the past year, AggieAir has continued to develop the technology and used its fleet of GreatBlue aircraft (and others) to map vineyards, collect new air quality data, and fly scientific missions in many locations for many purposes.

Principal Investigators:

Calvin Coopmans (PI)
Scott Budge (Co-PI)
Baron Wesemann (Co-PI)
Steve Petruzza (Co-PI)

Partners/Collaborators:

Local: USU Space Dynamics Laboratory

Commercial: DeseretUAS, ArcTech Charge, Fortem Inc., Northrop Grumman

Geographic Areas:

Study Areas: Most of the test flights took place at our test site near Cache Junction, UT. We have official approval from the FAA to conduct flights here (FAA Form 7711-1 2013-WSA-63). AggieAir has been flying at sites around the state of Utah as well as in California (partnered with Gallo Wineries) in the past year as well.

Areas Benefited: All counties in the state could benefit.

Contacts:

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Website:

https://aggieair.usu.edu/

Publications:

- C. Coopmans, S. Slack, D. J. Robinson, and N. Schwemmer, *A 55-pound Vertical-Takeoff-and-Landing Fixed-Wing sUAS for Science: Systems, Payload, Safety Authorization, and High-Altitude Flight Performance*, in 2022 International Conference on Unmanned Aircraft Systems (ICUAS), Jun. 2022, pp. 1256–1263
- A. Nassar et al., *Using Remote Sensing to Estimate Scales of Spatial Heterogeneity to Analyze Evapotranspiration Modeling in a Natural Ecosystem*, Remote Sensing. 2022; 14(2):372. https://doi.org/10.3390/rs14020372
- R. Gao et al., *Assessment of TSEB-PT and-2T in ET partitioning estimation over California commercial vineyards based on sUAS information*, in Autonomous air and ground sensing systems for agricultural optimization and phenotyping VII, 2022, vol. 12114, p. 121140I
- R. Gao et al., *LAI estimation across California vineyards using sUAS multi-seasonal multi-spectral, thermal, and elevation information and machine learning*, Irrigation Science, pp. 1–29, 2022

The 55-pound hybrid quadplane drone "GreatBlue" has been updated to newer redundant radio command and control systems as well as improved autopilot and data collection software code. Work has also progressed on real-time data processing, which will allow the data collected to be readily delivered in much less time. AggieAir traveled again (for the 7th successive year) to California and collected valuable agricultural data during another intensive campaign combined with other world-class groups such as the USDA ARS, NASA, Gallo wineries, and the Almond Board of California (ABC). In addition, GreatBlue was used to deliver 'dessert' to the Utah NASA Space Grant yearly meeting at the Space Dynamics Laboratory in Logan, UT. Dropping Aggie Ice Cream and Aggie Chocolate by parachute demonstrated a student-led senior design project funded by the Utah Space Grant for package delivery (see Fig. 1).

Figure 1: *AggieAir GreatBlue drone delivering "dessert" via parachute to the UT NASA Spacegrant meeting in May 2022. .*

Work Plan FY 22–23

With two working GreatBlue aircraft, AggieAir plans to continue water-based missions within the State, such as mapping reservoirs, etc., as well as outside the State (for example, studying almond farms in California), furthering the world-class research, and through partnerships, integrating new science and technology back into Utah. Built on now established large-scale, stable flight, AggieAir will continue work on streamlining and improving the aerial data processing pipeline allowing for near-real-time data delivery (mapping), which will lead to many applications and opportunities for new research, aircrafts, and student experiences.

Mapping Invasive Aquatic Weed (Eurasian Watermilfoil) in Browns Pond, Utah, Using an Unmanned Aerial Vehicle

Project Description:

Need and Purpose

The purpose of this research was to capture high-resolution multi-spectral aerial imagery of Eurasian Watermilfoil (Myriophyllum spicatum) over Browns Pond, (North and South), Uintah County, Utah. Aerial imagery was captured using a MicaSense RedEdge-MX and the RedEdge-MX Blue camera sensor, which together comprise 10 spectral bands. Two flights were proposed, and the first pre-herbicide treatment flight captured detailed information regarding aquatic vegetation within both ponds prior to the proposed herbicide treatment. The second flight captured imagery of aquatic vegetation post herbicide treatment. The two sets of imagery are being used to quantitatively assess both the abundance of watermilfoil and the effectiveness of the herbicide treatment plan in eradicating Watermilfoil. Watermilfoil is a non-native, invasive aquatic plant that out competes native vegetation, has little nutritional value and reduces invertebrate abundance and diversity. Analysis of the imagery will also provide the division of wildlife resources, detailed information regarding the diversity and composition of aquatic species within both ponds.

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

Benefits to the State

This project benefits the State of Utah by showing the effectiveness of the herbicide treatment in eradicating Watermilfoil, a non-native invasive aquatic plant. The project also highlights the creative use of drones and how they can be used in a variety of water resource applications.

Findings/Results

We have shown the effectiveness of using drones to map and monitor invasive aquatic vegetation within water bodies in the state of Utah. The change

Principal Investigators:

Ian Gowing (PI)
Shannon Syrstad (PI)
Alfonso Torres-Rua (PI)

Partners/Collaborators:

State/National: Richard Gibbs, Utah Division of Wildlife Resources; Craig Walker, Utah Division of Wildlife Resources

Geographic Areas:

Study Areas: Uintah County, Utah

Areas Benefited: Fish Lake, South Central Utah and other water bodies within the State of Utah that affected by Eurasian Watermilfoil

Contacts:

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detection between the two sets of imagery was performed using eCognition, which is a robust tool for monitoring change between several dates. The findings from the analysis show that the herbicide treatment plan was extremely effective in eradicating virtually all floating watermilfoil mats that were present on both ponds. The results from this project will lead to further opportunities to work at other water bodies within the state of Utah with plans to implement herbicide treatment.

Work Plan FY 22–23

This project is now complete. A final report has been delivered to the Division of Wildlife Resources.

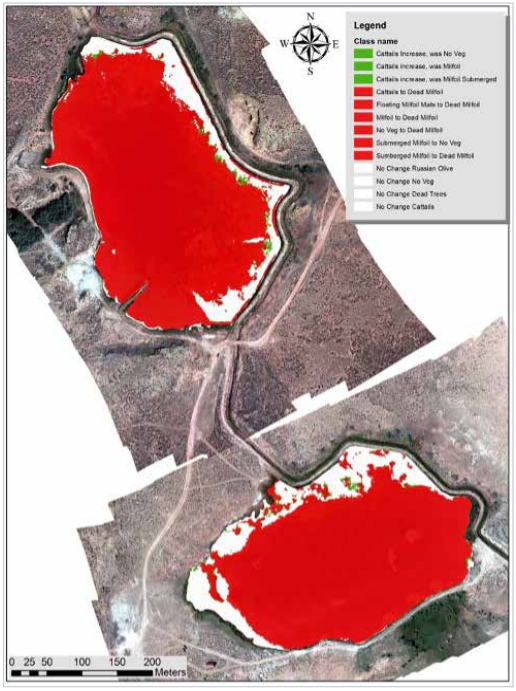

Figure 2: *Change detection analysis map showing Watermilfoil decrease (red) in both ponds.*

Cyberinfrastructure for Intelligent Water Supply

Project Description:

Need and Purpose

High-resolution residential water use data collection using smart water meters can enhance our ability to characterize water demand and water use behavior, estimate peak water use, reduce undetected leaks, and improve urban water management. However, obtaining high-temporal-resolution data at a scale larger than a few houses presents challenges in terms of data collection, storage, management, and processing. This research advanced smart water metering and developed cyberinfrastructure for building the scientific data and knowledge base for sustainably managing urban water supplies.

