MINERAL LEASE FUND REPORT

Utah Water Research Laboratory

Fiscal Year 2020

for

Office of the Legislative Fiscal Analyst
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by

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Foreword

Water is a precious and scarce resource in the State of Utah 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. This report describes the work funded by Mineral Lease funds (MLF) during fiscal year 2019–20 (FY 20) at the Utah Water Research Laboratory (UWRL) in pursuit of its mission to generate the knowledge needed to solve water problems through research and help the State meet its water, food, and energy resource needs now and in the future. The projects described in this report focus on cutting-edge research to find practical solutions to 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 pharmaceuticals and cyanotoxins) and research ways to address them. Current water resources research is addressing the occurrence of drought and uncertainty in river systems, such as the Colorado and Weber rivers, critical for the State of Utah. Several projects focus on the Logan River as an observatory and microcosm for study that facilitates development of the understanding needed to solve problems throughout Utah, and beyond.

To support our mission, the UWRL receives 2¼% of deposits made to the Mineral Lease (ML) Account, "to be used for activities… having as a purpose the development… of water resources in the State of Utah." With this basic support, UWRL is able to leverage significant funding from other public and private sources to enhance the scope and impact of our projects. Over $4.5 million in project funding from other sources in FY 20 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 oldest, most respected and unique University-based water research facilities, the UWRL's goals and mission remain the same: to provide data, tools, and solutions to better manage and use the limited water and land resources of the State. We look forward to many more decades of service to 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 20, budgeted expenditures for FY 21, and planned expenditures for FY 22. 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 COVID-19 pandemic has impacted research at the UWRL, as it has affected everyone. In March 2020 we quickly pivoted to enable remote work (from home) wherever possible, and implemented vehicle cleaning and physical distancing protocols so that laboratory and field research could continue safely. We also invested some funds to set up a program to monitor for remnant RNA from SARS-Cov-2 (the virus causing COVID-19) in wastewater from USU student living communities. This has helped USU's stabilization efforts by providing aggregate information about the presence of infection (perhaps asymptomatic) in student living areas that can be acted upon (through focused testing and isolation) to contain the spread of COVID-19. One economic impact from the pandemic was a sharp downturn in ML revenue in March to almost no incoming revenue. April and May revenues were also down. Although we were able to complete FY 2020 research as planned, relying on residual funds, we will also need to adjust plans for next and future fiscal years to account for diminished revenue if these pandemic effects persists.

Foreword

Notwithstanding the pandemic, the pressures on our water and environmental resources continue to increase, and the problems are becoming more complex. The UWRL brings together world-class faculty whose work focuses on finding ways to provide for Utah's water resource and environmental needs today and in the future. We look forward with optimism to meeting this challenge. The UWRL is pleased to submit this year's report to the Legislature through the Office of the Legislative Fiscal Analyst, and to the Community and Economic Development Appropriation Subcommittee of the Legislature, which reviews this report as part of its normal budgetary process.

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

David G. Tarboton, UWRL Director

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Introduction

HISTORY OF THE UTAH WATER RESEARCH LABORATORY

The Utah legislature authorized the establishment of the UWRL at Utah State University in 1959 as an important component of the State of Utah's commitment to water resources research, assuring cutting-edge solutions to the State's water problems. Today, the UWRL continues its service as one of the oldest and most respected university-based facilities performing research and providing practical solutions to the most pressing problems facing Utah, and indeed our nation and the world.

Water is often referred to as the lifeblood of Utah. As we look to the future, it is important to recall how important water resources have always been to the prosperity and quality of life of Utah's citizens. This was evident in the vision of our State leaders when USU was established as the State's Land Grant University in 1888, and water, and particularly irrigation science and the engineering of water works, were of foremost importance as curricular and research components. During the 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.

As an acknowledged world leader in water engineering, the opening of the new Utah Water Research Laboratory building in 1965 provided the State and USU with a world-class research facility to support the work of faculty, students, and water professionals from across the state and around the world. The Laboratory's facilities include one of the best hydraulics laboratories in the United States and a unique erosion testing facility with a large rainfall simulator. In 1981, an extensive remodeling project added an environmental quality laboratory wing, significantly upgrading facilities and equipment needed for water quality testing and research. In 2009, the UWRL completed a hydraulics modeling and testing laboratory in order to support expanded hydraulics research activities associated with releases from dams (and related hydraulic phenomena, such as venting) and the design of hydraulic structures in Utah, such as the 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 55 years has allowed the UWRL to have a significant state, national, and worldwide impact in water resources research and applications.

PRODUCTIVITY

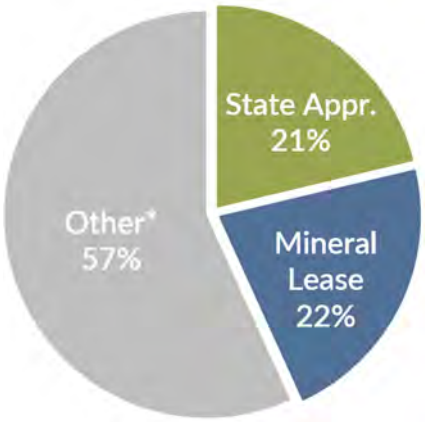
The table below summarizes the productivity of the Lab in terms of research, education, outreach, and training**.** The total research funding through the UWRL in FY 20 of almost $8 million makes it one of the largest institutes in the nation.

UWRL Financial/Academic Summary (FY 20)	
Number of Active Projects	193
Dollar Value of Active Projects	$7,982,717
Scholarly Publications in Peer-Reviewed Journals	101
Scholarly Presentations at Professional Conferences	47
Outreach Products (FY 20)	
Short Courses and Field Training	8
Degrees Granted (FY 20)	
PhD	3
MS	5
ME	2

In order to leverage the expertise of the UWRL, our faculty collaborate with colleagues from various USU departments, as well as faculty from other institutions and professionals from the private sector and government agencies in Utah and elsewhere. Several of our faculty members, including a former UWRL Director, have been awarded the Utah Governor's Medal for Science and Technology. In addition, our faculty have received many national honors and recognitions, and served on numerous state, national, and international engineering and science panels and committees.

RESEARCH PROGRAM STRUCTURE AND ORGANIZATION

The research programs of the Utah Water Research Laboratory (UWRL) directly address current and future water resources needs of the state, and most are relevant to national and worldwide issues as well. The State of Utah provides state-appropriated funds (SAF) and Mineral Lease funds (MLF) for research support at the UWRL. These funds directly target problems facing the State of Utah. In FY 20, MLF funding of just under $1.75 million accounted for 22% 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 20 were over $7.9 million.



UWRL Funding FY20

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

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

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

- Civil and Environmental Engineering (College of Engineering)
- Electrical and Computer Engineering (College of Engineering)
- Biological Engineering (College of Engineering)
- Engineering Education (College of Engineering)
- Watershed Sciences (College of Natural Resources)
- Plants Soils and Climate (College of Agriculture and Applied Sciences)
- School of Teacher Education and Leadership (Emma Eccles Jones College of Education and Human Services)

The overall UWRL research, education, and training activities related to Mineral Lease funding are very diverse, as is indicated by the project summaries in this report. 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 new faculty members: one in the area of applying chemistry principles to understand pollutant degradation and research new treatment technologies for water, and the other focused on fundamental processes for transport of water and sediment through river corridors. 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.

In addition to our research role, the UWRL is involved in university graduate and undergraduate education through hands-on projects, part-time employment, and research assistantships. In order to train future water professionals, almost all research and applied projects include graduate student involvements and result in masters or doctoral degrees. Undergraduate student involvement in UWRL projects for the purpose of student education and training is also integrated into the basic and applied research programs.

UWRL Student Involvement FY 20

Graduate Students Supported	50
Undergraduate Students Supported	83

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

MANAGEMENT OF USGS 104 PROGRAM FOR STATE BENEFIT

The Water Resources Research Act of 1964 created a national network of Water Resources Research Institutes (WRRIs) in the United States and an allotment program providing funds for the institutes, called the Section 104 Program. The Utah Institute, known as the Utah Center for Water Resources Research (UCWRR), is located at the Utah Water Research Laboratory (UWRL). Currently, the Section 104 Program receives federal funds of $125,000 through the U.S. Geological Survey (USGS) that are required to be matched 2:1 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. Developing a new process for producing accurate, low-cost, high-resolution estimates of seasonal snow depth at watershed scale, which is critical for water supply forecasts, by integrating existing LIDAR terrain attributes with citizen-science. Snowpack is an essential water resource that supplies more than 95% of Utah's water and the majority of freshwater for more than a billion people globally.

2. Exploring alternative dynamic and adaptive management options to improve outcomes in the face of changing, uncertain future water supplies, demands, and river ecosystems in the Colorado River. This project is identifying adaptive policies that will also extend an ongoing Future of the Colorado River project at Utah State University that is suggesting alternative management paradigms for Colorado River parties to consider as they renegotiate the Interim Guidelines and Drought Contingency Plans due to expire in 2026.

3. Obtaining Lidar data to support research in the Logan River Watershed. This project uses LIDAR flight data to provide detailed topography information in support of effective water resources management in snow recharged karst aquifers, which are the primary source of municipal and agricultural water supply in many mountainous areas including northern Utah. Projected variability in climate may result in shifting patterns of snow and rain, thus creating uncertainty in water resources sustainability. The dataset produced in this research provides detailed topography information that is complementary to other research focused on the development and testing of predictive hydrologic tools.

4. Investigating different methods to improve hydraulic models for predicting the possibility and extent of inland flooding, using the Logan River as a case study. These models can be used to forecast flooding before it happens, which may lead to preventative measures such as placing sand bags or other flood barriers or evacuating certain urban areas. This research is undertaken in coordination with the City of Logan to identify locations of interest and

includes acquiring more accurate terrain data using LiDAR and aerial photography, testing sensitivity of the 1-D model, and comparing 1D and 2D modeling with a fully 3D computational fluid dynamics model.

RELEVANCY AND BENEFITS OF THE MINERAL LEASE FUND

As one of the driest states in the union, the LIFE BLOOD of Utah's economy and quality of life is WATER. Our average precipitation of only 13 inches of water 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 assure Utah's ability to meet the water needs of its citizens and economy in the future. 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. In return, this helps the UWRL to identify current and future research needs that will affect our state and assures that projects 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:

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, Drinking Water Operator's Certification Commission, Water Operators 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
- Crockett Canal Company Technical Advisory Board
- Logan City (Air Quality Board, Renewable Energy/Conservation Advisory Board, Water Board)
- Logan River Task Force
- Logan River Water Users

Other State and National Agencies and Organizations

- California Water Quality Monitoring Council, Environmental Flows Strategic Workgroup
- EPA Science Advisory Committee on Chemicals
- FEMA National Dam Safety Review Board Research Workgroup
- FEMA Dam Intervention Initiative Advisory Board
- NOAA National Water Center Community Advisory Committee for Water Prediction
- OpenET Colorado River Basin Working Group

Professional Organizations

- American Water Works Association (AWWA)
- ASTM Erosion Control Committee
- Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)
- European Working Group on Overflowing and Overtopping Erosion
- Hydraulic Structures Committee of IAHR
- United States Society on Dams, spillways committee
- American Society of Civil Engineers (ASCE), Environmental Water Resources Institute (EWRI)
- American Water Resources Association (AWRA)
- American Geophysical Union (AGU)
- National Institutes for Water Resources (NIWR)
- Society of Hispanic Engineers
- Universities Council on Water Resources (UCOWR)

MINERAL LEASE FUND EXPENDITURES

The table below summarizes the actual, budgeted, and planned expenditures of ML funds allocated to the UWRL for FY 2020 through FY 2022 for research projects in the five major **Program Areas.** UWRL administration and technology transfer expenditures account for approximately 18% of total MLF budgeted and planned expenditures.

Mineral Lease Funds Expenditures			
Research Program Area	**Actual FY20**	**Budgeted FY21**	**Planned FY22**
UWRL Administration	$321,660	$281,827	$290,282
Education, Outreach, and Technology Transfer	$227,492	$250,912	$258,439
Environmental	$538,197	$539,700	$521,691
Hydraulics	$6,411	$156,371	$146,912
Measurements, Sensing, and Information Systems	$298,631	$154,128	$185,797
Water Resources	$357,603	$429,262	$409,079
Totals	**$1,749,994**	**$1,812,200**	**$1,812,200**

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.

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.

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 and 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, this year many UWRL faculty have 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.

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.

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 the use of 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. These data are then analyzed using innovative image processing

techniques and used to enable more efficient irrigation of crops, identification and management of invasive vegetation, and for improved water and environmental management.

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. The also 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 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 Quality Nutrient Criteria Development Core Advisory Team Utah Division of Water Resources, Utah Agricultural Water Optimization Task Force (UDWR)	**Other State/Local Boards/Committees** Cache County Solid Waste Advisory Board Logan City Renewable Energy and Conservation Advisory Board Logan City Water Board Logan River Task Force Logan River Water Users Crocket Avenue Project Technical Advisory Board NOAA National Water Center Community Advisory Committee for Water Prediction OpenET Colorado River Basin Working Group
Peer Review Journal Articles Environmental Modelling & Software Journal, editorial board Hydrological Processes, associate editor Journal of Coastal and Hydraulic Structures, editor Journal of Hydraulic Engineering, ASCE, associate and guest editor Journal of Water Resources Planning and Management, ASCE, associate and reproducibility editor WIREs Water, associate editor	**Conference/Workshop Leadership Service** Society of PhotoOptical Instrumentation Engineers Conference Committee National Science Foundation. workshop on Integrated Hydro-Terrestrial Modeling Science Gateways Community Institute Federal Workshop USGS Inland Bathymetry Workshop
Proposal/Program Review NASA Research Opportunities in Space and Earth Science program review panel National Science Foundation. Review panels on Integrated Hydro-Terrestrial Modeling USDA NIFA Proposal Review Board	

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.

Administration, Advisory Support, and Special Equipment

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

Project Name	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
Business Office	$ 150,122	$ 140,116	$ 144,320
Publications Office	$ 102,365	$ 87,190	$ 89,806
UWRL Administration	$ 69,173	$ 54,521	$ 56,156
Total	**$ 321,660**	**$ 281,827**	**$ 290,282**

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, so as 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 20 administrative costs represented approximately 4% 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, more than 200 active research contracts are administered at the UWRL. These projects require significant support from the UWRL Business Office in the form of accounting and financial oversight. Further, the UWRL Publications Office provides support for outreach activities (such as the production of presentations, maintenance of the UWRL and UCWRR web pages, etc.). MLF expenditures in FY 20 on these support activities accounted for 14% 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 Reports section of this document.

Research Project Summary Categories

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

	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
UWRL Administration	$321,660	$281,827	$290,282
Education, Outreach, and Technology Transfer	$227,492	$250,912	$258,439
Environmental	$538,197	$539,700	$521,691
Hydraulics	$6,411	$156,371	$146,912
Measurements, Sensing, and Information Systems	$298,631	$154,128	$185,797
Water Resources	$357,603	$429,262	$409,079
Totals	**$1,749,994**	**$1,812,200**	**$1,812,200**

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:

Education, Outreach, and Technology Transfer

Environmental

Hydraulics

Measurements, Sensing, and Information Systems

Water Resources

Education, Outreach, and Technology Transfer

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

Project Name	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
Center of Excellence for Water	$ 37,573	$ 26,181	$ 26,967
Development of an On-Site Demonstration Site at the Ash Creek Special Service District	$ 35,406	$ 15,803	$ -
Logan City Renewable Energy and Conservation Advisory Board (RECAB)	$ 12,733	$ 28,079	$ 28,921
Making Water Research Results MoreRreproducible	$ 12,573	$ 19,753	$ 20,345
State of Utah Drinking Water Board	$ -	$ 5,000	$ 5,150
State of Utah Operators Certificate Commission	$ 5,000	$ 5,000	$ 5,150
USU Stars! Gear Up Summer Engineering Camp	$ 58,473	$ 28,079	$ 28,921
Utah On-Site Wastewater Treatment Training Program	$ 65,734	$ 15,803	$ 16,277
Designated Projects		$ 5,969	$ 6,148
Undesignated Projects		$ 101,245	$ 120,560
Total	**$ 227,492**	**$ 250,912**	**$ 258,439**

Center of Excellence for Water

Principal Investigators:

David K. Stevens
R. Ryan Dupont
Kurt Becker
Mohammad Al Mestiraihi (PhD Student).

Partners/Collaborators:

- ***Local**: Logan, UT*
- ***National**: US AID*

Project Description:

- **Need and Purpose:**

  Water resources education and research is needed to provide the workforce who will address water resources sustainability problems worldwide. The mission of the UWRL involves both knowledge generation and education, in Utah and throughout the world. This project applies UWRL expertise in water education towards the creation of a center of excellence for water research and education in Egypt, with the recognition that the curricula and research knowledge generated will have application in Utah and the U.S.

  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 to face water challenges, develop policy, and prepare a next generation of graduates and entrepreneurs to be change agents that stimulate economic growth. Inclusion of women, disabled persons, and talented yet financially needy faculty and students, is central to all aspects of our design and implementation.

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

- **Geographic Areas:**

  Study Areas: Logan, UT.

  Areas Benefited: Statewide.

- **Accomplishments:**

  This is an international collaborative project funded by USAID using partnerships between 5 US universities (Utah State, Washington State, Univ. of California-Santa Cruz, Temple University, and the American University of Cairo (Egypt), 5 Egyptian Partner Universities (EPUs, Alexandria University, Ain Shams University, Zagazig University, Beni Suef University, and Aswan University), and number agency, public, and industrial partners in Egypt. During FY 19-20, the project was in its first year. The major accomplishment was for the USU team to travel to Egypt to get acquainted with the human and physical landscape, and to follow-up on a survey produced by the USU team to inform a needs assessment of the water-related programs at the 5 Egyptian partner universities in terms of teaching, research, outreach, governance, and sustainability. This resulted in a Needs Assessment Report submitted in December 2019 and finalized in March 2020. In addition, the USU team put on a two-week workshop for nine Egyptian participants in Logan for training in the use of web-based Learning Management Systems. We also coordinated a call for proposals for development of 17 new courses for Egyptian Universities with teams comprised of US faculty members and two or more Egyptian partners.

Work Plan FY20/FY21

This project will continue through 2026 and in the coming fiscal year we will be completing the development of the 17 undergraduate courses, issue a call for proposals and development for 23 graduate level courses in water resources sustainability for implementation at the 5 EPUs, put on a workshop on Innovative Teaching Strategies to 10 Egyptian participants, in addition to individual faculty efforts in the course development portion of the project. If the situation allows, we will travel as a team to Egypt early in calendar 2021 to put on Phase II of the Innovative Teaching Workshop on location.

Informational Resources

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

Publications:

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

Websites: https://www.usaid.gov/egypt/higher-education/center-excellence-water

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

Principal Investigators:

Judith L. Sims
Brian Cowan
Richard Jex
Jeff Crandall
Nathan Guymon

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)*

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, a similar demonstration site in the southern part of the state would be beneficial 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 allow instructors and regulatory staff from the area 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 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, monitoring, and maintenance, especially professionals located in central and southern Utah.

- **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.

- **Accomplishments:**

  The approach to the development of the project is design/build. Demonstration displays will include (a) septic tanks displays; (b) displays of distribution devices for septic tank effluents in absorption systems; (c) in-ground 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, packed bed systems (intermittent sand filter, recirculating sand and gravel filters, textile system, peat system, and synthetic polystyrene media filter), and sand-lined

trenches; (e) pump systems, tanks, and vaults; (f) control panels; (e) effluent filters for septic tanks; (g) valves for alternating drain fields; (h) dosing tanks; and (g) drip irrigation systems.