Benefits to the State

In Utah and the western US, populations are growing quickly, water supplies are already highly allocated between human and environmental uses, and variability in water availability related to drought are all challenges in urban water management. Mitigating these pressures and ensuring the sustainability of urban water supplies can be enabled through new data and analytics that provide detailed, actionable information for optimizing the planning, design, and operation of water management infrastructure. Precise accounting and management of urban water consumption is necessary for a sustainable water future. This project advanced the human and cyberinfrastructure available for building and managing next generation smart metering systems and their resultant data.

Findings/Results

We developed low cost dataloggers (~$100) that can be deployed on existing water meters to collect high-temporal-resolution data. Using these dataloggers, we completed two smart water metering and water use behavior studies, one in USU's student housing complexes and one with residential homes in Logan City and Providence City, UT. We developed a computer algorithm to identify individual water use events and classify them by end use type (e.g., toilets, faucets, etc.). We then developed an advanced datalogger capable of collecting data and running the classification algorithm in the field, converting existing water meters into "smart" computational nodes rather than requiring transmission of high data volumes and resource-intensive central post-processing of data. We investigated the timing and distribution of water use behavior within participating homes to better understand and quantify indoor and outdoor water use. We created cyberinfrastructure to automate management of high-resolution data collected as part of our residential smart water metering studies and deployed and tested it in a production environment, demonstrating successful management of

Principal Investigators:

Jeffery S. Horsburgh (PI)

Students:

Nour Attallah (PhD)
Camilo Bastidas (PhD)
Joseph Brewer (MS)

Partners/Collaborators:

Local: Logan City, UT

Providence City, UT

Utah State University Housing and Facilities Departments

State/National: National Science Foundation

Geographic Areas:

Study Areas: Logan City, UT

Providence City, UT

Areas Benefited: Data collection activities were focused in Logan and Providence Cities in Cache County, but we anticipate that results are applicable statewide and beyond.

Contacts:

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

Publications:

- Bastidas Pacheco, CJ, Horsburgh, JS, Beckwith Jr., AS (2022). *Impact of data temporal resolution on quantifying residential end uses of water*, Water, 14(16):2457. https://doi.org/10.3390/w14162457
- Bastidas Pacheco, CJ, Horsburgh, JS, Attallah, NA (2021). *Variability in consumption and end uses of water for residential users in Logan and Providence, Utah, USA*, Journal of Water Resources Planning and Management, (Accepted for publication).

the large volume of data produced by our field data collection activities. Finally, we developed a new model for simulating residential water use behavior using detailed end use data and investigated data resolution as a constraint to identifying end uses within smart metering data.

This project created student training opportunities, including (1) degrees granted to two PhD and one MS student; (2) a program for undergraduate students who worked on independent data collection and research projects using the data collection infrastructure we have established; (3) teaching modules for CEE courses designed to teach students how to manage, read, manipulate, subset, summarize, and visualize high-resolution water use data collected using our water meter dataloggers, introduce machine learning concepts in Python, and analyze geospatial patterns in urban water use; and (4) a student data visualization challenge using high-resolution water use datasets produced by this project.

Work Plan FY 22–23

This project is complete.

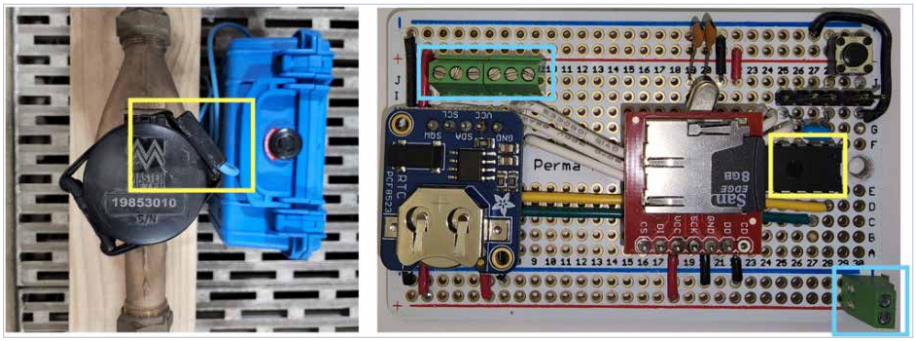

Figure 1: *A custom datalogger created by this project installed on a water meter. The yellow rectangle in the left panel shows the sensor attached to the meter. The right panel shows the datalogger with sensor and battery connections indicated by the top and bottom blue rectangles and a microcontroller highlighted with the yellow rectangle. When deployed, the datalogger is enclosed in the blue box shown in the left panel .*

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

Project Description:

Need and Purpose

The overarching goal of this project is to increase the volume of water saved by the Utah State University (USU) Extension Water Check program. 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. In 2014, the Utah legislature funded development of a tablet-based app and database to collect and store Water Check program data. In 2017, the program added a web app, the ability for USU County Extension faculty around the state to participate, and data sharing with the Utah Division of Water Resources. We are now working to enhance the Water Check program by collecting 5-second water use data using Flume Inc. Smart Home Water Monitor devices (Figure 1) to target outdoor water use. Outdoor use is the largest component of Utah residential water use and has the largest opportunity for conservation. We are working to identify which Water Check recommendations participants implement, why participants implement some recommendations and not others, and how to make recommendations more actionable to enhance water conservation.

Benefits to the State

The purpose of this project is to help Utah's Water Check program become 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; identification of conservation potential; quantification of water savings; adaptation to changing weather; and 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: Cache County, Utah, and counties throughout Utah

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

Contacts:

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Websites:

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

Findings/Results

We recruited 102 participants from Hyde Park and Logan City, installed 78 Flume, Inc. Smart Home Water Monitor devices, and have so far delivered 65 Water Checks (Figure 2). We also added 15 additional households, not included in the study, to the Water Watch program from other cities.

Work Plan FY 22–23

- Collect extracts of high-frequency data from each Flume device through the end of the irrigation season.
- Disaggregate landscape water use events, timing, and volume from the Flume data extracts using existing USU software tools.
- Normalize for factors pre- and post- Water Check such as evapotranspiration, precipitation, and changes to the landscape.
- Link the disaggregated water use and Water Check datasets to determine which recommendations participants implemented.
- Identify the timing, duration, and volume of water saved by participant conservation actions and how participant conservation actions aligned with recommended actions.
- Identify cases where participants did not adopt Water Check recommendations.
- Interview a subset of those participants to learn why they did not adopt, what they did, and how to improve effectiveness of conservation messages.
- Formulate new timing, content, and/or delivery methods for Water Check recommendations.