During FY19/20 we designed and built various demonstration displays. We developed the wording for signs and produced 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. The COVID-19 pandemic prevented us from transporting the displays from Utah State University to the Ash Creek Special Services District in Hurricane for installation in the Spring of 2020.

Work Plan FY20/FY21

We will continue to procure materials and demonstration materials, build more displays, and begin installation of the educational models at the Ash Creek demonstration site.

Informational Resources

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

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

Logan City Renewable Energy and Conservation Advisory Board (RECAB)

Principal Investigators:

R. Ryan Dupont

Partners/Collaborators:

- ***Local**: Emily Malik, Logan City Environmental Department; Amy Anderson, Tom Jensen, Logan City Council*

Project Description:

- **Need and Purpose:**

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

  RECAB's goals include:

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

- **Benefits to the State:**

  The RECAB mission is to provide Logan City with technical expertise and experience on the potential of new renewable energy sources, carbon emission estimates, and public education. The PI attends monthly meetings of the Logan RECAB, provides comments and input on renewable energy and waste management issues that arise, and has responded to special requests from RECAB regarding technical issues related to alternative renewable energy sources. Recent examples of special project requests during the reporting period include: (1) an in-depth analysis of the renewable energy potential of landfill methane gas recovery and power generation at the closed municipal landfill; and (2) additional evaluation of the potential for energy use reduction at the planned mechanical wastewater treatment plant through process modification and installation of anaerobic digesters for secondary treatment load reduction and energy production. The PI is a member of RECAB's Community Solar subcommittee, which is evaluating program options for increasing participation in the existing Logan City solar farm, and considering options for expanding the current program and facilities to include a commercial customer base.

- **Geographic Areas:**

  Study Areas: Logan City and Cache County.

  Areas Benefited: Logan City and Cache County.

- **Accomplishments:**

  The PI attended all regularly scheduled Logan RECAB meetings throughout FY19–20 and provided review and comment on all RECAB items relevant to his area of expertise. Topics included the following:

  - Analysis of current and future resource mix to meet a 50% renewables component in Logan City's power portfolio by 2030.
  - 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.
  - Participation on the Community Solar program analysis RECAB subcommittee.

Work Plan FY20/FY21

The PI will continue Involvement with the Logan RECAB and will respond to special project requests as they arise to support Logan City RECAB's mission and goals.

Informational Resources

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

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

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

Making Water Research Results More Reproducible

Principal Investigators:
David E. Rosenberg

Partners/Collaborators:

- ***Business/Commercial/Not-for-Profit**: Dave Watkins, Michigan Tech University; Dana Compton, American Society of Civil Engineers; Brian Parsons, Environmental Water Resources Institute; David Mellon, Center for Open Science*

Project Description:

- **Need and Purpose:**

Science and engineering communities show a broad interest in making research results reproducible, even though few published results are currently reproducible. This contradiction exists because of several perceived and real challenges: (1) Reproducing article figures, tables, and other results requires more author effort to prepare and share 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) It takes time and expertise to reproduce others' results. (6) Funders, universities, and institutions value publication of novel, peer-reviewed journal articles rather than datasets, documentation, or reproduction of others' efforts. (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 with today's tools. The authors, journals, funders, and institutions that produce, publish, and support research must better coordinate to overcoming these challenges. Here we share practices to encourage the research community to make research data, models, code, and directions more available and results more reproducible (Figure 1).

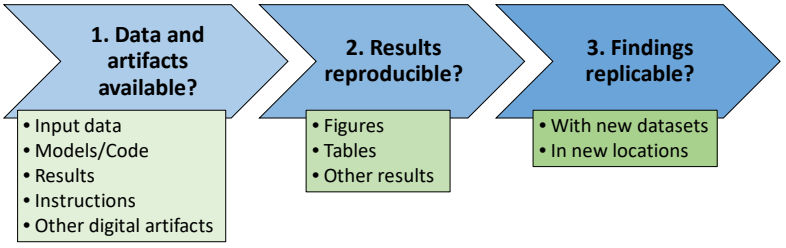


***Figure 1.** Reproducibility is a continuum. The goal is to push research up the continuum to be more reproducible. Definitions for available, reproducible, and replicable follow definitions by U.S. National Science Foundation, U.S. Department of Education, and the National Academy of Sciences*

- **Benefits to the State:**

Making research results more reproducible will give more Utahns access to research. Improved access will also give Utah researchers and businesses the ability to use and extend research produced in Utah, the U.S., 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.

- **Geographic Areas:**

  Study Areas: This project does not have a specific study area. Reproducibility work is conducted across Utah, other U.S states, and the world.

  Areas Benefited: Areas throughout Utah

- **Accomplishments:**

  - Wrote an editorial with 10 co-authors from Utah, other U.S. states, and two other countries for the Journal of Water Resources Planning and Management that presents 40 best practices to make research results more reproducible (Rosenberg et al, 2020) (Figure 1).
  - Drafted new result-reproducibility policy for the Journal of Water Resources Planning and Management published by the American Society of Civil Engineers (ASCE). The policy sets up a new process to verify the availability of data, models, and code use in manuscripts and reproducibility of results in tables, figures, and text. The policy offers authors of manuscripts with verified reproducible results the financial incentive of free open access publishing. The policy also offers awards to (1) the authors of the article with outstanding effort to reproduce results, and (2) the reviewer who makes outstanding effort to reproduce results.
  - Recruited seven other new associate editors for reproducibility to handle the process of verifying that manuscript results are reproducible.
  - Initiated outreach with the Environmental Water Resources Institute of the American Society of Civil Engineers and the Center for Open Science for financial backing to cover open access fees for manuscripts with verified reproducible results and to publicize the new reproducible results policy.

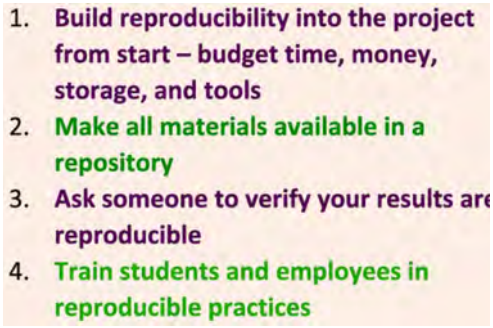


Figure 2. Four recommended best practices to make results more reproducible

Work Plan FY20/FY21

- Secure final financial commitments to fund free open access for manuscripts with verified reproducible results.
- Launch and publicize the new reproducible results policy.

Informational Resources

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

Publications:

Rosenberg et al. (2020). The Next Frontier: Making Research More Reproducible. https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29WR.1943-5452.0001215; Preprint: https://digitalcommons.usu.edu/water_pubs/156/.

Stagge et al. (2019). Assessing data availability and research reproducibility in hydrology and water resources. https://doi.org/10.1038/sdata.2019.30.

Rosenberg and Watkins (2017). New Policy to Specify Availability of Data, Models, and Code Editor's Note. https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0000998.

State of Utah Drinking Water Board

Principal Investigator:

Blake P. Tullis

Partners/Collaborators:

- ***State**: Marie Owens, Director, Division of Drinking Water*

Project Description:

- **Need and Purpose:**

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

- **Geographic Areas:**

  Study Areas: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  Findings/Results: The PI attended all regularly scheduled Drinking Water Board meetings and facility tours from July 1, 2019 to June 30, 2020, with the exception of one due to a conflict in schedule, and provided review and comment on all Board items relevant to his area of expertise.

Work Plan FY20/FY21

Dr. Blake Tullis from the UWRL will continue with the board service from 2019 to 2023.

Education, Outreach, and Technology Transfer

Informational Resources

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

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

State of Utah Operators Certificate Commission

Principal Investigators:

David K. Stevens

Partners/Collaborators:

- ***State**: Marie Owens, Director, Division of Drinking Water; Michael Grange, Division of Drinking Water*

Project Description:

- **Need and Purpose:**

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

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Areas: State of Utah.

  Areas Benefited: State of Utah.

- **Accomplishments:**

  The PI attended all scheduled Operators Certification Commission meetings July 1, 2019 to June 30, 2020, and provided review and comment on all Commission items relevant to his area of expertise. The PI also serves on the Drinking Water Board and its Finance Committee, reviewing projects and making recommendation to the full board concerning action on proposals.

Work Plan FY20/FY21

Involvement on the Board will continue through 2021.

Informational Resources

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

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

USU Stars! Gear Up Summer Engineering Camp

Principal Investigators:

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

Partners/Collaborators:

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

Project Description

- **Need and Purpose:**

  The USU Stars! Gear Up Project is designed to improve high school graduation rates and enhance college-readiness for Utah students, focusing specifically on underrepresented student populations (women and minority students) in STEM fields of science and engineering. The Gear Up summer program provides an opportunity to encourage middle and high school students to pursue post-secondary STEM educational opportunities by providing them with pre-college experiences on the USU campus focused on specific areas of engineering practice.

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Area: Logan City and Cache County

  Areas Benefited: For the summer 2019 workshop, teacher and student attendees came from Logan, North Davis, Gunnison, Manti, North Sanpete, Cottonwood, and Salt Lake City.

Figure 1. Engineering Camp students venture through Logan Canyon collecting Logan River data.

- **Accomplishments:**

  A total of 60 students and six teachers from school districts across the State attended a week-long summer engineering workshop focused on the science and practice of water and environmental data collection including remote submersible drone water sampling, high frequency water quality sampling using a river sensor network, and air quality and water resources data collection using aerial drones. As a culmination of the experience student groups were tasked with generating a poster highlighting science and engineering principles they discovered during the week.

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

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

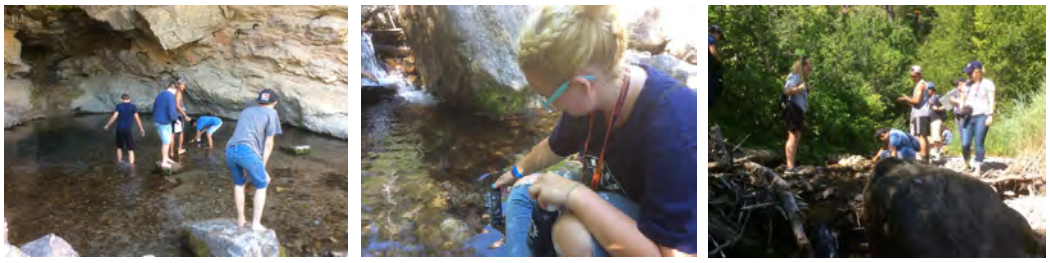


Figure 2. Students making water quality measurements throughout Logan Canyon

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

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

Work Plan FY20/FY21

Planning for the 2020 USU Stars! Gear Up Engineering Camp, was put on hold due to the COVID-19 outbreak. Planning for a virtual or limited exposure Engineering Training Experience for Teachers will be developed for possible presentation in spring to summer 2021 as the pandemic allows.

Informational Resources

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

Utah On-Site Wastewater Treatment Training Program

Principal Investigators:

Judith L. Sims
Margaret Cashell
Brian Cowan
Richard Jex
Jeff Crandall (Student)
Nathan Guymon (Student)
Ivonne Harris

Partners/Collaborators:

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

Project Description:

- **Need and Purpose:**

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

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

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

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Areas: Entire State of Utah.

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

- **Accomplishments:**

  During FY19/FY20, the Utah On-Site Wastewater Treatment Training Program conducted eight training workshops for 117 trainees. This state-mandated program provides training and certification for persons involved in siting, designing, operating, and maintaining both conventional and alternative septic systems. The Utah On-Site Wastewater Treatment Training Program at the Utah Water Research Laboratory was established by a state legislative initiative (House Bill 14s, 2001) and is administered by the Division of Water Quality in the Utah Department of Environmental Quality.

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

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

  The workshops offered this year included one Level 1 workshop, one Level 2 workshop, one Level 3 workshop, three Level 1 & 2 recertification workshops, and two Level 3 recertification workshops taught at two locations: Park City and Logan. Due to the COVID-19 pandemic, all Spring 2020 workshops were postponed until Fall 2020.

Work Plan FY20/FY21

We will continue to provide workshops in support of the mandatory State of Utah certification program for on-site wastewater professionals (through FY25). Because of the COVID-19 pandemic, Fall 2020 workshops will be broadcast through video conferencing to various health departments around Utah and Idaho. Instructors will lecture remotely from the Weber-Morgan Health Department. Depending on the state of the pandemic, classes in Spring 2021 will be presented through video conferencing, as in the Fall of 2020, or taught in person at various locations around Utah.

Informational Resources

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

Publications:

Sims, J.L., M. Cashell, B. Cowan, and R. Jex (2019, 2020). *Course Manuals for Levels 1, 2, and 3 Original Certification and Recertification Workshops*. Utah Water Research Laboratory, Utah State University, Logan, UT.

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

Environmental

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

Project Name	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
Air Quality Ammonia Studies (Ambient and Vehicle Emissions)	$ 65,177	$ 79,673	$ 82,063
Assessment and Modeling of Cyanotoxin Presence and Occurrence Risk in Utah Surface Waters	$ 45,606	$ 26,181	$ 26,967
Evaluation of the Presence, Fate, and Exposure Pathways of PFAS Compounds in Northern Utah Communities	$ 68,005	$ 28,079	$ 28,921
Impact of Metals and Metal Ions on Soils and Plants	$ 43,584	$ 99,920	$ 102,917
Mitigation of Methane Emissions	$ 43,139	$ 10,615	$ 10,933
Optimizing Stormwater BMP Performance through Vegetation Selection and Harvesting Strategies	$ 57,917		
Pollution Prevention and Water Reuse at Utah Department of Transportation Facilities	$ 34,718	$ -	$ -
Treatment and Bioenergy Recovery from Beverage Wastewater	$ 28,063	$ 7,049	$ 7,261
Trisiloxane Adjuvants in Pollen	$ 65,195	$ -	$ -
Use of Magnetite to Improve Settling and Effluent Quality in Wastewater Treatment Plants	$ 86,793	$ 66,386	$ 68,378
Designated Projects		$ 71,797	$ 73,951
Undesignated research projects in program area		$ 150,000	$ 120,300
Total	**$ 538,197**	**$ 539,700**	**$ 521,691**

Air Quality Ammonia Studies (Ambient and Vehicle Emissions)

Principal Investigators:
Randal S. Martin
Joe Thomas (UDAQ, WSU NCAST)
John Sohl (WSU)
Nancy Daher (UDAQ)
Motasem Abualqumboz (MS Student)

Partners/Collaborators:

- ***Local****: Logan, Cache County, UT; Wasatch Front (Brigham City to Mona, UT)*
- ***State/National****: Utah Division of Air Quality, UT Air Monitoring Center*

Project Description:

- **Need and Purpose:**

  Preventative and protective strategies are needed to address the $PM_{2.5}$ (particulate matter) and O_3 (ozone) air pollution health issues in Cache Valley, along the Wasatch Front, and the Uintah Basin. This is especially true during the wintertime inversion conditions typical of northern and northeastern Utah. Previous research and regulatory work has shown vehicle emissions are the dominant emission sources of Utah's direct and precursor pollutants. Additionally, it has become apparent the current air pollutant emission inventories underestimate available ambient ammonia (NH_3), a key component of our local/regional $PM_{2.5}$ (ammonium nitrate). Statewide photochemical modeling attempts must be artificially enriched by two to six times to adequately predict observed ambient concentrations. Literature searches have shown little available data on raw NH_3 emissions from mobile sources, although the mobile sector is often inferred as a significant source of these underestimations. This summary combines two projects funded via the Utah Division of Air Quality (UDAQ) and Mineral Lease funds to expand the overall scope of the research.

- **Benefits to the State:**

  Accurately assessing the ambient NH_3 and other relevant pollutants and their emissions from sources relevant to the fleets and conditions of northern Utah will help to identify their significance, particularly under wintertime, inverted conditions. This will also facilitate the development of information that can be provided to the general public through local and statewide outreach programs.

- **Geographic Areas:**

  Study Areas: A majority of the automobile emissions testing has been and will be conducted at the Utah Water Research Laboratory (UWRL) and at Weber State University's National Center for Automotive Science and Technology (WSU/NCAST). Ambient measurements were conducted from Brigham City to Mona, and out to the western boundary of the Great Salt Lake.

  Areas Benefited: Northern Utah populations will see the most direct and immediate benefit. UDAQ can also use results in planning future mitigation and modeling strategies. Air quality research partnerships have also been established among UDAQ/AMC, USU/UWRL, WSU, the U of U, and BYU.

- **Accomplishments:**

  Findings/Results: Ambient NH_3 measurements are shown in Figure 1. The average NH_3 concentrations were 11.5 ppb in the winter and 18.1 ppb in the winter, with a strong south-to-north gradient observed during both seasons. During the winter observations, the north Wasatch, Salt Lake Valley, and Utah Valley averaged 8.8, 11.3, and 14.5 ppb, respectively. In the summer, these same areas averaged 15.0, 23.7, and 37.5, respectively. A large landfill location in the southwest SLC valley consistently showed elevated ammonia levels, as is evidenced for both the winter and summer periods on Figure 1. This finding could be important in future attribution studies. To date, almost 50 passenger gasoline vehicles have been tested

on-road for ammonia and related pollutant emissions, and nearly 10 diesel-fueled passenger vehicles have been tested. Initial analysis suggests current EPA mobile emissions models may reasonably estimate the average ammonia emissions from northern Utah's gasoline fleet, but may not adequately account for variability across age-related Tier structures. Also, preliminary analysis of the diesel studies suggest the selective catalytic reduction (SCR) technologies for NOx remediation may not increase NH_3 emissions.

Work Plan FY20/FY21

Some outstanding, dynamometer measurements are planned for spring 2021 as these studies have been delayed by equipment availability and COVID issues. Dr. Martin has also become involved with studies on potential long-range COVID transport and COVID associated with aerosols and wastewater treatment, which have been initially funded via MLF funds.

Informational Resources

Contact: Dr. Randy Martin, Telephone: (435) 797 158, E-Mail: randy.martin@usu.edu.

Publications:

A poster presentation of the mobile source studies was accepted for the CRC 30th and 31st Real World Emissions Workshops. Although the 2020 (30th) workshop was canceled, presentation will be presented virtually at the 2021 (31st) meeting. The results of the mobile source and ambient studies were presented virtually at the Utah-centric Science for Solutions Conference in March 2020. The project Statements of Work are available through Dr. Martin.

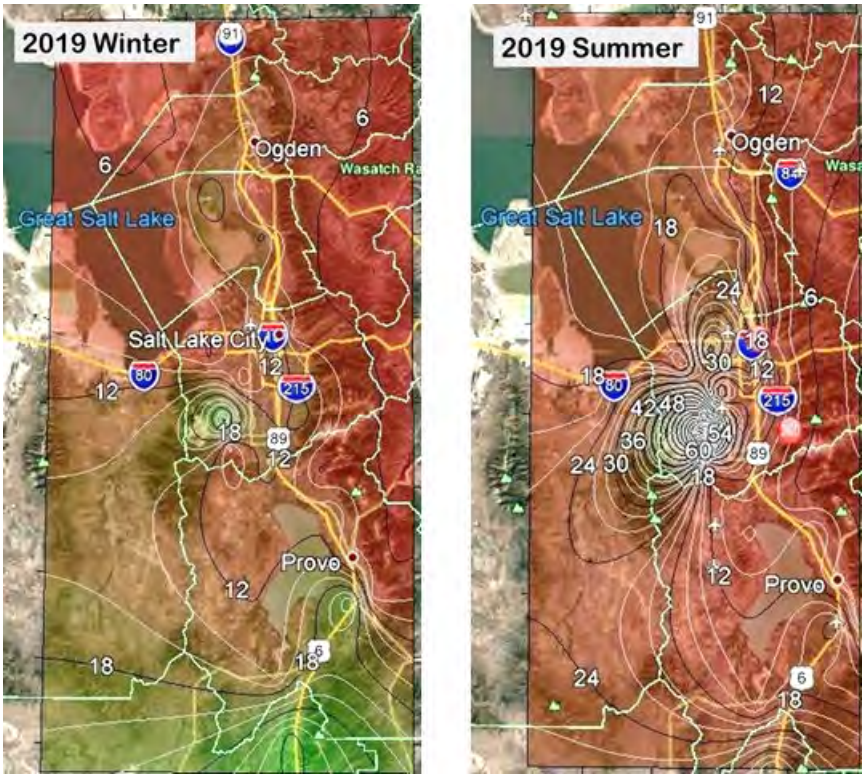


Figure 1. Summer and winter 2019 ambient ammonia along Utah's Wasatch Front

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

Principal Investigators:
David Stevens
Joan McLean
Jade Echard (DEE Student)

Partners/Collaborators:
- ***Local**: Brigham City, UT*

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 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 (Banack et al. 2015). 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 the fall of 2014 resulted in the death of a swimming dog (UDEQ 2014) that created a stir on social media and in traditional news outlets, 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) (UDEQ 2015). Additional water suppliers have noted cyanobacteria blooms in late summer and fall in their source waters (Childers, 2016, personal communication). 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 monitoring and assessment programs for cyanotoxin risk and to determine data needs;
  3. Monitoring and assessment for key selected Utah Drinking Water Utilities, and
  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 assessment of cyanotoxin risk to the State of Utah include (1) guidance for development of long term monitoring programs for cyanotoxins, (2) preliminary data collection and database development for cyanotoxin-related information, and (3) an assessment of the current risk of cyanotoxins in water supplies along with identification of problem supplies that are at risk of increasing cyanotoxin presence.

- **Geographic Areas:**

  Study Areas: Cache, Box Elder, Carbon, Weber, and Washington counties

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

- **Accomplishments:**

  We began a literature review of mathematical models for cyanobacteria growth and cyanotoxin production. A report detailing the findings of the review will be completed in January 2021. In addition, we have identified seven sites in and surrounding Mantua reservoir and began sampling water from those sites for cyanotoxins and nutrient concentrations in June 2020.

Work Plan FY20/FY21

The literature review portion of the study will be completed by Jan. 1, 2021. We will be negotiating with water utilities to send samples to the UWRL for cyanotoxin and nutrient testing. Monitoring at Mantua will continue through October 2020 and resume in spring 2021 (after lake thaws). Laboratory studies will begin in fall 2020 and continue through the duration of the project

Informational Resources

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

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

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
J. Hortin, R. Chen (Technicians)
S. Kovik (MS Student)

Partners/Collaborators:
- ***Local**: Hyrum City, Logan City, UT*

Project Description:

- **Need and Purpose:**

  Polyflorinated alkyl substances (PFAS) represent a wide range of compounds 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 a lifetime health advisory level in drinking water of 70 ng/L proposed by EPA in 2019 to limit human exposure to PFAS compounds. This project is designed to generate PFAS concentration data for various potential exposure routes of PFAS (municipal wastewater treatment plant effluent, municipal landfill leachate, wet deposition) in northern Utah. Potential human risks will be evaluated via direct exposure to secondary water, recreational contact, and ingestion of fruits and vegetables irrigated with treated effluent and contaminated rainwater.

- **Benefits to the State:**

  Findings from this study will provide the first data describing PFAS fate and transformation in wastewater treatment lagoons and will document the potential risks of PFAS compounds in reclaimed wastewater, recreational settings impacted by precipitation, landfill leachate influences, and produce grown in urban gardens with reuse water. Treatment and reuse options limiting PFAS risks will be identified, 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 with water scarcity issues driving the development of treated wastewater for secondary water reuse.

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Methods for sample processing, extraction, and analysis have been developed in the UWRL Environmental Quality Laboratory to identify and quantify 24 different PFAS compounds in a wide variety of environmentally relevant samples. Quantitation in field samples has focused on C4–C9 carboxylic and sulfonic acids because of their relatively low Method Reporting Limits (MRLs), below 40 ng/L, and because they have been detected routinely in the samples analyzed in this study. Compounds > C9 rarely appear and tend to have MRLs at 40 ng/L and above. A range of PFAS compounds have been identified in both wastewater influent and treated effluent samples, in some rainwater samples, and in landfill leachate and leachate pond sediment samples collected throughout Cache Valley. Figure 1 indicates the concentration of six commonly detected carboxylic acid PFAS isomers, along with six commonly detected sulfonic acid

PFAS isomers in local wastewater influent and effluent samples. While the mechanical treatment plant used by Hyrum shows some evidence of compound removal, both Logan and Wellsville used lagoon systems for their wastewater treatment, and both show increases in a number of PFAS compounds during retention in these lagoon systems, likely due to concentration via water evaporation.

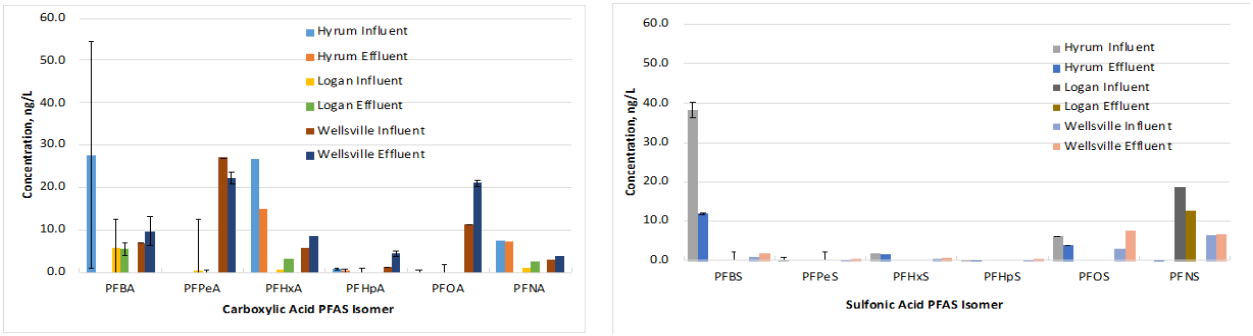


Figure 1. Influent and effluent concentrations of selected PFAS compounds found in local Wastewater Treatment Plants in Cache Valley Utah. Error bars are 95% CI of replicate measurements

Figure 2 indicates the concentration of these same carboxylic and sulfonic acid PFAS isomers in landfill leachate from the Cache County Landfill. As can be seen, PFAS concentrations in the leachate are significantly higher than in the treated wastewater. These leachate concentrations are being generated from wastes that were placed in the landfill starting in the 1960s. These legacy wastes appear to be a significant exposure risk and will be evaluated further in the next project period.

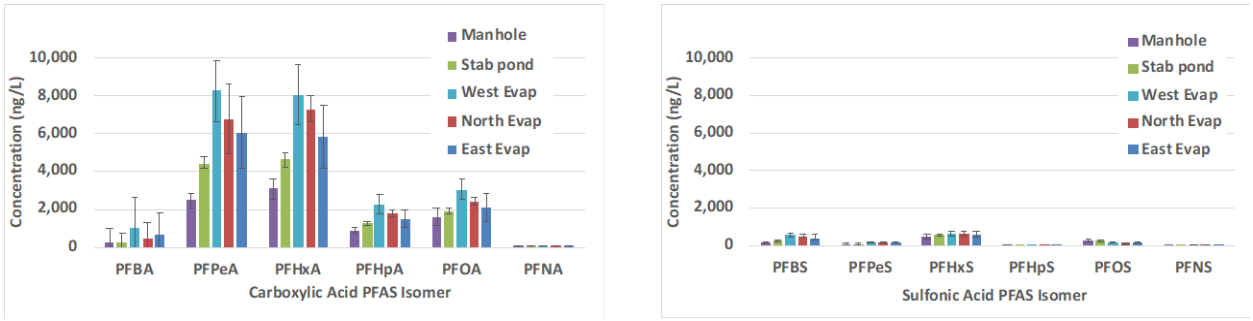


Figure 2. Concentrations of selected PFAS compounds found in the Cache County Landfill leachate, Logan, Utah. Error bars are 95% CI of replicate measurements.

Work Plan FY20/FY21

This project will continue into FY20/FY21, expanding wastewater reuse system sampling to include additional locations in the Salt Lake and Provo valleys; completing the analysis of fruits and vegetables irrigated with reclaimed wastewater in Hyrum, Utah; and completing sampling around the Logan City landfill leachate ponds to assess potential exposure routes adjacent to these concentrated point locations.

Informational Resources

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

Impact of Metals and Metal Ions on Soils and Plants

Principal Investigators:
Joan E. McLean
Anne Anderson (Biological Engineering)
David Britt (Biological Engineering)
Astrid Jacobson (Plants, Soils, and Climate)
Joshua Hortin (Researcher)
Dakota Sparks (MS Student)

Partners/Collaborators:
- *In support of NSF and USDA funding*

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 bacteria. Soils are exceedingly complex and many properties influence the behavior of Cu in the soil. Plant roots and bacteria add to the complexity as they exude chemicals (exudates) (Figure 1). The focus of this year's effort was to evaluate the influences of soil-derived versus plant/bacterial-derived organic matter on the dissolution of CuO NPs since soluble Cu2+ is the bioavailable form of Cu in soil. We used three Utah alkaline soils as the solubility of Cu is limited under alkaline conditions compared to acidic to neutral pH environments. Alkaline soils however contain natural dissolved organic matter in the form of fulvic acid, and plants and bacteria release organic compounds for signaling, defense, and acquisition of nutrients. These organic compounds can complex with Cu (Figure 1), increasing CuO NP solubility to levels commonly observed in more acidic environments.

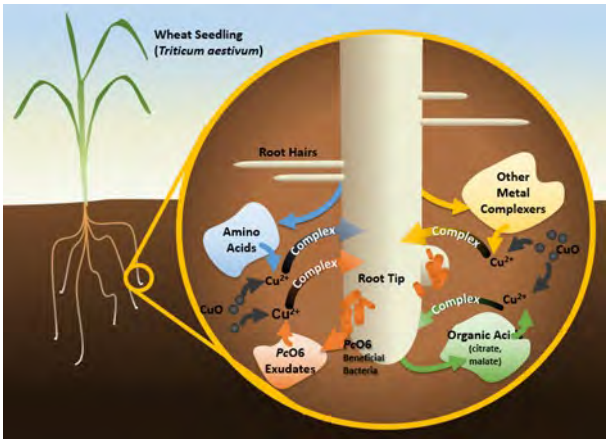


Figure 1: Our evolving understanding of the wheat rhizosphere with CuO NPs

- **Benefits to the State:**

  Although the research focuses on CuO NPs, it is also relevant to metal pollution and other NPs in general. Results directly benefit Utah counties 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 in frequency.

- **Geographic Areas:**

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

  Areas Benefited: All counties in Utah.

- **Accomplishments:**

Dissolution of CuO NPs in alkaline soil pore water is driven by the type and quantity of organic matter present. Wheat was grown in the presence or absence of a beneficial soil bacterium in sand with the addition of pore waters from three Utah alkaline soils that varied in agricultural management practices. The dose of CuO NPs was 100 mg Cu/kg sand. Wheat was grown for 10 days then harvested, and the sand pore water was analyzed. Solubility of CuO NPs was limited in the absence of plants and soil derived organic matter (266 µg/L), but increased with soil organic matter (795-3780 µg/L); the addition of wheat exudates further increased solubility 1.5–3.5 times (4050–6250 µg/L) (Figure 2). Large molecules (>3 kDa), presumably fulvic acid from the soil, primarily complexed Cu when wheat was absent. Crops, bacteria, and soil organic matter, not just pH, have large effects on the dissolution of CuO NPs and thus the bioavailability of Cu to plants. This may aid in nutrient availability for healthy plant growth and nutritional benefits to humans, but it may also contribute to Cu toxicity to various soil organisms. We also observed that soils (presumably organic matter in the soils) partially protected wheats from the toxicity of Cu, and that certain Cu compounds (Cu-deoxymugineic acid, Cu-malate) were much more bioavailable than other Cu compounds (Cu-citrate, Cu-fulvic acid). These results provide an explanation for why soils had a protective effect against Cu toxicity and may provide a future strategy for minimizing adverse effects of NPs.

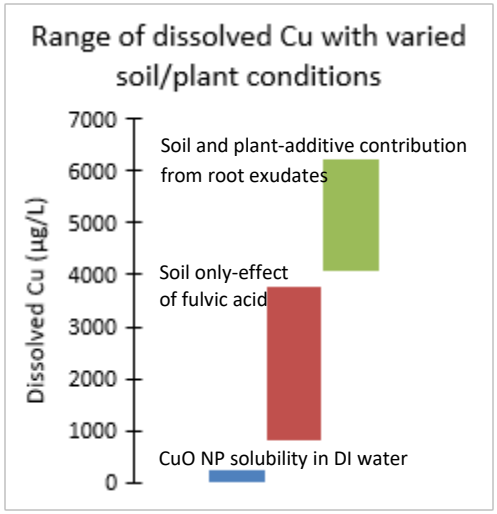


Figure 2: Dissolution of CuO NPs (100 mg Cu/kg sand) under various conditions

Work Plan FY20/FY21

We have been conducting our research under controlled conditions using sand as the growth media and inoculation with a single bacterium. In the coming year, we will conduct studies, again under different soil management practices, using three new soils from northern Utah that differ in pH, soil organic matter, and whole microbial populations and composition. This system will be the most representative of a soil system for this project to date, without the analytical challenges of a whole soil.

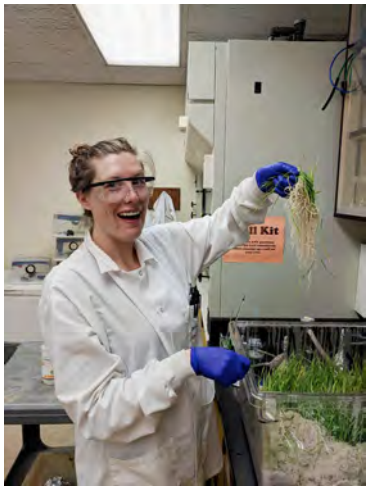


Figure 3: Harvesting young wheat

Informational Resources

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

Publications:

Hortin, J.M., A.J. Anderson, D.W. Britt, A.R. Jacobson, and J.E. McLean, J.E. (2019). Soil-derived fulvic acid and root exudates, modified by soil bacteria, alter CuO nanoparticle-induced root stunting of wheat via Cu complexation. *Environ. Sci. Nano*. 6: 3638-3652.

Hortin, J.M., A.J. Anderson, D.W. Britt, A.R. Jacobson, and J.E. McLean (2020). Copper oxide nanoparticle dissolution at alkaline pH is controlled by dissolved organic matter: influence of soil-derived organic matter, wheat, bacteria, and nanoparticle coating. *Environ. Sci. Nano*. 7: 2618-2631.

Mitigation of Methane Emissions

Principal Investigators:
Judith L. Sims,
Charles Miller
Ronald C. Sims
Jace Parkinson (Student)
Jacob Watkins (Student)

Partners/Collaborators:

- None

Project Description:

- **Need and Purpose:**

Concerns about climate change have led to efforts to reduce greenhouse gas emissions (GHGs). Methane has been identified as a GHG that is over twenty times more effective at trapping heat in the atmosphere than carbon dioxide. Using assumptions developed by the Intergovernmental Panel on Climate Change (IPCC), the U.S. Environmental Protection Agency GHG inventory (2009) estimated that 76% of wastewater sector methane emissions in the United States are from onsite (septic) systems. This is due to the large number of individual septic systems in use and the anaerobic conditions present in septic tanks. Landfills are also a source of methane. According to the U.S. Environmental Protection Agency (EPA), landfill gas (LFG) comprises 17.7% of all U.S. methane emissions.

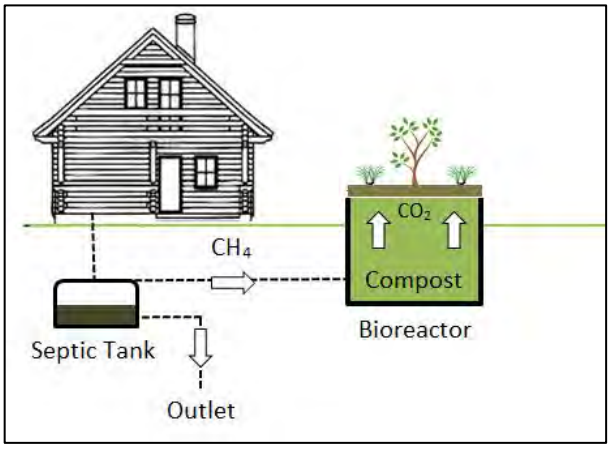


Figure 1. A schematic showing the process of mitigating methane at a local residence

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

In this project, we are investigating the potential effectiveness of a method to mitigate the impacts of methane produced in septic tanks and other anthropogenic sources such as landfills. We plan to collect the methane and treat it in a compost biofilter system seeded with methane-degrading microorganisms. The methane is converted to carbon dioxide, which can be used by plants growing on the compost. An example of a potential treatment system for methane from septic tanks is shown in Figure 1.

- **Benefits to the State:**

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

- **Geographic Areas:**

Study Areas: Cache County, Utah.

Areas Benefited: Areas of Utah where air quality problems exist and septic systems and landfills are commonly used.

- **Accomplishments:**

A computer model was generated to optimize ectoine production by *Methylomicrobium alcaliphilum*, yielding predictions for theoretical methane consumption rates and ectoine production rates. The growth rate previously determined for the organism has been experimentally verified, with less variability in the data compared to previous experiments. Standard lab procedures have been adjusted and improved iteratively to provide for better comparison to existing literature standards for work with *M. alcaliphilum*. Column requirements for quantification of ectoine through HPLC have been determined.

Using the COBRA Toolbox, it was determined that ectoine production of *M. alcaliphilum* can be improved through introduction of a vector containing the MEALZ¬¬_3258 gene, or through adjustment of the ECTS (ectoine synthase) enzyme promoter. Additionally, a theoretical optimal phenotypic state for ectoine production was determined, under which conditions the ectoine production rate is predicted to be 0.9 mmol ectoine gDCW-hr-1, occurring at a growth rate of 0.04 hr-1. The experimentally calculated growth rate for *Methylomicrobium alcaliphilum* was determined to be 0.1319 ± 0.0025 hr-1, which is consistent with the literature.