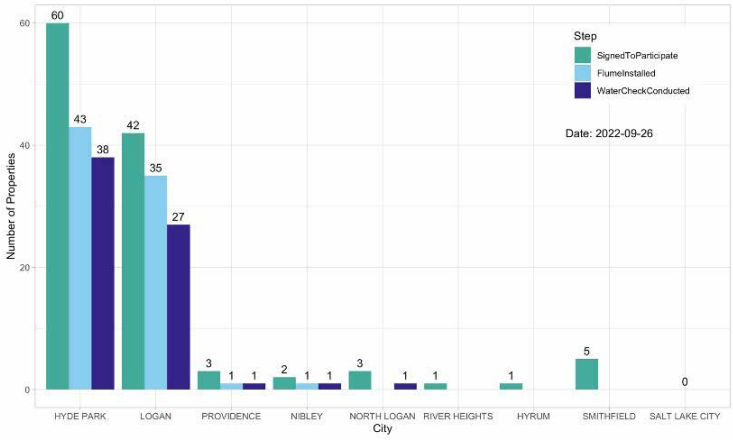

Figure 2: *Project participation by city and project step to sign up, install Flume, Inc. Smart Home Water Device, and conduct Water Check.*

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 FY2022	Budgeted FY2023	Planned FY2024
Dupont, R.	Logan City Renewable Energy and Sustainability Advisory Board (RESAB)	$3,000	$3,090	$3,183
Rosenberg, D.	Making Water Research Results More Reproducible	$20,440	$21,054	$21,685
Rosenberg, D.	Sustaining Water Conservation Behaviors	$20,000	-	-
Sims, J.	Development of an On-Site Demonstration Site at the Ash Creek Special Service District	$6,000	$6,180	$6,365
Sims, J.	Utah On-Site Wastewater Treatment Training Program	$6,000	$6,180	$6,365
Stevens, D.	Center of Excellence for Water	$28,000	$28,840	$29,705
Stevens, D.	State of Utah Operators Certification Commission	$4,000	$4,120	$4,244
Tullis, B.	State of Utah Drinking Water Board	$4,780	$4,923	$5,071
	New projects		*$38,795*	*$35,747*
	Undesignated		*$33,605*	*$33,605*
	TOTALS	**$92,220**	**$146,787**	**$145,970**

Logan City Renewable Energy and Sustainability Advisory Board (RESAB)

Project Description:

Need and Purpose

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 provides 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. He 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 the steps necessary for greenhouse gas emission reductions to address climate change.

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
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Websites:

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

Findings/Results

The PI attended all regularly scheduled remote RESAB meetings throughout FY21–22 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 RECAB subcommittee, and 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.

Work Plan FY 22–23

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. Anticipated FY 22-23 activities include planning for future renewable energy options, enhancing Logan City's EV charging network, and reviewing greenhouse gas emission inventory and reduction prioritization.

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

Making Water Research Results More Reproducible

Project Description:

Need and Purpose

A broad interest exists to make science and engineering results reproducible even though few published results are reproducible currently. 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 their 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 overcoming these challenges (Figure 1). Here we share community practices to 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 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.

Findings/Results

- Accepted 4 papers with reproduced results into the Special Collection of Papers with Reproduced Results in the Journal of Water Resources Planning and Management.
- Awarded 2 commendations for outstanding effort to make results more reproducible and 1 commendation for outstanding effort to reproduce results.
- Developed 3 short videos to guide authors through the submission process for papers with reproducible results.

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:

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- Recruited 14 new reproducibility reviewers during a presentation at the Environmental Water Resources Institute World Congress in Atlanta, GA in June 2022.

Work Plan FY 22–23

Work will continue for the reproducible results program as follows:

- Recruit more Associate Editors for Reproducibility and Reproducibility Reviewers.
- Add papers with reproduced results to the Special Collection of Papers with Reproduced Results.
- Obtain digital object identifiers for short videos to describe program and how to make results more reproducible.
- Expand program to other journals.

Figure 1: *Organizations participating in the Reproducible Results Program*

Sustaining Water Conservation Behaviors

Project Description:

Need and Purpose

Water conservation can help extend limited existing surface and groundwater supplies to accommodate future population growth and/or carry a utility through drought. The Utah Legislature and Governor have recognized the importance of water conservation and set targets to reduce average per-capita water use by 25% by 2025. Generic education and awareness efforts such as "Slow the Flow" have reduced per-capita water use over the last decade. it is still unclear what exactly caused reduced use, whether reductions can persist, which users to target to save the most water, and how to message users so they sustain conservation behaviors. This work has as its purpose synthesizing work from the fields of behavior sciences, environmental psychology, resource management, and health communication fields to learn why some voluntary message campaigns sustained conservation behaviors.

Benefits to the State

Customized message campaigns that target household motivations such as intention, altruism, peer pressure, and perception of ease or difficulty in adopting new conservation behaviors can help Utah water providers sustain water-saving behaviors past temporary crises such as a drought. Sustaining conservation behavior can also help communities grow without having to build more expensive water supply infrastructure. Customized message campaigns can increase the effectiveness of existing generic state conservation campaigns such a "slow the flow" or "hall of fame and shame."

Findings/Results

Past campaigns reduced residential water use by 0.6% to 54%; however, reductions lasted less than 1 year. To sustain conservation behavior for longer periods of time, campaigns should include a public plea, social comparison information, easy-to-adopt conservation tips, and links to additional resources (Figure 1).

Our work synthesized 11 suggestions for water supply managers to sustain household water conservation behaviors:

1. Learn user's intentions and informational preferences
2. Launch feedback programs during critical periods such as drought.
3. State what the water authority is doing to achieve the conservation goal.
4. Customize message content based on a user's attitude and information preferences.

Principal Investigators:

David E. Rosenberg (PI)

Students:

Mahmuder Aveek (MS)

Geographic Areas:

Study Areas: Cache County, Utah, and counties throughout Utah

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

Contacts:

David E. Rosenberg
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Publications:

- Aveek, M. R. (2022). *Sustain Water Conservation Behaviors Using Nonparametric Ranking and Social Marketing*. MS Thesis, Utah State University, Logan, Utah.
- Aveek, M., and Rosenberg, D. E. *Sustaining water conservation: a synthesis of research on motivators, message tailoring, and tactics*. Earth's Future (Submitted).

5. Target one easy to implement conservation action at a time.
6. Praise efficient behavior.
7. Communicate through a variety of mediums.
8. Regularly update message contents.
9. Encourage users to publicly commit to conservation.
10. Publicly recognize water savers.
11. Allow users to share their conservation experiences.

Work Plan FY 22–23

This project is complete; however, we will continue to help the USU Extension Water Check program become more efficient as part of a separate project.