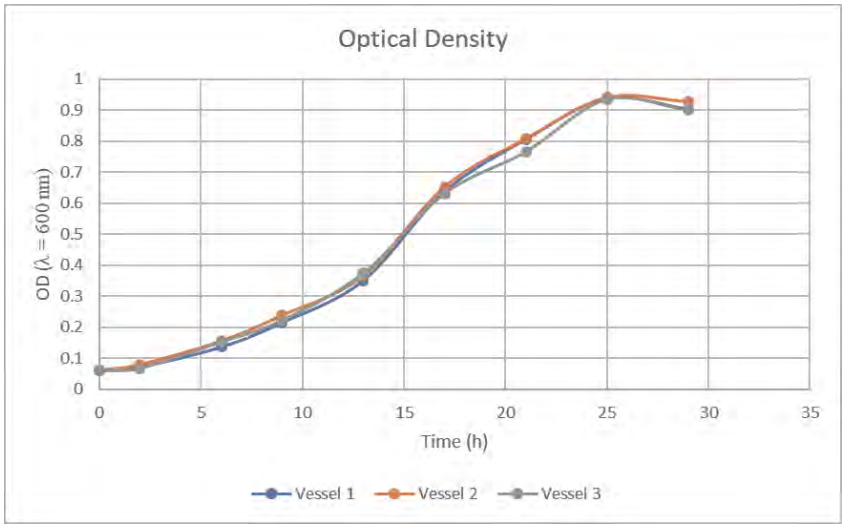


Figure 2. The experimental growth curve of M. alcaliphilum is shown from the time of inoculation to t = 29 hours

Work Plan FY20/FY21

During FY 2020-21, we will focus on investigating 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). The methane degradation rate and ectoine production rate by *M. alcaliphilum* under batch conditions will be calculated. A cost analysis will be performed to determine the feasibility of widespread methane remediation through the organism.

Informational Resources

Contact: Ms. Judith L. Sims, Telephone: (435) 79- 3230, E-Mail: judith.sims@usu.edu.

Publications:

Parkinson, Jace C. and Katelyn A. Ellis (2019). Methane Emission Mitigation Using Methylomicrobium alcaliphilum. *Poster presentation at Utah State University Student Research Symposium*, Logan, UT, April 1.

Optimizing Stormwater BMP Performance through Vegetation Selection and Harvesting Strategies

Principal Investigators:
R. Ryan Dupont
Joan E. McLean
Trixie Rife (PhD student)

Partners/Collaborators:

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

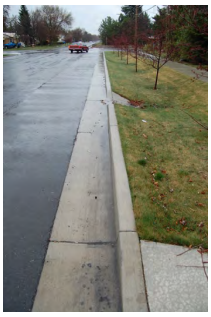


Figure 1: Stormwater BMP site, 300 E Logan, UT

Figure 2: Field demonstration site, Logan, UT

Figure 3: Sample collection at a stormwater BMP site, Salt Lake City Public Utilities building

Project Description

- **Need and Purpose:**

  The EPA National Pollutant Discharge Elimination System (NPDES) water pollution control program mandates municipalities across Utah to install structural stormwater best management practices (BMP) as a means of reducing polluted runoff from major industrial facilities, city storm sewers, and construction sites that disturb one or more acres of land. Stormwater detention basins are often as a used in response to this federal mandate. Objectives of this work are to: (1) minimize discharge volumes and pollutant loadings from urbanized areas flowing into receiving water bodies, and (2) address increased flooding and decreased water quality from urban and rural non-point stormwater sources.

  Utah municipalities are beginning to address stormwater quality and quantity issues. To do this effectively, these municipalities need locally generated, quantitative research to accurately characterize the effectiveness of vegetated storm water management systems. This study measured biomass production and water quality improvement in a controlled greenhouse environment and validated these findings at a field demonstration study site at the Green Meadows subdivision in Logan. Water and pollutant uptake for seven plant species were quantified in the laboratory under simulated (frequency and duration) rainfall events. The field demonstration site used three of these plant species, as well as naturally propagated plant species and non-vegetated control plots. Plant growth was quantified, and contaminant (nutrients and metals) removal was measured in response to periodic plant harvesting. To evaluate the effectiveness of stormwater BMPs for storms under real environmental conditions, studies were completed to evaluate green infrastructure performance in capturing and treating storm water and storing it via groundwater recharge at sites in Logan (Figures 1 and 2) and Salt Lake City (Figure 3).

- **Benefits to the State:**

  This study quantified stormwater nutrient and metal removal effectiveness of local plant species, including a standard turf grass mixture, that Utah municipalities can use to optimize stormwater BMP systems. These data are specific to Utah's climate and geologic conditions. In addition, these quantitative results support design decisions of Utah municipalities and counties that are responsible for meeting new MS4 storm water management permit requirement by the State and U.S. EPA.

- **Geographic Areas:**

  Study Area: Field demonstration sites in Logan: Green Meadows Subdivision detention basin, 600 S and 1600 W; curb cut/bio-swale, 300 E between 900 and 1000 N; parking lot vegetative strip, Early Education

Building, USU campus; roof drain/dry well, Engineering Building, USU campus; Green roof on Early Education Building, USU campus. Field demonstration site in Salt Lake City: SLC Public Utilities Complex bioretention system.

Areas Benefited: All counties in Utah would potentially benefit.

- **Accomplishments**:

Findings: Evidence of species differences in nutrient and metal concentrations accumulated in the harvestable, above-ground biomass at both greenhouse and field-scale suggests that the cabin grass mixture used at the 300 E, Logan site was equally efficient at pollutant uptake for most nutrients and trace metals as BR specific plants studied at the Green Meadows site to improve water quality of storm water in arid northern Utah. Total containment of stormwater generated at all of the field sites resulted in 100% pollutant removal from surface water discharge for storm events with return periods as long as 10 years, depths of up to 2.4 in, and intensities up to 0.37 in/hr.

Results: Soil pore water lysimeter data collected at the 300 E bioswale site (Figure 4) vegetated with a cabin grass turf grass indicated complete removal of stormwater pollutants in the upper soil and root zone when results from plots receiving roadway runoff were compared to a site control bay. These results are significant in that they verify that (1) a turf grass mix can be effective in stormwater pollutant removal, and (2) site soil can be a significant source of pollutant release to groundwater, and should be evaluated through water extraction testing or background site monitoring to assess the true treatment potential of vegetated stormwater BMPs.

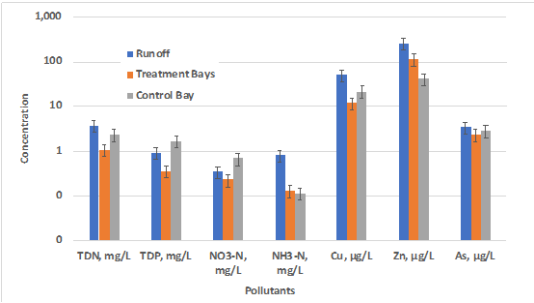


Figure 4: Stormwater BMP site pollutant removal performance at 300 E Bioswale, runoff versus treatment bays versus site control bay

Results from field studies conducted in the summer of 2019 at the at the Field Demonstration site at Green Meadows in Logan have confirmed the variability of pollutant removal and protection of groundwater as a function of species planted within a bioretention area. Groundwater concentrations for all pollutants evaluated were lower below vegetated bays than non-vegetated test bays. In addition, data from the two vegetated BMP sites (Green Meadows and the 300 East site) have indicated that pollutant removal performance was not reduced over pollutant loading ranges up to the maximum values observed in this study as follows: TDN 0.43 lb/BMP ac, TDP 0.31 lb/BMP ac, NO_3-N 1.3 lb/BMP ac, NH_3-N 0.90 lb/BMP ac, Cu 0.07 lb/BMP ac, Zn 0.56 lb/BMP ac, As 0.005 lb/BMP ac, and Pb 0.03 lb/BMP ac.

Work Plan FY20/FY21

This project is complete with no expectation of additional work on the project.

Informational Resources

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

Pollution Prevention and Water Reuse at Utah Department of Transportation Facilities

Principal Investigators:
Wade Goodridge
Joan E. McLean
R. Ryan Dupont
Amanda Scout (MS Student)

Partners/Collaborators:

- ***Local****: UDOT Maintenance Facilities throughout Utah*
- ***State/National****: Utah Department of Transportation*

Project Description:

- **Need and Purpose:**

  The application of road salt is crucial for wintertime public safety, but road salt has many negative environmental impacts. In Utah, road salt is stored at Utah Department of Transportation (UDOT) facilities and is distributed throughout the winter by salt trucks. After storms, trucks are washed and the wash water is captured in retention ponds. Without data informing pond design and maintenance plans, the ponds can become contaminated or overflow. Because of the environmental impacts of pond overflow and regulation under a Phase I municipal separate stormwater sewer system (MS4) permit, UDOT is required to develop best management practices (BMPs) for salt storage and vehicle wash water containment (UDEQ 2015a). With the construction of retention ponds to capture salt-laden wash and stormwater, UDOT must also develop guidelines to address the accumulation and disposal of pond water and sediments. Other states reuse pond water for brine, but the practice is limited by the concentration of toxic elements and oil and grease (O&G). The same pollutants can also limit the disposal of pond sediments. The objective of this study was to develop BMPs and pond design guidelines to help reduce UDOT retention pond contamination and overflow events, which will allow UDOT to comply with their MS4 permit while decreasing environmental impact.

- **Benefits to the State:**

  The design guidelines and best management practices developed in this project using pollution prevention assessments, analysis of water and sediment samples collected from the 12 UDOT maintenance stations, and surface water quality modeling will help UDOT comply with their MS4 permit and reduce contamination or potential overflow events.

- **Geographic Areas:**

  Study Areas: 12 UDOT maintenance facilities were included in this study (Kamas, Heber, Lehi, Provo/Orem, Clearfield, Brigham City, Salina, Junction, Silver Summit, Echo, Huntsville, and Hooper).

  Areas Benefited: All UDOT maintenance facilities.

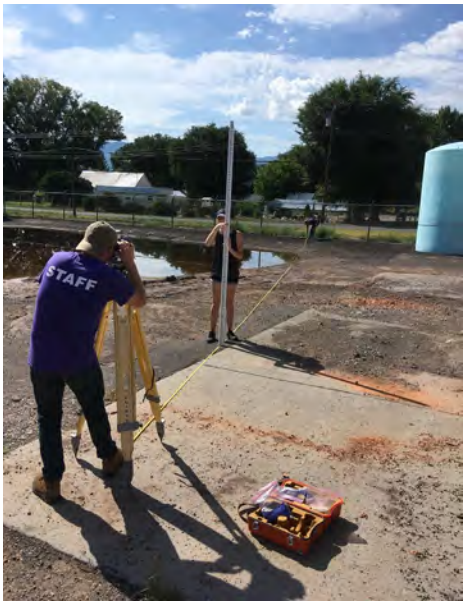


Figure 1. Surveying a site

- **Accomplishments:**

  Through pollution prevention assessments, analysis of water and sediment samples collected from 12 UDOT maintenance stations, and surface water quality modeling, design guidelines and BMPs were developed to help UDOT comply with their MS4 permit. Pond sediments from the maintenance stations will need to be treated before land disposal. To reduce accumulation of contaminants in pond sediments, oil/water separators should be installed, when appropriate, upstream of the retention ponds. Pond water analyses and surface water quality modeling indicate that the pond water at the tested maintenance stations can be used for brine without violating aquatic standards. Reusing pond water, diverting stormwater, and implementing vehicle washing standard operating procedures will reduce pond contamination and overflow events at UDOT maintenance stations, effectively reducing permit violations and the environmental footprint of winter maintenance operations in Utah.

Work Plan FY20/FY21

This project is completed.

Informational Resources

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

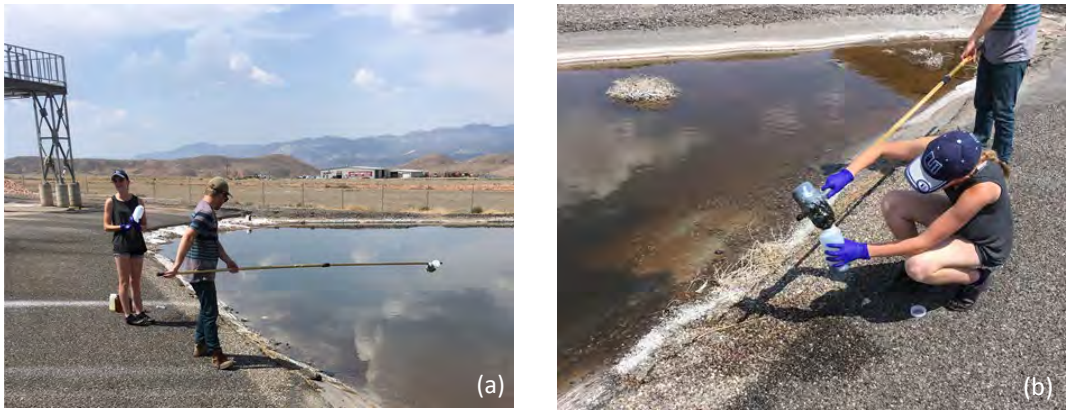


Figure 2. Using the grab sampler to collecting (a) pond water samples and (b) sediment samples

Treatment and Bioenergy Recovery from Beverage Wastewater

Principal Investigators:
Ronald C. Sims
Charles Miller
Yehor Pererva (PhD Student)

Partners/Collaborators:

- ***Business/Industry**: WesTech Engineering, Inc., Logan and Salt Lake City, Utah*

Project Description:

- **Need and Purpose:**

  The environmental firm of WesTech Engineering, Inc., located in Logan, along with its national center in Salt Lake City, is interested in introducing a new technology for both treatment of waste and recovery of energy in the form of biomethane for the expanding beverage industry in Utah. The technology is referred to as Upflow Anaerobic Sludge Blanket (UASB). Advantages include requiring less electricity, less cost for treatment, and recovery of sustainable bioenergy for utilization in powering the technology. The UASB technology does not require oxygen and utilizes the biogas produced (methane and carbon dioxide) for mixing the contents of the UASB reactor. The purpose of this project was to test and evaluate the UASB technology for the management of distillery waste, specifically to determine the "bio-methane potential" (BMP).

- **Benefits to the State:**

  The UASB technology for treating wastewater would benefit the State of Utah by providing an alternative low cost, environmentally protective, and sustainable energy recovery-based management option for the expanding beverage industry in Utah. The technology is potentially advantageous for other types of industry wastes currently produced in Utah. Implementing the UASB technology can also boost economic growth through creation of new engineering jobs and services in Utah.

- **Geographic Areas:**

  Study Areas: The State of Utah and, most immediately, the Salt Lake City area.

  Areas Benefited: All areas of the state of Utah that must meet strict wastewater treatment plant nutrient limits, including mechanical plants and ponds or lagoons.

- **Accomplishments:**

  The UASB technology has high potential for treating beverage wastewater (distillery) without the need for more expensive additions that would include oxygen and mechanical mixing. The microorganisms can be cultivated successfully as a "blanket" within the biological reactor and can remove organic chemicals from the wastewater.

  The technology can generate bioenergy in the form of bio-methane and bio-hydrogen that can serve as sources for electricity, heat, and power generation for reuse by the industry.

  Figure 1 shows the bio-gas produced in the Bio-methane Potential (BMP) tests. The results demonstrate the cumulative yield of biomethane per gram of organic material represented as chemical oxygen demand (COD) for time of wastewater treatment using UASB technology for the beverage waste. Total number of data points is 120, with triplicates of 40 measurements over 55 days of UASB operation. These results demonstrated the success of mixed culture anaerobic microorganisms for treating beverage industry wastewater and producing valuable bioenergy.

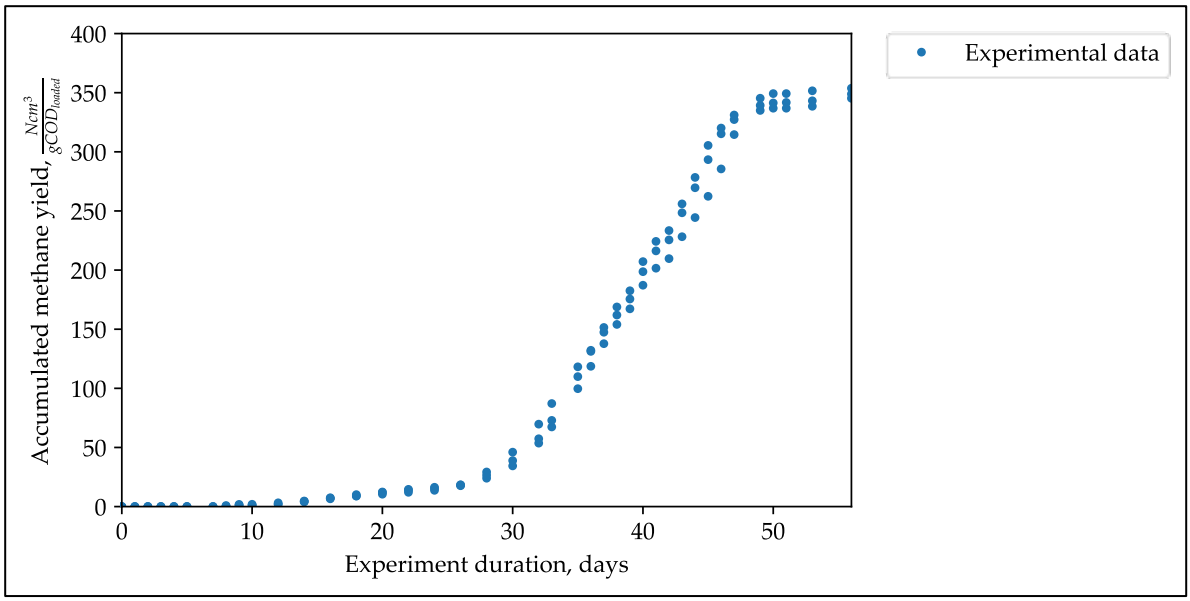


Figure 1. Experimental results for biomethane yield over time using Upflow Anaerobic Sludge Blanket (UASB) technology to treat food beverage wastewater

Work Plan FY20/FY21

This project is complete with the demonstration of successful treatment of food beverage wastewater using Upflow Anaerobic Sludge Blanket (UASB) technology along with the concurrent production of bioenergy in the form of methane (biomethane). Results were further utilized to generate kinetic information (rate of treatment and rate of biogas production) as well as amount of biomethane produced per wastewater organic matter content represented as chemical oxygen demand (COD).

Informational Resources

Contact: WesTech Engineering, Inc.:

- Keith Albresten, Biological Engineer, WesTech Engineering, Inc., Logan, UT. kalbretsen@westech-inc.com.
- Tyler Garr, Environmental Engineer, WesTech Engineering, Inc., Salt Lake City, UT. tgarr@westech-inc.com.
- Rex Plaizier, President and CEO, WesTech Engineering, Inc. Salt Lake City, UT, (801) 856-5323, rplaizier@westech-inc.com.

Publications:

Pererva, Y., C.D. Miller, and R.C. Sims (2020a). Existing empirical kinetics models in biochemical methane potential (BMP) testing, their selection and numerical solution. *Water Journal*, 12(6): 1831. https://doi.org/10.3390/w12061831.

Pererva, Y., C.D. Miller, and R.C. Sims (2020b). Approaches in the Design of Laboratory-Scale UASB Reactors. Processes Section. https://doi.org/10.3390/pr8060734.

Pererva, Y., C.D. Miller, and R.C. Sims (2020c). Sulfur, Phosphorus and Metals in the Stoichiometric Estimation of Biomethane and Biohydrogen Yields. *Processes Journal*, 8(6); Green Processes Section. https://www.mdpi.com/2227-9717/8/6/714.

Trixiloxane Adjuvants in Pollen

Principal Investigators:
William J. Doucette
Autumn Slade, GRA (Student)

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

Project Description:

- **Need and Purpose:**

  Trisiloxane surfactant (TSS) adjuvants are used to improve the wetting, spreading, rainfastness and plant penetration of active ingredient(s) in pesticide products. They are assumed to be biologically inert and are not required to be EPA registered. However, TSS adjuvants have been found in pollen, beeswax, and honey and have been shown to impair honey bee learning and interact synergistically with viral infections in bee larvae. Commercial TSS adjuvants contain a hydrophobic trisiloxane backbone with hydrophilic side chains containing ethylene and propylene oxide (EO/PO) units end capped with acetoxy, hydroxy, or methoxy groups (Figure 1).

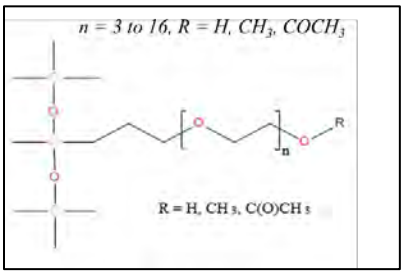


Figure 1: TSS structure common in adjuvants

The objectives were to assess the prevalence and concentrations of TSSs in pollen collected by bees using pollen traps (Figure 2) and look for relationships between TSS and pesticide levels.

- **Benefits to the State:**

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

- **Geographic Areas:**

  Study Areas: US.

  Areas Benefited: All of Utah.

- **Accomplishments:**

  Packages containing three empty 50 mL centrifuge tubes, one centrifuge tube containing clean pollen, and one centrifuge tube containing pollen fortified with TSS were sent to five different beekeepers. A total of 99 pollen samples were mailed back along with the blank and fortified pollen controls sent to the field. Pollen samples were homogenized with liquid nitrogen in a mortar and pestle, then 1g of sub-samples were extracted with 15 mL acetonitrile (ACN) using an EDGETM automated extraction system. The extracts were analyzed by high performance liquid chromatography coupled to a triple-quadrupole

mass spectrometer. Limits of quantitation (LOQ) ranged from 0.4-25 ng/g depending on the oligomer. The pollen extracts were also screened for 66 pesticides in the same analysis run as the TSS.

In the 99 pollen samples collected and analyzed, 43% had hydroxyl-capped TSSs (<LOQ - 62.9 ng/g), 15% had acetoxy-capped like TSS compounds (<LOQ - 722.7 ng/g), and no methoxy-capped TSSs were found above the LOQ *(Table 1)*. Nine pesticide were identified with cyprodinil having the highest concentration (5888 ng/g). In samples where both TSS and cyprodinil were identified, concentrations were correlated. Recoveries of TSS added to clean pollen sent to the field and back were much lower than freshly spiked pollen.

Work Plan FY20/FY21

This project is complete

Informational Resources

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

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

Use of Magnetite to Improve Settling and Effluent Quality in Wastewater Treatment Plants

Principal Investigators:
Michael J. McFarland
David K. Stevens
Patricia Ayaa

Partners/Collaborators:

- ***Local**: Utah State University;*
  Logan City - Holly Daines, Mayor; Issa Hamud,, Environmental Director; Jim Harps, Wastewater Director; Tom Jensen, Sewer and Water Board

Project Description:

- **Need and Purpose:**

  The City of Logan is in the process of upgrading its wastewater treatment facility from a lagoon system to a mechanical facility in order to meet the new phosphorus and ammonia effluent limits imposed by the Utah Division of Water Quality (Carollo, 2015). The new treatment plant will use the 3-Stage Bardenpho process with BioMag® Technology, which adds magnetite to the secondary treatment process. The City of Logan chose BioMag® because the facility footprint would be much smaller than a conventional 3-Stage Bardenpho wastewater treatment facility and the soils at the new plant location would not support the conventional facility's size. Magnetite is an iron ore mineral with a specific gravity of about 5.2, which is much higher than the specific gravity of water and of individual biological floc particles. The high specific gravity of magnetite is expected to increase the settling velocity of the biological floc in the settling tanks, thereby improving their efficiency and enabling smaller sized tanks to be used. Magnetite is also said to improve the quality of effluent from wastewater treatment facilities (Evoqua, 2017).

  This research is investigating the effectiveness of magnetite in wastewater treatment in terms of Biological Nutrient Removal (BNR), and the use of the wasted solids containing magnetite in processes such as anaerobic digestion for facilities that digest their sludge anaerobically. The information obtained should give the City of Logan a clearer picture of the level of biological nutrient removal to expect with the new treatment plant and provide information on how the magnetite in the sludge may affect the gas composition if they decide to digest their sludge anaerobically in the future.

- **Benefits to the State:**

  This project benefits the State of Utah in the following ways:

  - Savings on the initial capital cost of erecting larger new facilities to meet more stringent effluent quality standards, as well as savings on operation and maintenance costs.
  - Improvement in the capacity of existing wastewater treatment facilities, thus eliminating the need to erect entirely new facilities to meet effluent quality requirements.
  - Improvement in effluent quality from wastewater treatment facilities to meet requirements imposed by the Division of Water Quality.
  - Possible reduction in hydrogen sulfide production, its corrosion effect on metal, and toxicity to humans for facilities that digest their sludge anaerobically to produce biogas.

- **Geographic Areas:**

  Study Areas: Logan City, Utah.

  Areas Benefited: Other areas of the state using similar wastewater treatment facilities.

- **Accomplishments:**

  Findings from the research showed that the magnetite technology has helped improve nitrogen and phosphorus removal at the Marlay-Taylor Water Reclamation Facility in Maryland, and that the facility is effectively treating peak flows in compliance with their effluent discharge regulations. A reduction in the effluent total nitrogen of 167.5 kg/d and 8.6 kg/d for the effluent total phosphorus was realized at the facility, as shown in Figures 1 and 2, respectively. Therefore, Logan City, and any other facilities struggling with nutrient (nitrogen and phosphorus) removal from their wastewater, may benefit from this technology. A paper on this research titled "Estimating the Effect of Magnetite on Nitrogen and Phosphorus Removal Using Intervention Analysis" was published in ASCE's Journal of Environmental Engineering (https://doi.org/10.1061/(ASCE)EE.1943-7870.0001780).

  Research on the effect of magnetite in anaerobic digestion is still on-going, and so far, findings show that magnetite added to the anaerobic digestion process reduces the concentration of hydrogen sulfide gas in the biogas produced. This research is nearing conclusion and will be submitted for review and publication.

Work Plan FY20/FY21

1. Complete on-going research on the effect of magnetite in the anaerobic digestion process.
2. Develop a method to produce magnetite nanoparticles from larger sized magnetite particles to increase its adsorption properties, as other researchers have shown that magnetite nanoparticles can facilitate removal of heavy metals from water/wastewater.
3. Investigate any other issues that may arise as a result of magnetite use in wastewater treatment and other applications during the course of this research.

Informational Resources

Contact: Dr. Michael J. McFarland, PE, BCEE, Telephone: (435) 994 0905, E-Mail: farlandm1@outlook.edu.

Publications:

Ayaa, P., K. Stevens David and M. McFarland (2020), Estimating the Effect of Magnetite on Nitrogen and Phosphorus Removal Using Intervention Analysis. *Journal of Environmental Engineering*, 146(9): 05020007, http://doi.org/10.1061/(ASCE)EE.1943-7870.0001780.

Evoqua (2017). *BioMag System for Enhanced Secondary Treatment*. (Aug. 24, 2017). Logan City Environmental Department, Logan, UT. http://www.evoqua.com/en/brands/Envirex/Pages/biomag.aspx.

Carollo. (2015). *City of Logan Wastewater Treatment Final Master Plan 2015*, SLC, Utah.

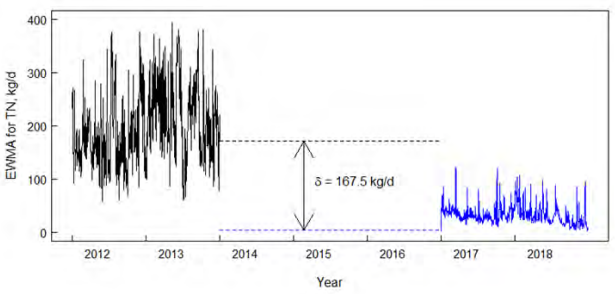


Figure 1: Exponentially Weighted Moving Average (EWMA) for effluent total nitrogen (TN) at the Marlay-Taylor Water Reclamation Facility

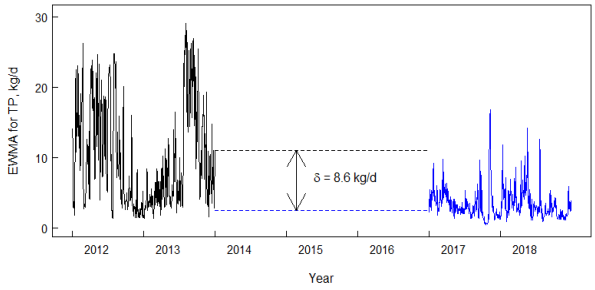


Figure 2: Exponentially Weighted Moving Average (EWMA) for effluent total phosphorus (TP) at the Marlay-Taylor Water Reclamation Facility

Hydraulics

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds

Hydraulics

Project Name	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
Hydraulics of Labyrinth Weir Preceding Steep Stepped Chutes	$ -	$ 7,318	$ 7,538
New Design and Analysis Guidance Regarding Potential Scour of Hydraulic Structures Located in Canals, Rivers, Dams, and Levees	$ 6,411	$ 21,346	$ 21,986
Designated Projects		$ 72,707	$ 74,888
Undesignated Projects		$ 55,000	$ 42,500
Total	**$ 6,411**	**$ 156,371**	**$ 146,912**

Hydraulics of Labyrinth Weir Preceding Steep Stepped Chutes

Principal Investigators:
Blake P. Tullis
Tucker Jorgensen (MS Student)

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

Project Description:

- **Need and Purpose:**

  Spillways are used to route flood waters passing through a reservoir into the downstream channel. Typical spillway components include a flow control structure (weir or gates), a conveyance channel, and an energy dissipation structure. Labyrinth weirs are commonly used as the flow control structure due to their high hydraulic efficiency. Stepped chutes are also being incorporated into more and more spillway because they function as both a conveyance channel and an energy dissipater. In some cases, the stepped geometry also provides cost-saving construction benefits. A recent development in hydraulic engineering combines the labyrinth weir and stepped chute in an effort to utilize the benefits of both. Of concern, however, is the fact that stepped chutes typically have a relatively uniform approach flow (discharge per unit width is uniform). With the labyrinth weir in close proximity to the beginning of the stepped chute, the transitional flow between the two is very non-uniform and turbulent. The purpose of this study was to identify the flow characteristics associated with the labyrinth/stepped chute configuration, primarily with respect to chute wall height requirements, flow surging on the downstream side of the weir, and the potential benefit of adding ramped floors to the outlet cycles of the labyrinth weir.

- **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 design.

- **Geographic Areas:**

  Study Areas: All work was conducted in the Hydraulics Lab at the Utah Water Research Laboratory

  Areas Benefited: Potentially any dam with a spillway

- **Accomplishments:**

  Adding ramped floors to the outlet cycle of the labyrinth weir helped to reduce flow surging of the nappe and wave heights in the downstream channel. An optimal ramp height of approximately half the weir height was identified. Video data were used to extract minimum and maximum water levels with respect to various ramp heights. Sufficient information was reported such that a designer could assess the cost/benefit ratio of using a stepped chute downstream of a labyrinth weir (chute wall height requirements to contain the flow) vs. using a smooth chute and a larger downstream spilling basin. A Master's thesis was produced from this study along with two journal articles (one under review, the second soon to be submitted for review). A new dam project in Texas is based around this design principle.

Work Plan FY20/FY21

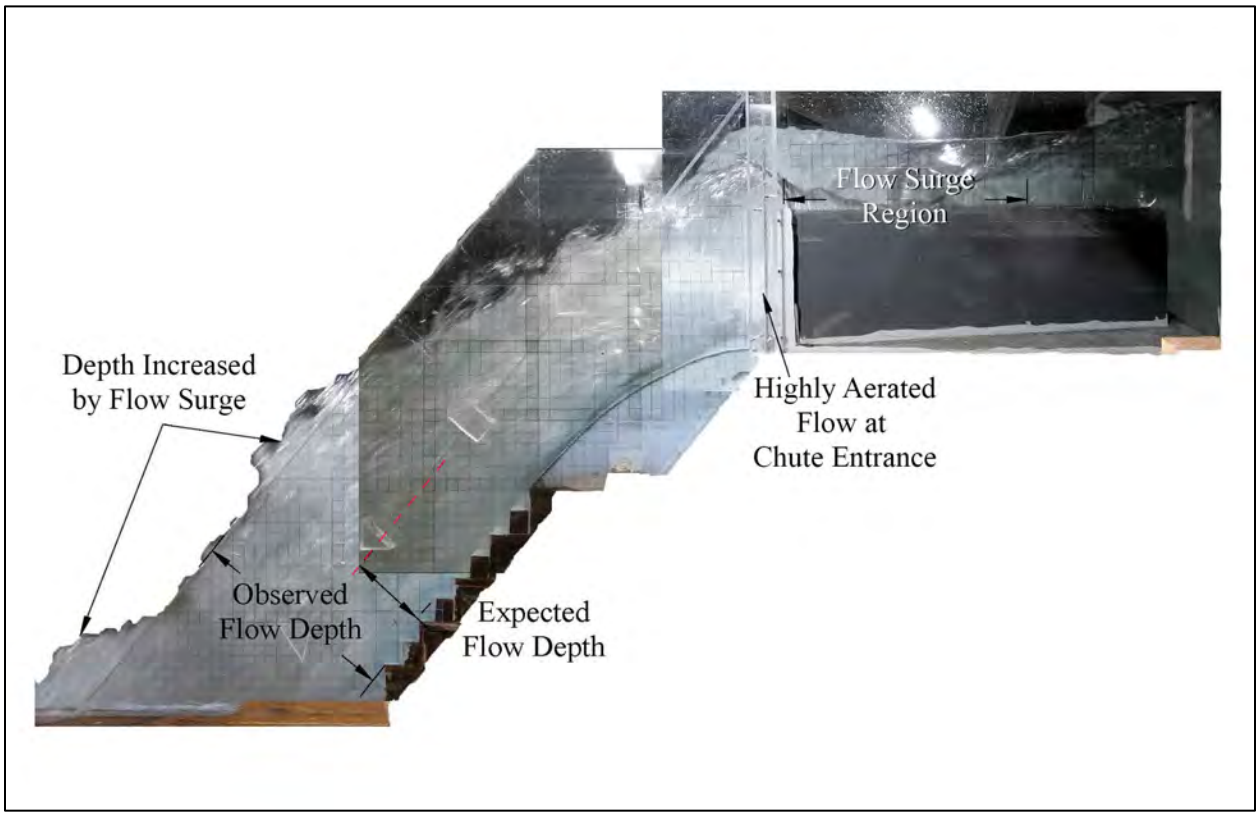
Work in the coming year will focus on information transfer, with the student finalizing/submitting the MS thesis and journal articles.

Informational Resources

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

Publication:

Jorgensen, Tucker J. (2020) Hydraulic Analysis of Coupling a Labyrinth Weir with a Steep Stepped Chute. *All Graduate Theses and Dissertations*. 7949. https://digitalcommons.usu.edu/etd/7949.



Labyrinth weir/stepped chute spillway study supporting general research and new dam construction

New Design and Analysis Guidance Regarding Potential Scour of Hydraulic Structures Located in Canals, Rivers, Dams, and Levees

Principal Investigators:
Brian Mark Crookston
Wyatt Lantz (MS Student)

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

Project Description:

- **Need and Purpose:**

  Looking at the immediate future, historic growth puts Utah at a crossroads, requiring significant changes in the State's water infrastructure – both in new construction and rehabilitation. Many Utah communities that have historically centered on agriculture are becoming urbanized, and Utah has a growing corridor of high-population density. This naturally puts increased demands on water infrastructure and the environment. One consequence of growth is the increased demand for flood protection since development can modify catchment response to snowmelt and rainfall, and instances of construction are occurring within floodplains in Utah. We have direct evidence an increased number of incidents related to flooding in Utah and the USA. A critical component of in-stream and flood infrastructure is foundation protection during operation and floods. Local scour can undermine footings and slabs, which could potentially result in structural failure and instability. The DMAD Reservoir in Utah experienced a dam failure due to local scour in 1983 and is currently being rehabilitated. According to Utah Dam Safety Engineer Everett Taylor, the State of Utah is in need of additional guidance for predicting local scour at many hydraulic structures. One particular flood control structure is the piano key weir, which is being constructed in many locations around the globe due to its cost effectiveness and hydraulic performance. Scour performance data for this structure would be useful for estimating eroded volumes, scour hole geometries, temporal evolution, and equilibrium scour depths. Knowing a maximum depth of scour is particularly useful for sizing cutoff walls where this type of concrete structure terminates.

- **Benefits to the State:**

  This research is of benefit to the State of Utah and others as it provides important design guidelines for piano key weir hydraulic structures.

- **Geographic Areas:**

  Study Areas: All work was conducted in the Hydraulics Lab at the Utah Water Research Laboratory.

  Areas Benefited: Potentially any canal, river, dam, or levee with this type of structure.

- **Accomplishments:**

  Adding ramped floors to the outlet cycle of the labyrinth weir helped to reduce flow surging at the nappe and wave heights in the downstream channel. An optimal ramp height of approximately half the weir height was identified. Video data were used to extract minimum and maximum water levels with respect to various ramp heights. Sufficient information was reported such that a designer could assess the cost/benefit ratio of using a stepped chute downstream of a labyrinth weir (chute wall height requirements to contain the flow) vs. using a smooth chute and a larger downstream spilling basin. A Master's thesis was produced from this study along with two journal articles (one under review, the second soon to be submitted for review). A new dam project in Texas is based around this design principle.

Work Plan FY20/FY21

Work in the coming year will focus on information transfer, with the student finalizing/submitting the MS thesis and journal articles.

Informational Resources

Contact: Dr. Brian Mark Crookston, Telephone: (435) 79-0247, E-Mail: brian.crookston@usu.edu.

Scour morphology and foundation protection experiments at Utah Water Research Laboratory supporting general research and projects

Measurements, Sensing, and Information Systems

Actual, Budgeted, and Planned Expenditures of Mineral Lease Funds
Measurements, Sensing and Information Systems

Project Name	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
Cyberinfrastructure for Intelligent Water Supply	$ 5,639	$ 23,495	$ 37,080
Development of an Inexpensive UAV for Remote Sensing in Water Management and Natural Resources Management	$ 132,446	$ -	$ -
Development of an Unmanned Aerial Vehicle (UAV) Application Center at Utah State University, Utah Water Research Laboratory, UT	$ 122,577	$ 30,000	$ 30,900
Use of sUAS for Mapping Wetland Flow Paths and Consumptive Use on the San Rafael River, Utah	$ 37,969	$ 20,216	$ 20,822
Designated Projects			
Undesignated Projects		$ 80,417	$ 96,995
Total	**$ 298,631**	**$ 154,128**	**$ 185,797**

Cyberinfrastructure for Intelligent Water Supply

Principal Investigators:
Jeffery S. Horsburgh
Nour Attallah (PhD Student)
Camilo Bastidas (PhD Student)
Joseph Brewer (MS Student)

Partners/Collaborators:

- ***Local**: Logan City, UT, Providence City, UT, Utah State University Housing and Facilities Departments*
- ***State/National**: National Science Foundation*
- ***Business/Industry**: None*

Project Description:

- **Need and Purpose:**

  High-resolution water use data collection using smart water meters promises to enhance our ability to characterize water demand and water use behavior, estimate peak water usage, 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 is advancing smart water metering and supporting cyberinfrastructure for building the scientific data and knowledge base for sustainably managing urban water supplies.