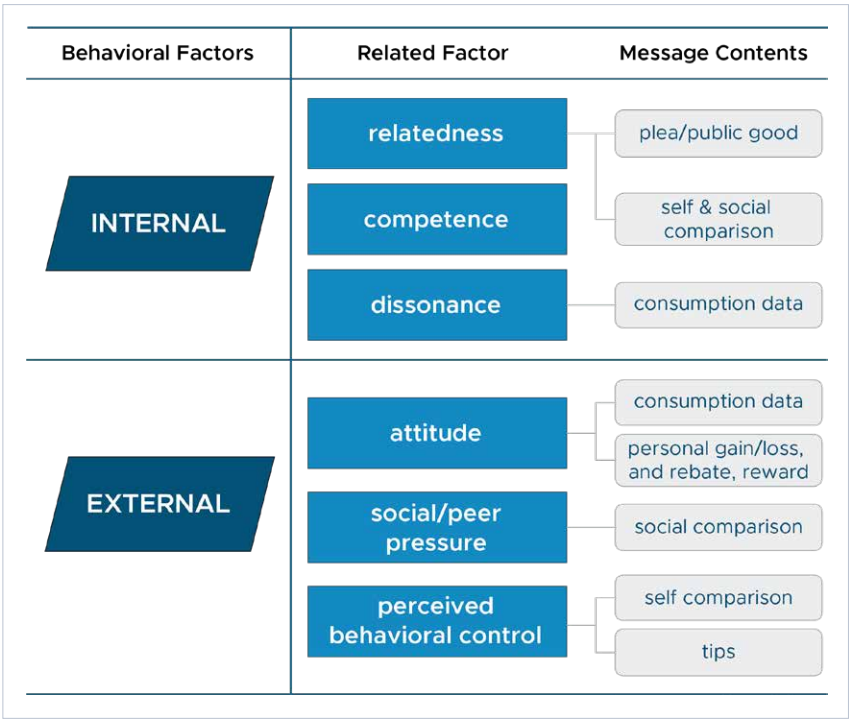

Figure 1: *Message campaigns to sustain water conservation behaviors activate different household motivators with different message contents.*

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

Project Description:

Need and Purpose

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 for 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 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 their clients, real estate developers, consulting engineers, 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 will benefit the 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.

Findings/Results

The approach to the development of the project is design/build. Demonstration displays include (a) septic tanks displays; (b) a 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; (e) pump systems, tanks, and vaults; (f) control panels;

Principal Investigators:

Judith L. Sims (PI)
Brian Cowan
Richard Jex

Students:

Zachary McClellan

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)

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.

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https://uwrl.usu.edu/partnerships/training

(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

Work Plan FY 22–23

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.

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

Project Description:

Need and Purpose

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

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

Utah will continue to grow, and as housing developments continue to expand into current open space, such developments may include areas of groundwater recharge, shallow soils, or shallow ground water. Current Utah rules allow the use of conventional septic tank systems, as well as 10 alternative treatment systems that may be installed in areas where soils are unsuitable for conventional systems. Training those involved in the use of both conventional and alternative systems will ensure that these systems will work correctly.

Benefits to the State

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

Principal Investigators:

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

Program Support:

Brittanie Carter
Carri Richards
Mindy Whitely

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)

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/partnerships/training

Contacts:

Judith L. Sims
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judith.sims@usu.edu

Publications:

- Sims, J.L., Cashell, M., Cowan, B., and Jex, R. 2021, 2022. *Course Manuals for Levels 1, 2, and 3 Original Certification and Recertification Workshops*. Utah Water Research Laboratory, Utah State University, Logan, UT.

Workshops:

Workshops held during FY 21–22:

- **Level 1**: 2 workshops at Salt Lake City and Ogden Utah locations—
  50 total participants
- **Level 2**: 2 workshops at Logan, Utah location—
  43 total participants
- **Level 3**: 2 workshops at Logan, Utah location—
  34 total participants
- **Level 1 & 2 Renewal**:
  4 workshops at Salt Lake City, Richfield, and Ogden, Utah locations—
  80 total participants
- **Level 3 Renewal**:
  4 workshops at Salt Lake City, Richfield, and Ogden, Utah locations—
  33 participants

FY 21–22 Total: 240 participants

Findings/Results

A state legislative initiative introduced and passed as House Bill 14s during the 2001 Legislative Session mandated a certification program for persons involved in siting, designing, operating, and maintaining both conventional and alternative on-site systems. The certification program, administered by the Division of Water Quality in the Utah DEQ, involves mandatory training provided by the Utah On-Site Wastewater Treatment Training Program. The certification program includes three levels, each of which requires workshops and testing provided through the Utah Training Program: (1) Level 1: Soil Evaluation and Percolation Testing; (2) Level 2: Design, Inspection, and Maintenance of Conventional Systems; and (3) Level 3: Design, Inspection, and Maintenance of Alternative Systems. As Level 1, Level 2, and Level 3 certifications expire after 3 years, workshops are also provided to renew certifications.

Work Plan FY 22–23

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 1: *Workshop participants in field and classroom training.*

Center of Excellence for Water

Project Description:

Need and Purpose

Egypt has a critical need 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 as they 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, our project hypothesizes that if research needs are identified for the private and public sectors and the required profile for graduates is drawn based on labor market needs, 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 the global Sustainable Development Goals.

Benefits to the State

The primary benefits to Utah are that the project will provide 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.

Findings/Results

This is an international collaborative project funded by USAID using partnerships between five US universities (Utah State, Washington State, University of California-Santa Cruz, Temple University, and the American University of Cairo (Egypt)), five Egyptian Partner Universities (EPUs, Alexandria University, Ain Shams University, Zagazig University, Beni

Principal Investigators:

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

Students:

Mohammad Al Mestiraihi (PhD)

Partners/Collaborators:

National: UD AID

Geographic Areas:

Study Areas: Logan, UT

Areas Benefited: Statewide and Universities in Egypt

Contacts:

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Websites:

https://www.egyptcoewater.eg/

Publications:

- Dupont, R.R., K. Becker, D. Stevens M. Al Mestiraihi. 2020. *Needs Assessment Report*. Center of Excellence for Water, Cairo, Egypt.

Conference Presentations:

- Al Mestiraihi, M., & Becker, K. H., & Dupont, R. R., & Stevens, D. K. (2021, July), *Developing Undergraduate Water Program Courses: Meeting the Needs of the Egyptian Workforce*. Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. 10.18260/1-2--36946.
- Al Mestiraihi, M., & Becker, K. H., & Dupont, R. R., & Stevens, D. K. (2021, June), *Skill Requirements for New Water Professionals Graduates in Egypt: Industry and Public Sector Perspective*, Paper presented at the 2021 UCOWR/NIWR Annual Water Resources Virtual Conference.

Suef University, and Aswan University), and a number of agency, public, and industrial partners in Egypt. During FY 21–22, the project was in its third year. The plans for FY 19–21 were disrupted due to travel and other restrictions resulting from the Covid 19 pandemic (that affected both the US and Egypt). The USU team had scheduled an in-Logan workshop in 2021 that had to be postponed due to travel restrictions. The workshop was modified for nine Egyptian participants via Zoom for training in the use of modern, innovative teaching strategies in water engineering and science over an eight-week period from January to March 2021. Follow ups for that workshop were completed in this Fiscal Year. We also coordinated, reviewed, and assigned development teams for 17 new courses for Egyptian universities with teams comprising US faculty members and two or more Egyptian partners. The USU team put on two webinars during FY 2021–22 on the use of Statistics in Water Science and Engineering. The USU team also ran monthly Zoom meetings for the Pillar II committee, consisting of both the US and Egyptian partners on the committee. A third workshop was begun in June 2022 with follow ups planned for October 2022 and February 2023. Finally, some work was done to extend the overall project through 2027 with a small increase in budget due to delays and increased costs due to the pandemic. A proposal and budget were developed for this, and the process is being negotiated with USAID and the Egyptian Ministry for Water Resources.