- **Benefits to the State:**

  In Utah and the western U.S., 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 will require new data and analytics that provide detailed, actionable information for optimizing the planning, design, and operation of water management infrastructure. A new paradigm is emerging that requires precise accounting and management of urban water consumption for a sustainable water future. This project supports this new paradigm by advancing the human and cyberinfrastructure available for building and managing next-generation smart metering systems and their resultant data.

- **Geographic Areas:**

  Study Areas: Logan City, UT, and Providence City, UT.

  Areas Benefited: Although our data collection activities have focused on Logan and Providence cities in Cache County, we anticipate that our results will be applicable statewide.

- **Accomplishments:**

  We have deployed a low cost datalogger (~$100) on existing water meters to collect high-temporal-resolution data without affecting the functionality of the meter. We also successfully developed and tested three prototype water meter dataloggers: (1) for commercial water meters with electronic signal outputs (4-20 mA and pulsed output) and additional digital inputs for other sensors such as water temperature for investigation of water-related energy use; (2) for low-power data collection only on existing analog residential meters; and (3) for combined low-power data collection and use as a computational node. These dataloggers were used to conduct two detailed smart water metering and water use behavior studies: one in USU's single student housing complexes and one with participating residential homes in Logan City and Providence City, UT. On USU's campus, we completed a "Water Wars" competition in collaboration with USU's Housing and Facilities department and the USU Sustainability Council. More than 500 residential students participated, and Resident Assistants and USU employees were engaged. Prizes were awarded to the dorm that achieved the greatest reduction in water use. The data collected from participating residential homes was used to develop a computer algorithm to identify individual water use events and classify them by end use type (e.g., toilets, faucets, showers, etc.), enabling us to examine water use behavior in each participating home. We created cyberinfrastructure

that handles automated data management of high-resolution data collected from on-campus water meters and data collected as part of our detailed residential smart water metering study. We deployed and tested our cyberinfrastructure in a production environment and are successfully managing the large volume of data produced by field data collection activities. This project has also created opportunities for student training: (1) an undergraduate monitoring program where students work on independent data collection and research projects using the data collection infrastructure we have established; (2) teaching modules for CEE courses designed to teach students 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 (3) a student data visualization challenge using high-resolution water use datasets produced by this project.

Work Plan FY20/FY21

This year, we will finalize field data collection in our detailed residential water use study; deploy and test the computational node version of our low-cost datalogger designed to move data management and processing to the meter location (i.e., converting existing meters into "smart" computational nodes rather than requiring expensive transmission of high data volumes and resource-intensive central post-processing of data); refine and finalize our cyberinfrastructure designs; and hold an additional data visualization challenge.

Informational Resources

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

Publications:

Attallah, N., D.E. Rosenberg, and J.S. Horsburgh (2019). Water End Use Disaggregation for Six Non-Residential Facilities in the City of Logan, Utah, *USA, Journal of Water Resources Planning and Management*, (In revision).

Bastidas Pacheco, C. J., J.S. Horsburgh, and R.J. Tracy (2020). A low-cost, open source monitoring system for collecting high-resolution water use data on magnetically-driven residential water meters, *Sensors*, 20(13), 3655, https://doi.org/10.3390/s20133655.

Websites:

https://github.com/UCHIC/ciws-server. Open source code repository containing current prototype of the back-end server implementation for storing and managing data from our campus water meter network and homes within our detailed residential water use study.

https://github.com/UCHIC/CIWS-MWM-Logger. Open source hardware and code repository containing hardware design, prototyping work, and associated source code for our "piggyback" water meter datalogger for analog, magnetically driven water meters.

https://github.com/UCHIC/CIWS-EWM-Logger. Open source hardware and code repository containing hardware design, prototyping work, and associated source code for our WiFi-enabled, electronic output smart water meter datalogger.

https://github.com/UCHIC/CIWS-WM-Node. Open source hardware and code repository containing hardware design, prototyping work, and associated source code for our computationally enabled water meter datalogger node.

https://github.com/UCHIC/CIWS-Data. Open source code repository containing current prototyping work on code related to analyzing and visualizing high-resolution water use data and disaggregating end uses.

USU PhD students Camilo Bastidas and Nour Attallah install a smart water metering data logger on a residential water meter in Logan, UT

Datasets:

Bastidas, C. and J.S. Horsburgh (2020). Supporting data for "A low-cost, open source, monitoring system for collecting high-resolution water use data on magnetically-driven residential water meters", *HydroShare*, https://www.hydroshare.org/resource/4de42db6485f47b290bd9e17b017bb51/.

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

Principal Investigators:
Calvin Coopmans

Partners/Collaborators:
- ***Business:*** *DeseretUAS*
- ***USU:*** *Prof. Scott Budge & Baron Wesemann*

Project Description:

- **Need and Purpose:**

  Many current sources of remote sensing (e.g., manned aircraft and satellite platforms) are too expensive, have low spatial resolution, or are not updated frequently enough to be practical for many applications. A low-cost, small, unmanned aerial system (sUAS) called AggieAir can fill this need 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 launch 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 type of data can also help canal operators manage water more effectively and wetland managers to monitor and manage invasive plant species that, if left unchecked, can replace native plant species, destroy bird habitat, and use excessive amounts of water. AggieAir can benefit the State by providing new jobs and economic growth to the state of Utah and bringing a focus to the State's place in aerospace, unmanned systems, and the civil uses for technologies such as remote sensing for agriculture. The eventual, long-term goal of the AggieAir system is to create a business within the state of Utah to market this technology.

- **Geographic Areas:**

  Study Areas: Most of this year's test flights took place at our test site near Cache Junction, UT, where we have official approval from the FAA to conduct flights (FAA Form 7711-1 2013-WSA-63). AggieAir has also flown at sites around the state of Utah, as well as in California, over the past year.

  Areas Benefited: All counties in the state.

- **Results:**

  Findings/Results: In the past year, The AggieAir Service Center has continued to fly the unmanned aerial systems and has collected data in many locations. In addition, the AggieAir program has developed and deployed a completely new, fully autonomous aircraft, GreatBlue, which incorporates best-in-class performance attributes:

Figure. 1: The new USU UWRL AggieAir aircraft, GreatBlue on the takeoff/landing pad, ready to fly in CA, June 2020

- up to 2.5 hours of fully autonomous electric flight
- takeoff and landing without a runway
- up to 11 pounds of payload capacity

GreatBlue (pictured in Fig. 1) is a hybrid 'quadplane' drone, which combines vertical takeoff and landing (VTOL) with long-duration fixed-wing cruise functionality, allowing for a gentler, more reliable flight. Weighing in at 55 pounds, GreatBlue is the largest aircraft that the FAA will allow without exception in the airspace. AggieAir was able to prototype, integrate, and fly a fully functioning version of this aircraft in less than 6 months, allowing the team to return to California to once again collect valuable agricultural data during an intensive campaign combined with other world-class groups such as the USDA ARS, NASA, and Gallo wineries. Internally, the AggieAir hardware and software systems were upgraded to be compatible with the new GreatBlue flight control and autonomy hardware, leading to upgrades in the performance of the data collection system (payload) and flight planning system for greater efficiency in mission planning and execution.

Work Plan FY20/FY21

The team has taken delivery of a second GreatBlue flying shell and is planning to create a fleet of 2 GreatBlue aircraft in the coming months. The AggieAir team plans to:

- Continue to integrate and refine the GreatBlue platform (and other AggieAir platforms) to allow for simple, powerful partnerships and research to be accomplished with the new technology,
- Support AggieAir's main stakeholders, the Utah Water Research Lab and AggieAir Service Center
- Research the ability of the GreatBlue aircraft and payload to implement real-time spatial data processing (mapping).

Informational Resources

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

Publications:

Givens, M. and C. Coopmans (2020). Exploring the Use of Reverse Thrust in a Dynamic UAS Landing Maneuver Using Kinodynamic RRT. In *2020 International Conference on Unmanned Aircraft Systems (ICUAS)*.

Aboutalebi, M., A.F. Torres-Rua, W.P. Kustas, H. Nieto, C. Coopmans, and M. McKee (2019). Assessment of different methods for shadow detection in high-resolution optical imagery and evaluation of shadow impact on calculation of NDVI, and evapotranspiration. *Irrigation Science*, 37(3), 407–429. https://doi.org/10.1007/s00271-018-0613-9

Aboutalebi, M., A. Torres-Rua, and N. Allen, (2018). Spatial and Temporal Analysis of Precipitation and Effective Rainfall Using Gauge Observations, Satellite, and Gridded Climate Data for Agricultural Water Management in the Upper Colorado River Basin. *Remote Sensing*, 10(12), 2058. https://doi.org/10.3390/rs10122058.

Aboutalebi, M., A.F. Torres-Rua, M. McKee, W.P. Kustas, H. Nieto, M.M. Alsina, and N. Dokoozlian (2019). Incorporation of Unmanned Aerial Vehicle (UAV) Point Cloud Products into Remote Sensing Evapotranspiration Models. *Remote Sensing*, 12(1), 50. https://doi.org/10.3390/rs12010050.

Nassar, A., A. Torres-Rua, W. Kustas, H. Nieto, M. McKee, L. Hipps, and N. Dokoozlian (2020). Influence of Model Grid Size on the Estimation of Surface Fluxes Using the Two Source Energy Balance Model and sUAS Imagery in Vineyards. *Remote Sensing*, 12(3), 342. https://doi.org/10.3390/rs12030342.

Websites: https://aggieair.usu.edu.

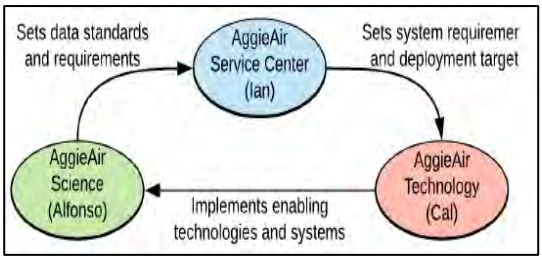
Development of an Unmanned Aerial Vehicle (UAV) Application Center at Utah State University, Utah Water Research Laboratory, UT

Principal Investigators:
Ian Gowing
Shannon Syrstad
Alfonso Torres-Rua

Partners/Collaborators:
- *State: BLM, Natasha Hadden, UDWR, Dan Keller*
- *Local: Dr. Neil Allen*
- *Federal: USDA, Dr. Jon Koch*

Project Description:

- **Need and Purpose:**



AggieAir Structure

The AggieAir Service Center https://uwrl.usu.edu/aggieair/uav-service-center/index is a critical turnkey solution by the Utah Water Research Laboratory for data collection logistics, sensor requirements, sensor and system integration, and data processing. The funding from this project has enabled the application center to explore, develop, and refine new remote sensing and photogrammetric techniques and protocols to enhance the processing of our remotely sensed data. This has been emphasized in a current research project where AggieAir is assessing white tailed prairie dog (WTPD) habitat from high-resolution imagery. Here we are applying a novel 'Deep Learning' technique to distinguish active WTPD burrows from non-active and surround grassland/scrublands. The application center continues to review new technological developments in unmanned aerial vehicles (UAV), sensor development and requirements, and remote sensing applications to be more cost effective and competitive in the open market, and, specifically, new developments that can set AggieAir apart from other UAV centers. One such development identified by AggieAir was the 'Propeller Areopoints', a new self GPS-ing aerial target that has significantly reduced overall deployment and post-processing costs to allow for highly accurate post-processing of all aerial imagery.

- **Benefits to the State:**

This project benefits the state of Utah in that by allowing the application center to provide a highly competitive, cost-efficient remote sensing application services to assess remote sensing demands, within Utah and beyond, by directly applying the most up-to-date remote sensing techniques and technology to assess most remote sensing requirements.

- **Geographic Areas:**

Study Areas: Cache valley including Cache Junction, Wellsville, Vernal, Green river, Modena, and USDA Bee Station UT.

Areas Benefited: Agricultural regions, bee studies, river corridors, and any region that is flown with AggieAir technology are all indirectly affected and benefitted.

- **Accomplishments:**

  This project has allowed personnel within the AggieAir Service Center to invest time and effort to research new technological developments and new remote sensing and photogrammetric techniques, which has resulted in the implementation of cost-effective procedures, including the purchase of Propeller Aeropoints aerial targets and a new multi-spectral camera. The service center has already realized significant cost reductions due to the purchase of these products. The state-of art camera allows AggieAir to collect extremely high-resolution multi-spectral imagery that can now be processed as one camera, which significantly reduces time and cost.

Data collection over white tailed prairie dog habitat, Vernal, Utah

Micasense Altum camera sensor

Propeller aeropoints aerial targets

Work Plan FY20/FY21

The AggieAir Service center will continue to research all new developments in remote sensing and photogrammetric techniques to remain at the forefront of remote sensing and UAV research.

Informational Resources

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

Websites: https://uwrl.usu.edu/aggieair/uav-service-center/index.

Use of sUAS for Mapping Wetland Flow Paths and Consumptive Use on the San Rafael River, Utah

Principal Investigators:
Alfonso Torres-Rua
Ian Gowing
Ayman Nassar (PhD Student),
Mahyar Aboutalebi (PhD Student)

Partners/Collaborators:

- ***State**: Dan Keller, Utah Division of Water Resources*

Project Description:

- **Need and Purpose:**

Tamarisk (Tamarix spp.) is a common invasive vegetation species that has colonized river floodplains throughout the western US. It began to invade Utah's he San Rafael River in the 1950s. While eradication efforts have been largely successful in limiting its spread, tamarisk has proven to be resilient due the amount of time between eradication efforts (2 to 3 years), which allows Tamarisk to develop again. Utah water agencies have concerns regarding riverbank morphological (flow paths) changes and consumptive water use relative to the current need for river restoration because of the drastic changes in flow paths from Tamarisk eradication (burning), bank erosion, and soil displacement, . Limited information is available regarding the actual consumptive water use (daily and seasonal) by these invasive plants. Current unmanned aerial technologies can help to achieve both purposes proposed in this project: (1) monitoring flow paths and invasive vegetation and (2) water use and impact on wetland flow paths from this invasive species. In addition, this project demonstrates the use of unmanned aerial technologies by water managers and policymakers for water management challenges and efforts in Utah.

San Rafael River

- **Benefits to the State:**

This project benefits the State of Utah by (1) documenting current conditions (occurrence, status, extension) of Tamarisk in a section of the San Rafael River where active eradication is in place, (2) identifying and assessing the changes in river and streams due to the occurrence of the invasive vegetation, 3) Mapping the current native vegetation conditions, and 4) determining consumptive water use of Tamarisk and native vegetation, all of which will allow state water managers to continue and adapt management strategies currently in place.

Data collection and the drone used in this study

- **Geographic Areas:**

Study Areas: The study area is located south of the intersection of San Rafael River and State Route 24 (38.839615°N, 110.351545°W).

Areas Benefited: River corridors and streams across the state of Utah indirectly benefit from the project.

- **Accomplishments:**

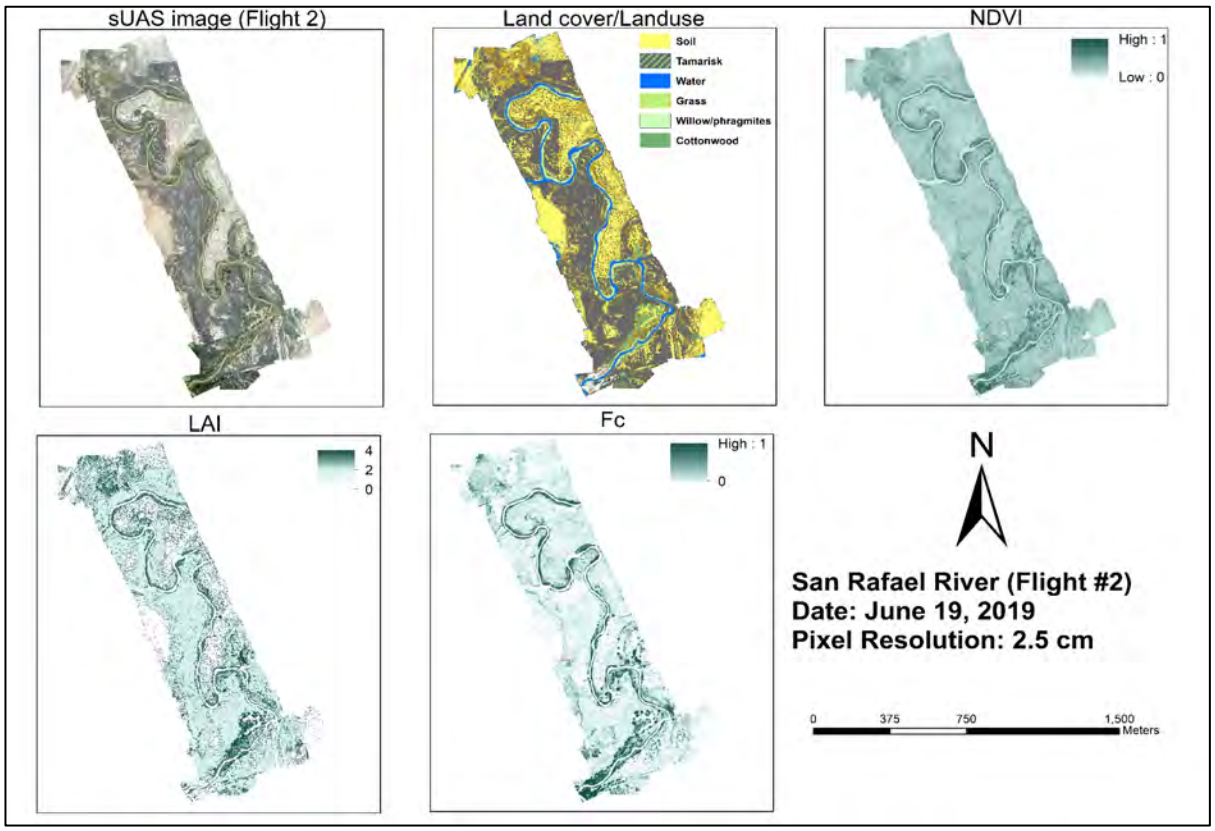
  An example of drone information from the Utah State University AggieAir UAV Program and initial results are presented in the figure below. The combination of aerial information and ground samples facilitates the generation of maps for land cover, vegetation status, (NDVI), biomass quantification (Leaf Area Index – LAI), and soil vs. vegetation occurrence (fractional cover). These initial results will be used for a more detailed analysis of geomorphology, changes in native vegetation and Tamarisk, as well as consumptive water use in the river corridor.

Work Plan FY20/FY21

This project is at the analysis stage and will be completed during FY 20–21. Upon completion, analysis results will be disseminated in publications, academic conferences, and within the Division of Water Resources.

Informational Resources

Contact: Dr. Alfonso Torres-Rua, Telephone: (435) 797 0397, E-Mail: alfonso.torres@usu.edu.