Work Plan FY 22–23

This project will continue at least through 2024, and in the coming fiscal year we will finalize the development of the 17 undergraduate courses, issue a call for proposals and develop 23 graduate level courses in water resources sustainability for implementation at the 5 EPUs, and hold Phase V of the Learning Management Systems workshop and Phase IV of the Innovative Teaching Strategies workshop. This is in addition to individual faculty efforts in the course development portion of the project. During September–December 2022 and January–May 2023, we will be hosting two visiting faculty members at the UWRL and 15 undergraduate and 4 graduate students for a semester abroad.

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

Project Description:

Need and Purpose

Under the Utah Drinking Water Act (the Act), responsibility for overseeing drinking water treatment and distribution rests with DEQ and the Utah Drinking Water Board (the Board). The Board has the authority to issue orders implementing the Act and to ensure compliance with the Act's provisions. Jurisdiction of the Board covers public and private community drinking water systems, including the various Federal facilities. The Board created the Water Treatment Operators Certification Commission in 1984 and David Stevens has been a member of that commission since 1987.

Benefits to the State

Membership on the Operators Certification Commission provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by managing training for water treatment plant operators. This includes setting policy, administering examinations, and making decisions on appeals. The PI attends yearly meetings of the Commission held in Salt Lake City and provides comments and inputs policies and procedures regarding the certification of water treatment and distribution system operators in accordance with federal and state drinking water laws.

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
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Websites:

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

Findings/Results

The PI attended all scheduled Operators Certification Commission meetings July 1, 2021, to June 30, 2022, and provided review and comment on all Commission items relevant to his area of expertise.

Work Plan FY 22–23

Involvement on the Board will continue through 2023.

State of Utah Drinking Water Board

Project Description:

Need and Purpose

Under the Utah Drinking Water Act (the Act), responsibility for overseeing drinking water treatment and distribution rests with DEQ and the Utah Drinking Water Board (the Board). The Board has the authority to issue orders implementing the Act and to ensure compliance with the Act's provisions. Jurisdiction of the Board covers public and private community drinking water systems, including the various federal facilities. Utah Water Research Laboratory faculty member Blake Tullis has served on the State of Utah Drinking Water Board from FY 2020 to the present.

Benefits to the State

Membership on the Drinking Water Board provides service to the citizens of the State of Utah, the Utah DEQ, and the regulated community by providing technical overview and expertise for drinking water management, as well as oversight of state and federal revolving loan funds, to the Division of Drinking Water in their rulemaking, facility inspections and reviews, policy implementation, and conflict resolution. The PI attends 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.

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
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Websites:

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

Findings/Results

The PI attended all regularly scheduled Drinking Water Board meetings and facility tours from July 1, 2021, to June 30, 2022, except one due to a schedule conflict, and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY 22–23

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 FY2021	Budgeted FY2022	Planned FY2023
Neilson, B.	Logan City Stormwater Monitoring	$28,000	$28,840	$29,705
Neilson, B.	Logan River Observatory	$51,344	$70,000	$72,100
Rosenberg, D.	Adapting to Low Colorado River Flows and Storage	$23,312	$40,011	$41,212
Tarboton, D.	Evaluating National Water Model Snow Components	$75,714	-	-
Tarboton, D.	Hydrology Scenarios in the Colorado River Basin	$62,593	$64,471	$66,405
Torres-Rua, A.	Water Use Assessment in Golf Courses and Urban Green Areas	$28,867	$29,733	$30,626
	New projects		*$113,512*	*$104,594*
	Undesignated		*$98,325*	*$98,325*
	TOTALS	**$269,830**	**$444,892**	**$442,967**

Logan City Stormwater Monitoring

Project Description:

Need and Purpose

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. 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.

Findings/Results

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 2021–2022, we collected continuous sensor data and discrete water quality samples (baseline and storm event sampling) during the irrigation season. Grab samples from these 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

Principal Investigators:

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

Partners/Collaborators:

Local: Logan City, Paul Lindhardt

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:

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Jeff Horsburgh
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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

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.

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.

Work Plan FY 22–23

We plan to continue work with Logan City to develop routine monitoring protocols, operate existing flow and water quality monitoring sites and equipment, interpret data, and establish new monitoring sites as needed.

Sampling Date	Sampling Begin Time	Sample Duration	Total Precip* (cm)	Pre-event UWRL Flow (cms)	Peak-event UWRL Flow (cms)	Pre-event NWF Flow (cms)	Peak-event NWF Flow (cms)
7/28/202	16:30	6:00	0.2	2.92	3.23	0.71	1.45
8/26/2020	0:00	5:00	0.37	2.48	2.56	0.78	1.76
9/19/2020	8:00	10:45	0.5	2.41	2.5	0.07	1.05
10/11/2020	0:00	9:30	0.71	2.49	2.92	0.43	1.32
5/22/21	22:30	23:15	0.3	5.3	5.5	0.44	0.72

Table 1: *Summary sample event timing, precipitation totals, background flows at the UWRL, and flows at the Northwest Field Canal sampling location.*

Logan River Observatory

Project Description:

Need and Purpose

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 the Logan River monitoring network was expanded 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 the development of innovative water management approaches in water scarce regions. Through the 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, 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.

The LRO meets many identified needs across the state of Utah. 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 to help fund additional stream restoration projects, and identify and address other water quality related problems. Cache County Water Conservancy District and Logan City are using data from these installations to gather information about drinking water source status and protection and inform Logan City's stormwater management efforts. Finally, LRO data provide information necessary for the Cache County Water Conservancy District to meet their mission of protecting and managing water resources in Cache County.

Principal Investigators:

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

Partners/Collaborators:

Local: Logan City, Cache Water District

State: Utah Division of Water Resources, Utah Division of Water Quality

Federal: USGS Utah Water Science Center

Geographic Areas:

Study Areas: Logan River watershed

Areas Benefited: This research directly benefits Utah's most populated areas that depend on mountain precipitation as their primary water source. However, the information gained and methods developed are applicable to the entire state of Utah.