Initial results from drone imagery for a section of the area of study (Top left, drone imagery, top center land cover, top right vegetation status, bottom left biomass, bottom center, soil / vegetation occurrence)

Water Resources

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

Project Name	FY2020 Actual Expenditures	FY2021 Budgeted Expenditures	FY2022 Planned Expenditures
Characterizing Streamflow and Temperature Patterns to Assess Impacts of Summer Depletion on the Blacksmith Fork River	$ 46,644	$ -	$ -
Evaluating National Water Model Snow Components	$ 71,460	$ 64,990	$ 66,940
Impacts of Beaver Dams on Stream Hydrology, Temperature, and Geomorphology	$ 16,145	$ -	$ -
Logan City Stormwater Monitoring	$ 21,785	$ 22,507	$ 23,182
Logan River Observatory	$ 32,233	$ 22,507	$ 23,182
Logan River Watershed LiDAR	$ 16,147	$ 22,507	$ -
Managing and Modeling the Colorado River for an Uncertain Future	$ 12,573	$ 19,753	$ 20,345
Quantification of Groundwater Influences in High-Gradient Utah Streams and Rivers	$ 36,449	$ 22,507	$ 23,182
Targeted Water Conservation	$ 32,472	$ 19,752	$ 20,346
The Future Hydrology of the Colorado River BasinThe Future Hydrology of the Colorado River Basin	$ 59,122	$ 64,990	$ 66,940
Weber Basin Drought Vulnerability Study	$ 12,573	$ 19,753	$ 20,345
Designated Projects		$ 34,461	$ 58,677
Undesignated Projects		$ 115,535	$ 85,940
Total	**$ 357,603**	**$ 429,262**	**$ 409,079**

Characterizing Streamflow and Temperature Patterns to Assess Impacts of Summer Depletion on the Blacksmith Fork River

Principal Investigators:
Belize Lane
Bethany Neilson
Sarah Madison Alger (MS Student)

Partners/Collaborators:
- ***Local****: Nibley City, UT*
- ***State/National****: Trout Unlimited*

Project Description:

- **Need and Purpose:**

  As one of the driest and fastest growing states, Utah faces a critical challenge in identifying how limited and increasingly uncertain water resources can be more efficiently allocated to meet human and environmental water needs. For example, northern Utah trout populations can take years to recover from a hot dry summer when irrigation diversions dewater lowland river reaches. Understanding how stream temperature and flow are altered by distributed irrigation diversions and seepage return flows is fundamental to predicting temperature changes under different water management practices and the ecological consequences of these changes.

- **Benefits to the State:**

  The focus of this project is to improve integrated freshwater management in Utah, particularly in lowland agricultural regions downstream from mountain canyons. We are monitoring trends in streamflow, groundwater exchange, and stream temperature over three summers to improve understanding of the combined roles of climate and irrigation activities in stream temperature trends. This in turn will allow us to assess tradeoffs between water uses and propose solutions that support both irrigators and fisheries. It also provides a detailed monitoring dataset to inform early water banking efforts following passage of the Utah Water Banking legislation this year.

- **Geographic Areas:**

  Study Areas: Lower Blacksmith Fork River, Nibley, UT

  Areas Benefited: This research will directly benefit Nibley, and the information gained and methods developed should be applicable the all of the lowland irrigated streams and rivers in Utah.

- **Accomplishments:**

  This research helped determine how river flow and temperature vary in the summer due to major diversions below the canyon mouth in a typical intermountain irrigated river valley. Results indicate that, during dry water years when flows are very low, small inflows from springs and irrigation seepage have a large impact on the amount of water in the channel and the temperature of that water. These return flows can cool the stream and help fish survive in otherwise excessively warm low flow conditions, particularly when riparian shading is limited.

Figure 1. High inter-annual climate variability can lead to depleted or fully dewatered valley streams in dry years, when remaining streamflow is diverted for irrigation. Improved monitoring of hydrologic fluxes including return flows and irrigation seepage will help better manage these streams for humans and river ecosystems.

Work Plan FY20/FY21

This project will not continue in FY20/FY21 due to funding limitations.

Informational Resources

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

Publications:

Alger, S., B. Lane, and B. Neilson (In preparation). Summer stream temperature patterns in an arid irrigation depleted stream. *Hydrologic Processes*.

Evaluating National Water Model Snow Components

Principal Investigators:
David G. Tarboton
Irene Garousi-Nejad (PhD Student)

Partners/Collaborators:
- *David Gochis, National Center for Atmospheric Research*

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. Snow water equivalent, or SWE, is the amount of water in the snowpack quantified as the depth of water that would result if the snowpack were to melt. This study is evaluating the strengths and limitations of the NWM snow representation by comparing its output against observations made at Snow Telemetry (SNOTEL) sites 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 predominant 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 that is providing forecasts at many more locations than those forecast by the River Forecast Centers. However, questions exist 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. This work aims to improve our capability to model snowmelt, the major source of water in the state that 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.

- **Geographic Areas:**

  Study Areas: The study area is the semi-arid Western U.S., which includes all of Utah.

  Areas Benefited: Streamflow and snowpack in watersheds throughout Utah are forecast by the NWM, and improved forecasts and a better understanding of the sources of uncertainty in NWM snow process representations will benefit water suppliers and users.

- **Findings/Results:**

  In 2019, NCAR made available its National Water Model v 2.0 Reanalysis output. This is a 25-year run of the NWM using observed rainfall as input with other required meteorological input fields from a weather reanalysis dataset (https://ral.ucar.edu/projects/supporting-the-noaa-national-water-model). A retrospective model run may be used to evaluate how well a model performs in comparison to historical data, and we undertook a comparison of the NWM retrospective snow water equivalent against observed snow water equivalent at 737 SNOTEL stations across the western US. We also compared the precipitation, air temperature, and elevation used in the NWM with the same quantities at SNOTEL

stations. We found that, while observed and modeled peak snow water equivalent generally compared reasonably well (r^2 = 0.71), a general bias was noted, with modeled SWE less than observed SWE (biased low by about 163 mm). We also found that the precipitation that had accumulated up to the date of the peak, was less in the model, in comparison to observed (biased low by about 140 mm). Thus, bias in the NWM reanalysis precipitation input is likely responsible for some of the under-modeling of SWE. We found no apparent bias due to elevation, but modeled input air temperature is slightly cooler than observed SNOTEL air temperature. This difference is in the wrong direction to explain the SWE bias. We also found that, even in locations where model precipitation inputs are relatively close to observed, there is "under-modeling" of SWE, possibly due to structural model errors.

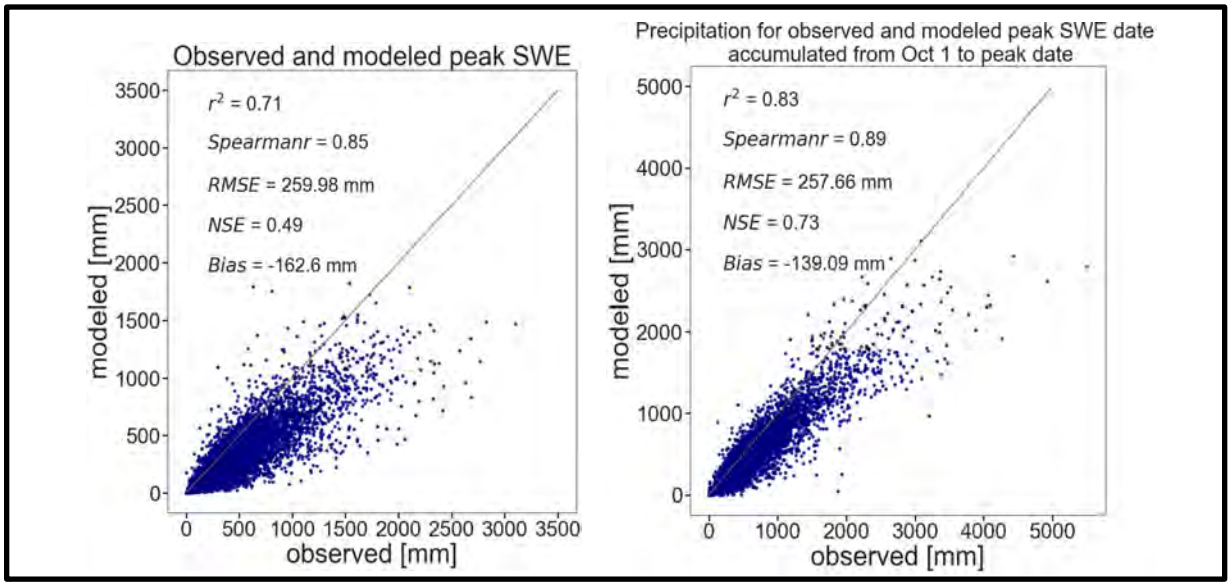
Work Plan FY20/FY21

This research is ongoing, with additional investigation under way to refine understanding the reasons for discrepancies in modeled SWE, and the ramifications of these discrepancies in terms of forecast streamflow. We also plan to evaluate alternative snow model physics, such as encoded in the Utah Energy Balance snowmelt model, for opportunities to improve NWM modeling of SWE. This work is the dissertation research of Irene Garousi-Nejad. A paper describing this work is in preparation for submission to a special issue of the journal *Hydrological Processes* focusing on the National Water Model.

Informational Resources

Contact: Dr. David G. Tarboton, Telephone: (435) 797 3172, E-Mail: david.tarboton@usu.edu.

Publications: Garousi-Nejad, I. and D.G. Tarboton (2020). An assessment of the Strengths and Limitations of the National Water Model Snow Representation against In-Situ Measurements, Remote Sensing Products, and Assimilated Data. *Presentation H121-03 at 2020 AGU Fall Meeting*, Virtual, 11 December, https://agu.confex.com/agu/fm20/meetingapp.cgi/Paper/742234.



Left panel. Comparison of NWM Modeled Snow Water Equivalent (SWE) Peak with SNOTEL Observed SWE peak. These may occur on different dates. Right panel. Comparison of precipitation accumulated from Oct 1 up to the peak date. Each dot represents a year of data and SNOTEL site. This figure shows the bias (under modeling of SWE), in part due to under modeling of precipitation input to the model

Impacts of Beaver Dams on Stream Hydrology, Temperature, and Geomorphology

Principal Investigators:
Bethany T. Neilson

Partners/Collaborators:

- ***Local**: Brad Hunt, Hardware Ranch*
- ***State**: UDFW, UDWR*
- ***Federal**: Brett Roper, USFS*

Project Description:

- **Need and Purpose:**

  Conditions within Curtis Creek changed significantly in 2007 when beaver colonized a 2-km section of the creek. Beaver dams alter channel hydraulics, which in turn change the geomorphic templates of streams. Variability in geomorphic units, the building blocks of stream systems, and water temperature, critical to stream ecological function, define habitat heterogeneity and availability. While prior research has shown the impact of beaver dams on stream hydraulics, geomorphic template, and temperature, the connections or feedbacks between these habitat measures are not well understood. Consequently, questions remain regarding relationships between temperature variability at different spatial scales and hydraulic properties such as flow depth and velocity that are dependent on the geomorphology.

- **Benefits to the State:**

  This research provides a method for understanding the influences of beaver dams on instream processes. This information is critical to the state of Utah, considering the ongoing debate regarding the pros and cons of beaver dams to stream function and what this means in terms of implementation of the current State of Utah Beaver Management Plan.

- **Geographic Areas:**

  Study Areas: Curtis Creek, Hardware Ranch, Cache County.

  Areas Benefited: Because of the broad application of our findings, the entire State of Utah could potentially benefit.

- **Accomplishments:**

  In prior work detailed in Majerova et al. (2015), Stout et al (2017), and Majerova et al. (2020), we combined detailed discharge and water temperature observations throughout a study reach to demonstrate the impact of beaver dams and beaver dam complexes on temperature and hydrologic responses at different spatial scales. In an effort that considers the longer-term impact of beaver dams at reach scales, Clark (2020) analyzed the full 10 years of data available for this study reach. The original 3 years of data presented in Majerova et al. (2015) showed that an increase in the number of beaver dams generally increased the baseflow discharge and water temperature variations during summer periods. However, longer-term data that represent a larger range of annual flows and different states of dam building and maintenance show that beaver dams only increase baseflow discharge when the dams are relatively young and consistently inundate the floodplain.

As shown in Figure 1, the amount of water gained and lost (ΔQ) over each portion of the study area varies. The upper reach with limited to no beaver dams is primarily losing water, but the lower reach with many beaver dams of different ages experiences variable gains and losses due primarily to dam age and changes in floodplain inundation. When comparing the water temperatures, the increase in lower reach water temperatures becomes greater when more beaver dams are present. However, as shown in previous work, even though there is an overall increase in temperature, these dams create significant temperature variability and increase habitat suitability at smaller spatial scales (Majerova et al. 2020).

Work Plan FY20/FY21

This project is now complete.

Informational Resources

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

Representative Publications:

Majerova, M., B.T. Neilson, N.M. Schmadel, C. Snow, and J. Wheaton (2015). Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream. *Hydrology and Earth System Sciences*, 19, 1–16, doi:10.5194/hess-19-1-2015.

Stout, T.L., M. Majerova, and B.T. Neilson (2017). Impacts of beaver dams on channel hydraulics and substrate characteristics in a mountain stream. *Ecohydrology*. 10:1 (e1767). doi: 10.1002/eco.1767.

Majerova, M., B.T. Neilson and B. Rope. (2020). Beaver dam influences on streamflow hydraulic properties and thermal regimes. *Science of the Total Environment*. 718, 134863. https://doi.org/10.1016/j.scitotenv.2019.134853 .

Clark and R. Timothy (2020). *Impacts of Beaver Dams on Mountain Stream Discharge and Water Temperatur*e. All Graduate Plan B and other Reports. 1485. https://digitalcommons.usu.edu/gradreports/1485.

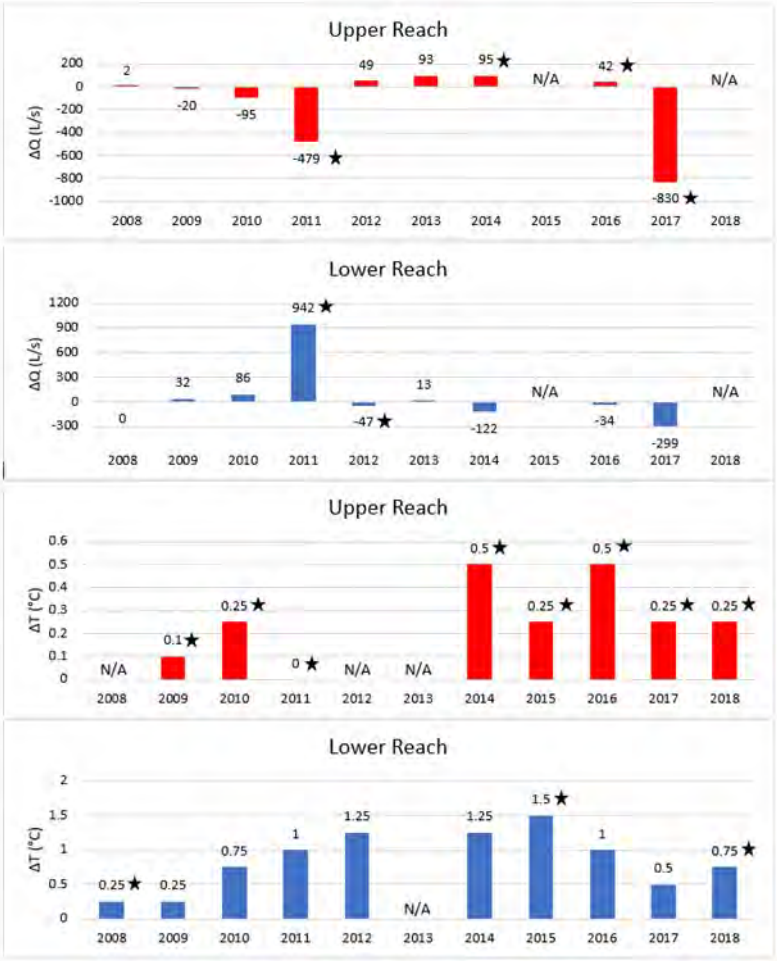


Figure 1. Average flow gains/losses and water temperature increases in an upper (without beaver dams) and lower reach (with variable number of beaver dams over time) averaged over July 1 to October 1 for each year. Temperature data in the lower reach were unavailable in 2013 and in the upper reach in 2008, 2012, and 2013. Note: Averages with stars are partial datasets.

Logan City Stormwater Monitoring

Principal Investigators:
Bethany T. Neilson
Jeff Horsburgh

Partners/Collaborators:

- ***Local****: Logan City, Paul Lindhart, Bill Young*

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 drains. Because of the historical role of agriculture in this area and the presence of irrigation canals within the city, Logan City's stormwater collection system was designed to collect stormwater in irrigation canals, which then convey stormwater downstream to Cutler Reservoir. This combined use system is 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 computer information systems for data management, and dissemination protocols we have developed can be adapted as needed to ensure these approaches can be transferred to other small cities across Utah.

- **Geographic Areas:**

  Study Areas: Canals within Logan City.

  Areas Benefited: Logan City and Cache County.

- **Accomplishments:**

  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 have coordinated with Logan City's flow structure installation at these locations and installed continuous monitoring equipment and telemetry capabilities. We have also installed storm-monitoring equipment at these locations and at the Utah Water Research Laboratory (UWRL) Logan River Observatory station. We have continued to collaborate with Logan City to address some key issues with flow measurements at the South Benson canal location and further implement a sampling and analysis plan for both continuous sensor data and discrete water quality samples (baseline and storm event sampling).

  We continue to work with Logan City to analyze monitoring results (see Figure 1) and determine future monitoring efforts that will develop advanced understanding of hydrologic and water quality processes within Logan City.

Work Plan FY20/FY21

We will continue to 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.

Informational Resources

Contact: Dr. Bethany T. Neilson, Telephone: (435) 797 7369, E-mail: bethany.neilson@usu.edu.
Dr. Jeff Horsburgh, Telephone: (435) 797 -2946, E-mail: jeff.horsburgh@usu.edu.

Datasets: Data are available for this work at the following links:

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

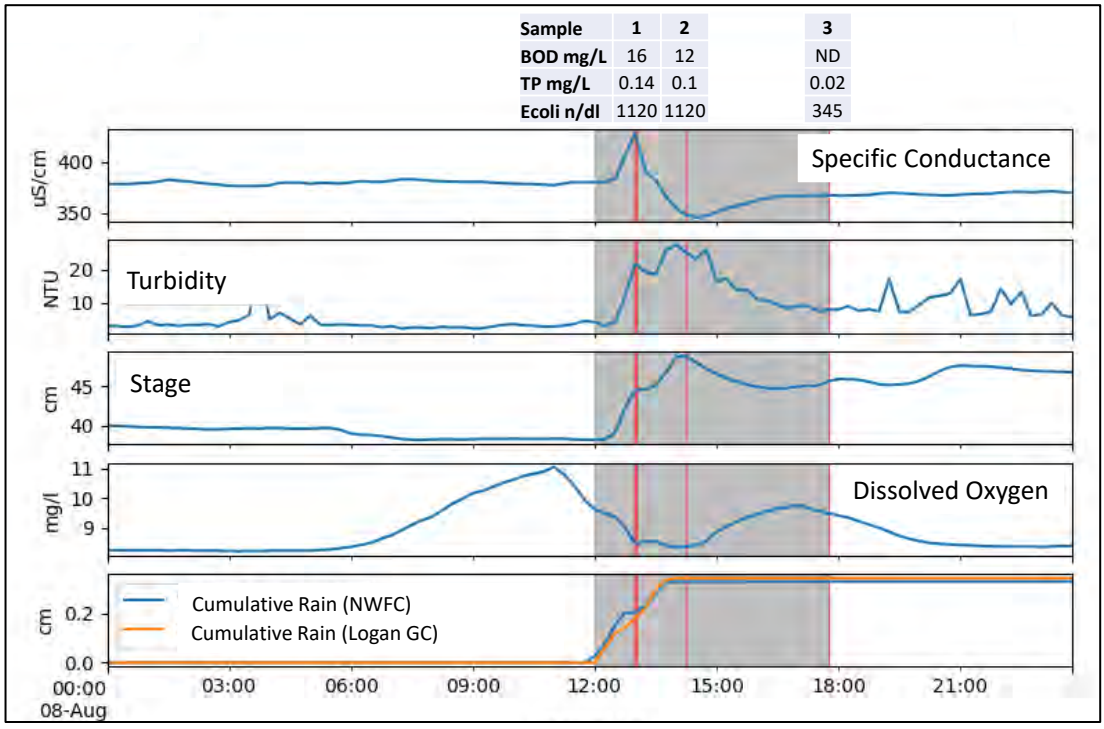


Figure 1. Northwest Field Canal (NWFC) continuous data and the water quality grab sample timing (shown as vertical lines) during a 2019 storm event. Laboratory analysis results are shown in the table above the plots. BOD = Biochemical Oxygen Deman. TP = Total Phosphorus. Ecoli = Escherichia coli

Logan River Observatory

Principal Investigators:
Bethany T. Neilson
Jeffery S. Horsburgh
Patrick Strong

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*

Project Description:

- **Need and Purpose:**

  The Logan River Observatory (LRO) monitoring network, originally established as part of a $20 million National Science Foundation EPSCoR project, has expanded to become one of the most highly instrumented watersheds in the United States, currently comprising many river flow, real-time water quality, and weather stations. This infrastructure and the associated data collected and produced provide an opportunity for Utah to lead the country in water-related research and in the development of innovative water management approaches in water-scarce regions. The Observatory integrates research, teaching, and the involvement of community member and local and state government entities to support the critical water-related management decisions now facing the State of Utah.