Contacts:

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Websites:

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

Publications:

- Xu, T., Q. Longyang, C. Tyson, R. Zeng, B.T. Neilson. 2022. Hy*brid Physically Based and Deep Learning Modeling of a Snow Dominated, Mountainous, Karst Watershed*. Water Resources Research.
- Lukens, E., B.T. Neilson, K.H. Williams, J. Brahney. 2022. *Evaluation of hydrograph separation techniques with uncertain end-member composition*. Hydrological Processes, 36(9), e14693. https://doi.org/10.1002/hyp.14693

Conference Presentations:

- Liljestrand, D., C. Oroza, B.T. Neilson, P. Strong, E. Cotter. 2021. *Leveraging LIDAR, Machine Learning, and Citizen-Science for Low-Cost, High-Resolution Snow-Depth Estimation*. American Geophysical Union Fall Meeting 2021. December 13–17, 2021. New Orleans, LA.
- Xu, T., Q. Longyang, B.T. Neilson, R. Zeng. 2021. *Inferring spatiotemporal precipitation-discharge patterns of a snow dominated mountainous karst watershed using a hybrid physically based and deep learning modeling approach*. American Geophysical Union Fall Meeting 2021. December 13–17, 2021. New Orleans, LA.

The long-term funding from the Utah Legislature and additional 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. Through these connections, a number of new opportunities to work with local entities have been identified, including (1) identification of a CEE Senior Design group in 2020–2021 that worked with the Cache County Water Conservancy District to determine the feasibility of a future water development project in a tributary to the Logan River, a second group in 2021–2022 that is investigating another potential project in a different tributary, and a third group in 2021–2022 that investigated alternative diversion structure strategies in Logan City; (2) support for Logan City and the greater Great Salt Lake basin in anticipating changes in water availability in the Logan River and similar watersheds in the region with changing snow patterns via a related NSF funded research grant; (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, and (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.

Findings/Results

We continue to improve, maintain, and relocate LRO sites to inform various ongoing management and research projects. We have also maintained and updated the Logan River Observatory website (http://lro.usu.edu) to ensure we meet the end users' needs, have refined procedures to provide quality-controlled data with a shorter lag time, and have provided real-time flow data online (http://lrodata.usu.edu/). Many faculty (https://uwrl.usu.edu/lro/people/faculty), staff (https://uwrl.usu.edu/lro/people/research-staff) and students (https://uwrl.usu.edu/lro/lropeople/students) continue to be involved in the LRO. We continue to build a growing network of collaborators and encourage faculty to use LRO data in their research and teaching. This past year, 7 ongoing funded research projects used LRO data (see https://uwrl.usu.edu/files/pdf/2021-22-lro-annual-report.pdf for more information). Many additional research and data collection efforts that assist in answering local water-related management questions have also relied fully or in part on LRO data.

Work Plan FY 22–23

During the coming year, data collection to support ongoing research will continue, including data collection and dissemination method refinements. We will also support new proposals being developed that will focus research efforts on the Logan River watershed and will utilize Logan River Observatory data.

Adapting to Low Colorado River Flows and Storage

Project Description:

Need and Purpose

As Colorado River flows and reservoir levels decline, we face a new era of aridity where we must 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.

Benefits to the State

This work developed real-time, online participatory modeling environment(s) to engage Colorado River water managers and experts and discuss more adaptive reservoir operations such as basin water accounts. I 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. Key benefits for combined management include the following:

- Giving each party more flexibility to make their individual water consumption, conservation, and reservoir storage decisions independent of other parties.
- Adapting 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.
- Allowing parties to manage all available water rather than just prior conserved water.
- Giving parties more flexibility to store water in Lake Powell and release colder water through the hydropower penstocks to advantage endangered, native Grand Canyon fish.

Findings/Results

This fiscal year, we (1) provided open source, real-time interactive spreadsheet and simulation models so parties can explore adaptive strategies under different basin inflows (Figure 1); (2) synthesized 10 lessons to improve model process, build trust, increase operational flexibility, and generate more actionable suggestions for reservoir management;

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Students:

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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

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Datasets:

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

(3) identified Lake Mead releases to stabilize reservoir level based on inflows (Figure 2); and (4) proposed "Bugs buy days of steady releases from hydropower operators" to reduce costs of experimental releases for aquatic insect production and lessen ecosystem-hydropower conflicts.

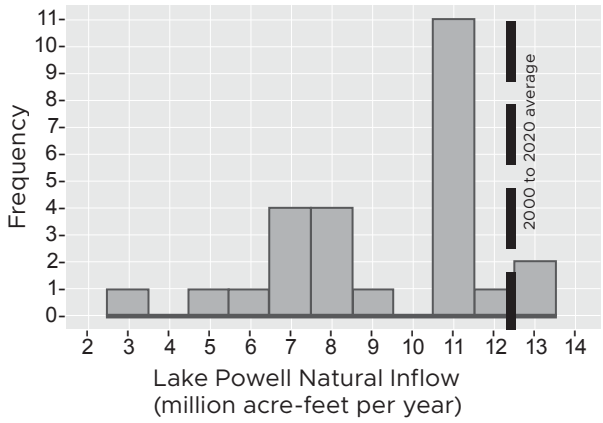

Figure 1: *Participant choices for future Lake Powell natural inflow*

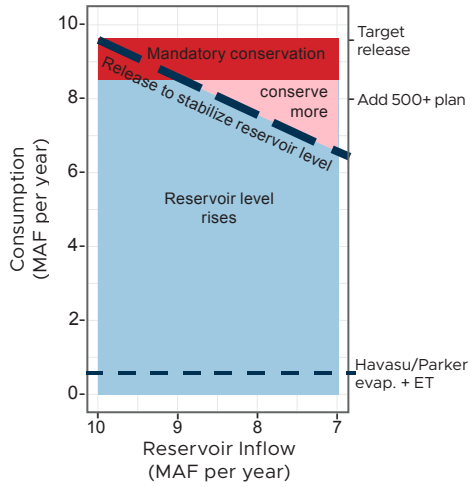

Figure 2: *Consumption to stabilize Lake Mead at elevation 1,041 feet for different reservoir inflows*

Work Plan FY 22–23

We will undertake Colorado River collaborative modeling efforts with colleagues from University of Wyoming, Oklahoma State University / USGS, and AMP Insights.

Publications:

- Rind, M. A. (2022). *Bugs Buy Steady Releases from Hydropower Producers to Encourage More Synergistic Reservoir Management*, Utah State University, Logan, Utah. https://digitalcommons.usu.edu/etd/8535/
- Rosenberg, D. E. (2022a). *Adapt Lake Mead Releases to Inflow to Give Managers More Flexibility to Slow Reservoir Drawdown*. Journal of Water Resources Planning and Management, 148(10), 02522006. https://doi.org/10.1061/(ASCE)WR.1943-5452.0001592
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- Rosenberg, D. E. (2022d). *Lessons from real-time, online participatory modeling to discuss more adaptive reservoir operations*. https://doi.org/10.4211/hs.b72e42096ff949babe95830a0d91d0bd
- Rosenberg, D. E. (2022e). *Opinion: 3 ways we can adapt to low Colorado River flows in a drought*. Deseret News. https://www.deseret.com/opinion/2022/8/12/23298509/opinion-3-ways-we-can-adapt-to-low-colorado-river-flows-in-a-drought-lake-powell-mead-glen-canyon

Evaluating National Water Model Snow Components

Project Description:

Need and Purpose

In many parts of the world, including Utah, snow is a significant component of water resources. The National Oceanic and Atmospheric Administration's (NOAA) National Water Model (NWM) simulates storages and fluxes of the land and atmosphere system across the United States and provides forecasts up to one month ahead. However, the current representation of snowmelt processes in the NWM may be responsible for inaccurate estimation of snow water equivalent in some mountainous regions. This study evaluated the strengths and limitations of the NWM snow representation by comparing its output to observations made at Snow Telemetry (SNOTEL) sites, and satellite measurements of snow cover, to identify causes for discrepancies and research approaches to improve the simulation of snow processes within the NWM.

Benefits to the State

Snowmelt is a dominant source for the origin of runoff and water supply in Utah. Water resources decision making relies on water supply forecasts, such as those from National Weather Service River Forecast Centers and, increasingly, the National Water Model, operated by the National Water Center. However, questions remain as to the accuracy of output from the NWM and whether its accuracy can be improved and bias reduced. Water supply forecasts are used for irrigation and water resources planning. The purpose of this work is to improve our capability to model snowmelt, the major source of water in the state, which then can improve the simulation of streamflow for flood forecasting, water supply, and stream ecosystems. Better streamflow forecasts also advance our understanding of the impacts of water resources development activities, such as around the Great Salt Lake. Planning for potential growth and development in the state requires information on water availability, as well as on the effects of growth on our water resources.

Findings/Results

This study compared the US National Water Model (NWM) reanalysis snow outputs to observed snow water equivalent and snow-covered area fraction (SCAF) at SNOTEL sites across the western US. Snow water equivalent (SWE) is the amount of water in the snowpack quantified as the depth of water that would result if the snowpack were to melt. SWE was obtained from SNOTEL sites, while SCAF was obtained from MODIS satellite observations. We compared results for SNOTEL sites to gridded NWM and MODIS outputs for the grid cells encompassing each SNOTEL site. Differences between modeled and observed SWE were attributed to model errors, as well

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Students:

Irene Garousi-Nejad (PhD)

Partners/Collaborators:

National: David Gochis, National Center for Atmospheric Research

Geographic Areas:

Study Areas: The study area is the semi-arid western US, which includes all of Utah.

Areas Benefited: Streamflow and snowpack in watersheds throughout Utah are forecast by the NWM, and water suppliers and users will benefit from improved forecasts due to improvements in NWM snow process representations.

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Publications:

- Garousi-Nejad, I. and D. G. Tarboton, (2022), *A comparison of National Water Model retrospective analysis snow outputs at snow telemetry sites across the Western United States*, Hydrological Processes, 36(1): e14469, https://doi.org/10.1002/hyp.14469
- Garousi-Nejad, I., (2022), *Improving Flood Inundation and Streamflow Forecasts in Snowmelt Dominated Regions*, Ph.D. Thesis, Civil and Environmental Engineering, Utah State University, https://doi.org/10.26076/167b-e53f

Datasets:

- Data and codes developed for this research are shared and publicly available as a collection on HydroShare
- Garousi-Nejad, I., & Tarboton, D. (2021a). *Data for a Comparison of National Water Model Retrospective Analysis Snow Outputs at SNOTEL Sites across the Western U.S.* HydroShare. https://www.hydroshare.org/resource/7a51f56c2cf24ae78012ac6a6d4815a6/
- Garousi-Nejad, I., D. Tarboton (2022). *Data for Evaluating Input Data and Rain Snow Separation Improvements to the National Water Model Simulation of Snow Water Equivalent*, HydroShare, https://www.hydroshare.org/resource/bdbecdef23b14848b5da46c4f465ec21

as errors in inputs, notably precipitation and temperature. The NWM generally underpredicted SWE, partly due to precipitation input differences. NWM also showed a slight general bias for model input temperature to be cooler than observed, counter to the direction expected to lead to under-modeling of SWE. SWE was also under-modeled for a subset of sites where precipitation inputs were good. Furthermore, the NWM generally tends to melt snow early. Limitations in the method used in the NWM for separating precipitation into its two components, rainfall and snowfall, was identified as one of the causes for these differences. We identified that improving inputs of temperature and precipitation has the potential to produce 59% improvement in the modeling of peak SWE. We also evaluated alternative precipitation partitioning approaches based on dew point or wet bulb temperature, rather than simply air temperature, and found that the dew-point-based approach that we evaluated reduced the bias in SWE by 18%. Improvements to the predicted melt timing also accrued from SWE magnitude being better modeled. The findings thus document the benefits of improved model inputs and better physically based process representations and suggest these as opportunities to improve the operational forecasts.

Work Plan FY 22–23

This project is complete. The student who was supported on this (Irene Garousi-Nejad) completed her PhD dissertation and published, in 2022, one paper reporting the results.

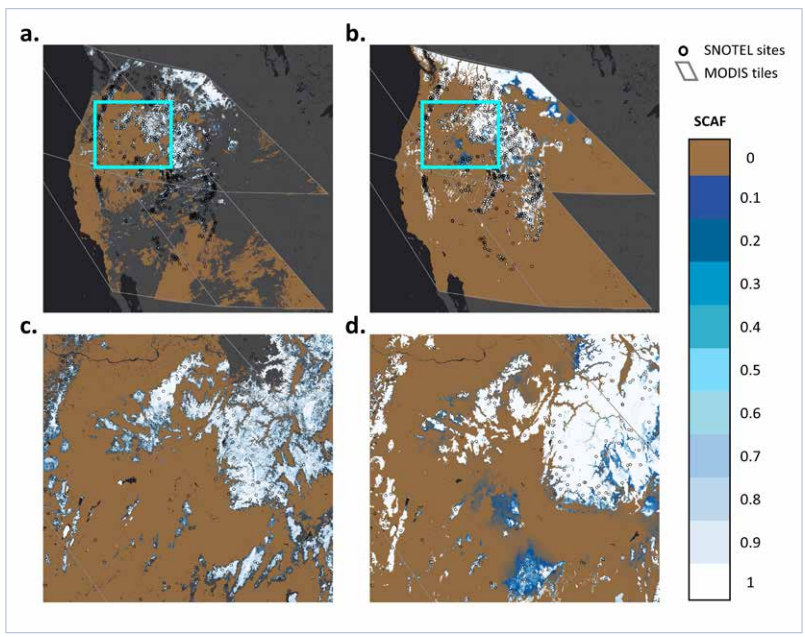

Figure 1: *Comparison of National Water Model (NWM) and Satellite (MODIS) snow covered area fraction on Dec 1, 2011. (a) MODIS estimated snow cover fraction. (b) NWM Snow Cover Fraction. (c) Zoomed-in to blue box map of MODIS Snow Cover Fraction. (d) Zoomed-in map of NWM Snow Cover Fraction.*

Hydrology Scenarios in the Colorado River Basin

Project Description:

Need and Purpose

Long-range planning of the water supply provided by the Colorado River requires assessments of 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. The objectives of this study are as follows: (1) quantitatively derive a set of drought scenarios that characterize plausible future Colorado River droughts that should be considered in planning for the future; and (2) develop an analytical framework for characterizing, categorizing, and establishing the suitability of scenarios to meet specific planning needs.

Benefits to the State

The Colorado River Basin drains much of Utah, and under the Colorado River Compact and other elements of the Law of the Colorado River, Utah is one of the upper basin states apportioned a fraction of the Colorado River water. 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 of the availability and variability of future streamflow in the Colorado River.

Findings/Results

To address our first objective, we used a methodology based on calculating duration-average and cumulative depletions relative to the natural flow mean to visualize and characterize severe droughts of the past 600 years from observed and tree-ring reconstructed streamflow at Lees Ferry, the Colorado River stream gaging site just below Lake Powell used for Colorado River planning and management. Three past droughts stand out in the record of prior flows. The millennium drought 2000–2021 (and ongoing), the mid-20th century drought 1953–1977, and the paleo tree-ring drought 1576–1600. We used random resampling from these periods to produce three drought scenarios, each comprising 100 streamflow sequences to be used as inputs to systems operation and management models, such as the Colorado River Simulation System (CRSS), widely used for Colorado River Basin planning. The results quantify the stresses that a severe sustained drought would place on the Colorado River system through evaluation of the frequency of Lake Powell elevations declining below a critical threshold if "business as usual" water management were pursued during a severe drought. The scenarios we developed indicate long periods where Lake Powell pool elevations would fall below the

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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)

Academic: Brad Udall (Colorado State University)

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: Agricultural, municipal and industrial water users and providers throughout Utah

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Publications:

- Salehabadi, H., D. G. Tarboton, B. H. Udall, K. G. Wheeler and J. C. Schmidt, (2022), *An Assessment of Potential Severe Droughts in the Colorado River Basin*, JAWRA Journal of the American Water Resources Association, https://doi.org/10.1111/1752-1688.13061

Datasets:

- Salehabadi, H. and D. Tarboton, (2020), *Data Collection to Supplement the Future Hydrology of the Colorado River Basin Study*", HydroShare, http://www.hydroshare.org/resource/6d351874f16947609eab585a81c3c60d

levels required to produce hydropower, thus suggesting that new strategies and plans will be necessary to confront the challenge of severe future droughts.

The scenarios we have developed, represented as ensembles of Colorado River Basin inflow sequences, are not the only ones available. Given the interest in planning for drought in the Colorado, many researchers and organizations have produced inflow ensembles, using a variety of methods, including climate change projections and alternative resampling approaches. Work on our second objective has developed an analytical framework for characterizing and categorizing these ensembles, so that their similarities and differences can be quantified and their suitability for planning uses established. This characterization is based on a broad range of metrics that describe hydrologic characteristics and system risks associated with streamflow ensembles. Collectively, the degree to which the historical metrics are reproduced by the scenarios provide information on the sufficiency of the ensemble. This information is valuable to the US Bureau of Reclamation and other organizations who need to plan for plausible, yet uncertain inflow scenarios, multiple of which have been suggested.

Work Plan FY 22–23

Work on objective 1, the development of drought scenarios, is complete and has been published in a Journal of The American Water Resources Association paper. Work on objective 2 is in progress and will continue in FY 22–23 in close collaboration with US Bureau of Reclamation collaborators who are supporting this work and intending to use it to characterize ensembles used for Colorado River Basin planning.

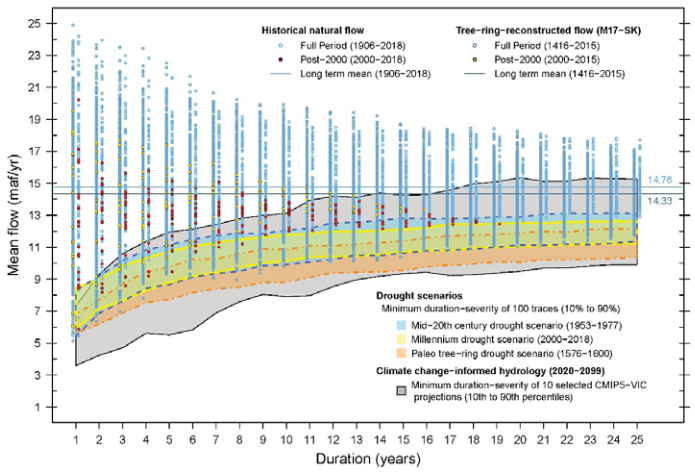

Figure 1: *Colorado River Basin drought scenario duration-severity characterized using annual streamflow at Lees Ferry, set in the context of historical and tree-ring reconstructed mean streamflow versus duration. This figure quantifies the interplay of duration and severity for mean flows across durations, providing information on expectations for extreme mean flows over longer durations. For details, see Salehabadi et al., 2022, Journal of the American Water Resources Association.*

Water Use Assessment in Golf Courses and Urban Green Areas

Project Description:

Need and Purpose

Urban open space areas provide multiple benefits to urban dwellers that range from emotional and physical wellbeing, urban, residential, cultural/touristic planning, and environmental and hydrological services (for example, drainage and cooling effects) to the city. The challenges of water scarcity (droughts), elevated summer temperatures (increased irrigation water need), and the increased value of outdoor activities in recent years underscore the need for science and tools to improve existing methodologies and recommendations for water use in urban areas. We began an initial effort in 2021 at the Eagles Lake Golf Course, located in Roy, Utah, that is advancing agricultural water use estimation using ground technology (eddy covariance), and remote sensing information (drones and satellites), with the goal to adequately validate and quantify water use of open areas (dominated by turfgrass and trees) prevalent in Utah and western US cities.

Benefits to the State

This project will enhance current knowledge on water use in urban green areas as well as explore remote sensing technologies for continuous monitoring. In addition, these efforts support the water management education of several Utah State University graduate students, providing valuable experience that will help them in their professional activities upon their graduation.

Findings/Results

Over the past year, we advanced the understanding of direct biomass measurement (turfgrass leaf area index). In addition, along with collaborators from Spain, we have implemented and improved methodologies to estimate single-tree biomass estimation. These advances will be presented at the American Geophysical Union, Fall Meeting 2022. During the summer season, we implemented significant efforts to collect ground information (biomass, eddy covariance, unmanned aerial vehicles), providing a complete dataset for the estimation of turfgrass water use in coming months. Initial results of this project were shared in the 2022 AmeriFlux Conference, and USU "Using Drones in Environmental Restoration" Summer class.

Principal Investigators:

Alfonso Torres-Rua (PI)
Lawrence Hipps (Co-PI)

Students:

Karem Meza (PhD)
Rui Gao (PhD)
Laura Christiansen (MS)
Oliver Hargreaves (MS)

Partners/Collaborators:

Local: Eagles Lake Golf Course, Roy, UT

State/National: Agricultural Research Service, United States Department of Agriculture

International: Hector Nieto, Spain

Geographic Areas:

Study Areas: Roy, UT

Areas Benefited: Urban green areas and golf courses in Utah and the western U.S.

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Figure 1: *Example of turfgrass health issues and water use in a golf course, in Roy, UT, on July 7, 2021*

Figure 2: *Change in turfgrass health issues and water use after two weeks, on July 23, 2021*

Work Plan FY 22–23

This project will continue in the following fiscal year with the analysis of the data collected, preparation of peer reviewed manuscripts, and participation in academic symposia.

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