- **Benefits to the State:**

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

  The LRO meets many identified needs in 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. The data also inform Logan City's stormwater management efforts. These data provide information necessary for the Cache County Water Conservancy District to meet their mission of protecting and managing water resources in Cache County. Utah State University uses the LRO infrastructure and data for teaching, research, and K-12 outreach. All LRO data are available to the public for free online.

  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) a CEE Senior Design group that is using LRO data and working with the Cache County Water Conservancy District to determine the feasibility of a future water development project in a tributary to the Logan River; (2) working with Logan City to determine potential changes to the

spring flow rate throughout the Logan River watershed and its relationship to their primary drinking water spring; (3) working with the Logan River Task Force to determine scientifically informed methods for invasive tree removal in the lower Logan River riparian zone while maintaining instream temperatures; and (4) future work with various Logan River stakeholders to determine appropriate minimum instream flow rates needed to maintain instream temperatures when redesigning a primary diversion structure.

- **Geographic Areas:**

  Study Areas: Logan River watershed

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

- **Accomplishments:**

  We have improved, maintained, and even relocated LRO sites to continue informing ongoing management and research projects. We have obtained 0.5-m resolution LiDAR data in the mountainous portion of the Logan River to ensure a complete data set for this watershed. We have also maintained and updated the LRO website (https://LRO.usu.edu) to ensure that we meet the needs of end users, refined QA/QC procedures to provide quality controlled data with a shorter lag time, and provided real-time flow data within the time series analyst (http://lrodata.usu.edu/). Many faculty, staff, and students (https://uwrl.usu.edu/lro/people/index) 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 and to leverage the data for ongoing proposal development.

Work Plan FY20/FY21

During the coming year, we will continue collecting data and refining methods of data collection and dissemination. We will also continue to support various proposals under development that will focus research efforts in the Logan River watershed and utilize Logan River Observatory data.

Informational Resources

Contacts: Dr. Bethany Neilson, Telephone: (435) 797 7369, E-Mail: bethany.neilson@usu.edu.
Dr. Jeffery S. Horsburgh, Telephone: (435) 797-2946, E-Mail: jeff.horsburgh@usu.edu.

Publications:

State of the Logan River Watershed (2020).
See https://uwrl.usu.edu/lro/research/projects and https://uwrl.usu.edu/lro/research/publications for additional presentations and publications.

Websites: https://LRO.usu.edu, https://uwrl.usu.edu/lro/.

Logan River Watershed LiDAR

Principal Investigators:
Bethany T. Neilson
Patrick Strong

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*

Project Description:

- **Need and Purpose:**

  Snow recharged karst aquifers are the primary source of municipal and agricultural water supply in many mountainous areas including Northern Utah. Logan City relies on karst springs for drinking water, and groundwater discharge to the Logan River is the primary water source for irrigation. Projected variability in climate may result in shifting patterns of snow and rain, thus creating uncertainty in water resource sustainability. Effective water resource management and planning needs to be informed by an assessment of climate change implications for karst mountain watersheds. Thus, there is a clear need for better data regarding snow distributions and to support predictive tools that provide insight regarding watershed response to shifting patterns of temperature and precipitation.

- **Benefits to the State:**

  As part of Logan River Observatory (LRO), the Logan River watershed has been instrumented longitudinally from mountain unimpacted areas to urban areas with flow gaging stations, multi-probe water quality sondes, and weather stations. This LiDAR data will complement the climatic, hydrologic, and chemical data collected in preceding and ongoing efforts. The resulting detailed topography and land cover information provided by LiDAR will allow for detailed hydrologic studies to be conducted. These data can more specifically provide: insight into methods for identifying sink holes that drive hydrologic responses within the basin; information regarding canopy cover, density, and evapotranspiration; and detailed information that can be used to support snow and other hydrologic modeling efforts. Additionally, these data are foundation for a collaborative snow-on LiDAR flight that will be used to further understand and predict snow distributions within the highly complex mountainous terrain in Logan Canyon. Together with other ongoing research in the Logan River watershed, these data will inform efforts assessing the resiliency of water resources in Northern Utah and other snow-recharged karst mountainous regions.

- **Geographic Areas:**

  Study Areas: Logan River watershed.

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

- **Accomplishments:**

  LRO staff and students installed and surveyed control points (Figure 1) necessary for calibrating the LiDAR data and producing the bare-earth and first-return DEM. The data from the LiDAR flight (Figure 2) are currently being processed.

Figure 1. Example of a control point

Work Plan FY20/FY21

During the coming year, we will support the snow-on LiDAR data collection (Figure 3). Once the bare-earth and first return DEMs are complete, we will work to get these data posted on open access platforms.

Informational Resources

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

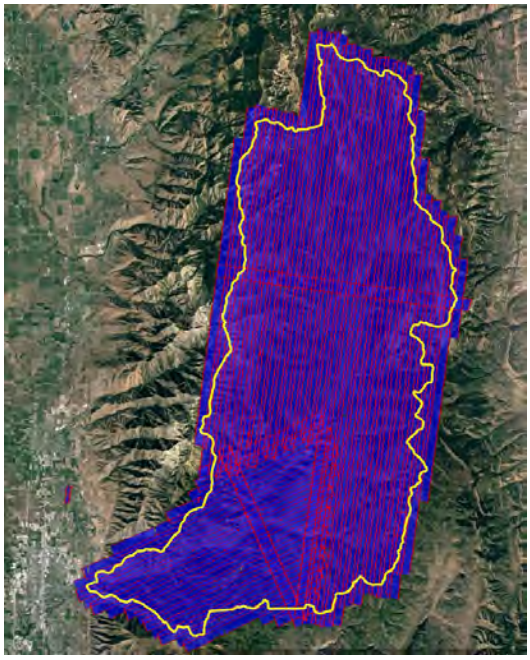


Figure 2. LiDAR flight lines for the Logan River watershed

Figure 3. Control points with marking posts for snow-on LiDAR

Managing and Modeling the Colorado River for an Uncertain Future

Principal Investigators:
David E. Rosenberg,
John (Jack) Schmidt, Watershed Sciences
Moazzam Rind (Student)
Jian Wang (Post-Doc Researcher)

Partners/Collaborators:
- ***Federal**: Clayton Palmer, Brent Oseik, Western Area Power Administration; Theodore Kennedy, USGS*
- ***Business/Industry**: Kevin Wheeler, Water Balance Consulting*

Project Description:

- **Need and Purpose:**

  Colorado River stakeholders face many uncertainties—issues like climate change, future water demand, and evolving ecological priorities. Managers and stakeholders need new ways to help classify uncertain conditions, manage for uncertain conditions, and create models in the face of oncoming uncertainties.

- **Benefits to the State:**

  This work distinguishes four levels of decision-making uncertainty to help Colorado River and other stakeholders think about, talk about, and better manage the future river (Figure 1). Some future conditions can be described by point estimates with small ranges, such as predicting short-term rainfall (Level 1). Some can be described by probabilities, such as next year annual flow (Level 2). Other future hydrologic, aquatic ecosystem, and demand conditions can only be described by scenarios of alternative possible futures (Level 3). Other future conditions are completely unknown (Level 4). This work also identifies tradeoffs between Glen Canyon Dam operations that generate hydropower and make steady low releases in the face of uncertain monthly release volumes and energy prices. Steady low flows help aquatic invertebrates lay and hatch eggs. Aquatic invertebrates are an important food base for native and sport fish.

- **Geographic Areas:**

  Study Areas: Portions of Daggett, Duchesne, Uintah, Carbon, Emery, Grand, Wayne, Garfield, Kane, and San Juan counties, Utah within the Colorado River basin. Also portions of Wyoming, Colorado, New Mexico, Arizona, California, and Nevada.

  Areas Benefited: Municipal and agricultural water providers throughout Utah.

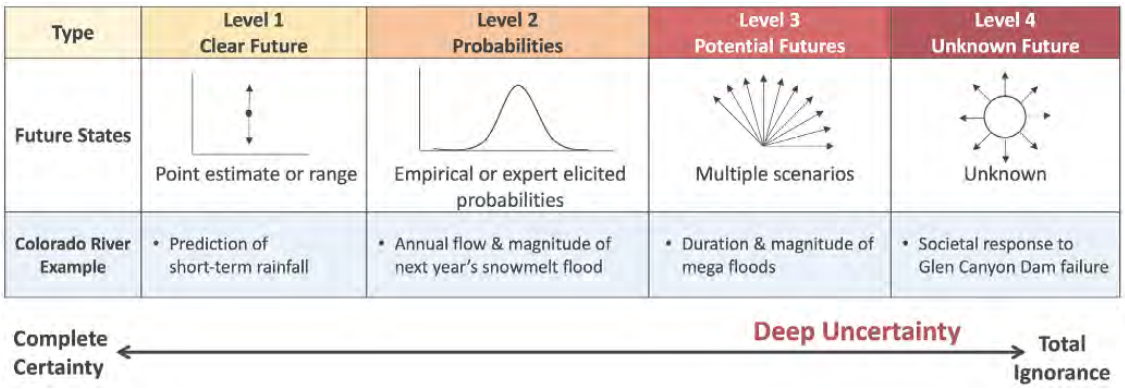


Figure 1. Classify uncertainty levels from complete certainty to total ignorance, with examples

- **Accomplishments:**
  - Using modeling and management approaches appropriate to the uncertainty level. For example, we use reservoir simulation or rules of thumb when uncertain future conditions are described by a narrow range (Level 1) and scenario planning, decision scaling, and dynamic adaptive policy pathways if scenarios are needed to describe possible future conditions (Level 3).
  - We follow suggested practices to manage for deeply uncertain conditions (Box 1).
  - Example finding: Each added weekday of steady low Glen Canyon Dam release above 8 weekend days will lower monthly hydropower revenues by $62,750 (Figure 2). Larger monthly release volumes shift tradeoff curves right to larger hydropower revenues.

Box 1. Suggested practices to manage for deeply uncertain future conditions

1. Classify uncertainties by level.
2. Define signposts to signal when future water supply and ecosystem outcomes deteriorate.
3. Construct potential pathways to connect signposts and alternative policies over time.
4. Store water in reservoirs towards end of planning horizon to save for future generations.
5. Seek policies that improve outcomes across more future scenarios, rather than best policies.

Work Plan FY20/FY21

- Finish validating an exploratory model for Lake Powell and Lake Mead.
- Build modeling tools to identify signposts, simulate, and improve adaptive policies.
- Identify tradeoffs between number of days of steady release, hydropower revenues, and annual release volume.

Informational Resources

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

Websites: Wang et al (2020). Managing the Colorado River for an Uncertain Future. http://qcnr.usu.edu/coloradoriver/files/CCRS_White_Paper_3.pdf.

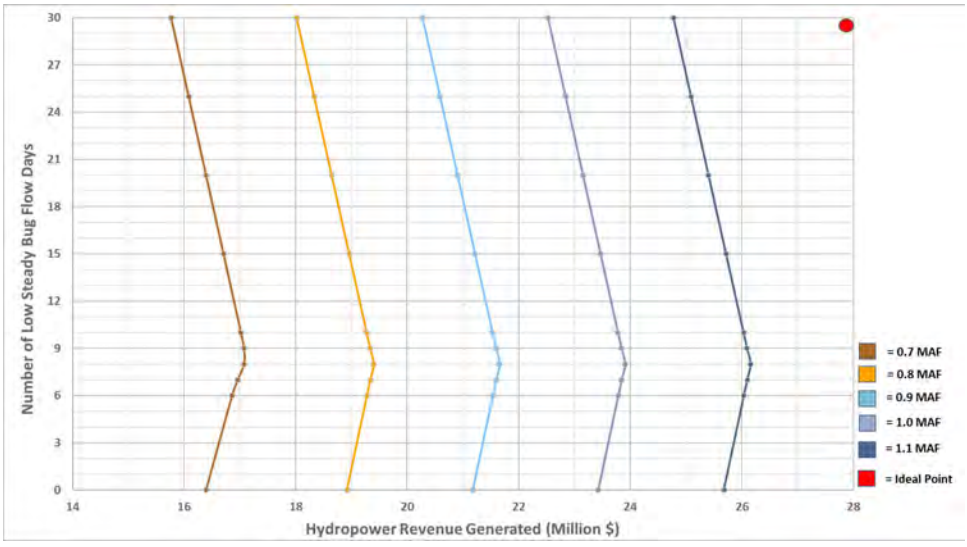


Figure2. Tradeoff between Glen Canyon Dam hydropower revenue, monthly release volume, and number of days of steady, low releases good for aquatic invertebrates to lay and hatch eggs

Quantification of Groundwater Influences in High-Gradient Utah Streams and Rivers

Principal Investigators:
Bethany T. Neilson
Tianfang Xu
Belize Lane

Partners/Collaborators:

- ***Local**: Logan River Observatory, Cache Water District, Logan City*
- ***State:** USGS Utah Water Science Center, Utah Division of Water Resources*
- ***Federal**: National Science Foundation, USGS*

Project Description:

- **Need and Purpose:**

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

- **Benefits to the State:**

  The overall focus of this research is to analyze existing flow and chemical data collected throughout northern Utah streams. The study aims to quantify groundwater influences in pristine mountainous and human impacted urban portions of each watershed. Detailed flow, temperature, and chemistry data have been gathered in the Logan River starting in 2014 and in the Blacksmith Fork starting in 2018 over various spatial scales and flow conditions. These data are available along the main-stem as well as tributary inflows and diversions. In the Logan River, many sampling efforts collected both chemical and flow data to combine flow and chemical mass balances and estimate groundwater contributions to surface water. Time series data from a subset of locations in each watershed also provide fundamental information regarding temporal variability of exchanges. The results of this research will contribute to better management of local water quantity and quality.

- **Geographic Areas:**

  Study Areas: Logan River, Logan, UT and Blacksmith Fork, UT

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

- **Accomplishments:**

  Tennant et al. (2020) established new methods for determining surface and groundwater flow sources and quantities contributing to the urban and agricultural portions of the Logan River during summer, low flow conditions. This research builds upon previous accomplishments (methods, and data collection in flow, chemistry and temperature) that used flow and mass balances to quantify karst and matrix groundwater in gaining, losing, and simultaneously gaining/losing reaches within the upper portion of the Logan River watershed (see Neilson et al. 2018 for details).

  Our efforts further understanding of karst mountain recharge and discharge continue as we investigate the variability in precipitation and snow accumulation throughout the Logan River watershed (see Tyson

2020) and the relationship to flow in the Logan River each year. We are using a combination of different process-based models, machine learning approaches, and field sampling methods to understand linkages between snow and river baseflow. An NSF proposal was resubmitted in July to fund future efforts along these lines.

In the Blacksmith Fork, we continued to collect flow and temperature data to determine how irrigation canals influence groundwater recharge to dewatered sections of rivers below diversions. We have found that groundwater seeps linked to adjacent canal systems that recharge shallow groundwater are critical to maintaining temperatures in river sections below irrigation diversions (Alger 2020). An additional NSF proposal was submitted in March to fund future efforts along these lines.

These unique approaches and data sets provide multiple methods for understanding complicated groundwater interactions in karst mountain watersheds, complex urban area influences on rivers, and rivers dewatered by irrigation divers. Twenty-five conference and seminar presentations about these findings have also been given. Over the last year 3 PhD and 3 MS students have been working on various aspects of these projects.

Work Plan FY20/FY21

Multiple journal articles are in progress based on these efforts. Two MS students defended theses this summer. Their theses will be finalized and one additional MS student will defend. Another student is starting MS work and plans to focus on analyzing the hydrologic responses of the Logan and Blacksmith Fork rivers to changes in precipitation and snow patterns. Additional work has been requested by the Logan River Task Force to support decision making in urban and agricultural portions of the Logan River.

Informational Resources

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

Publications:

Alger, S.M. (2020). *Controls on Summer Stream Temperature Patterns in Irrigation-Depleted Streams*. M.S. Thesis. Utah State University, Logan, UT.

Tyson, C. (2020). *Effects of Climate Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed*. M.S. Thesis. Utah State University, Logan, UT.

Targeted Water Conservation

Principal Investigators:
David E Rosenberg
Mahmudur Aveek (MS Student)
Ryan James (MS Student)

Partners/Collaborators:
- ***Other University**: Doug Jackson-Smith, The Ohio State University; Melissa Haeffner, Portland State University*

Project Description:

- **Need and Purpose:**

  Water conservation can help extend limited existing surface and groundwater supplies to accommodate future population growth 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. Initial education and awareness efforts such as "Slow the Flow" have reduced per-capita water use over the last decade, yet it is still unclear what exactly caused the reduced use, whether reductions can persist, which users to target to save the most water, and how to reach users so they act. Targeting exploits differences (heterogeneities) among users and should consider a user's overall water use (rank), behaviors (such as duration of showers or landscape irrigation), installed technologies (such as flow or flush rates of showers and toilets), and opportunities to conserve. Utah water utilities can benefit from better tools to help them group, target, and communicate with customers to reduce use.

- **Benefits to the State:**

  Water conservation projects are helping Utah water providers achieve the state goal of 25% reduction in per-capita water use. Research to target customers with the most potential to conserve can increase water volume saved while reducing water utility program costs and staff time. Households must have a positive attitude, support from peers, and opportunities to conserve water. Tools to target users with the most potential to conserve can help utilities plan for droughts or future growth. Using and extending tools to target users can reduce drought costs and decrease the likelihood that customers will face costly cutbacks through droughts.

- **Geographic Areas:**

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

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

- **Accomplishments:**

  Using the Residential End Uses of Water national data set (DeOreo et al, 2016), we compared differences among households in their total, indoor, and individual end uses of water (Figure 1). The top 25% of households by volume consume 45% of total indoor use, 55% of shower water, and 65% of bathtub water. For comparison, income, population, and carbon emissions by country are further skewed. A very small number of countries -- China, the U.S., and India – emitted 49% of global carbon emissions in 2014.

  Many households have opportunities to conserve water through behavior (use appliances less frequently or for shorter duration) and technology (Figure 2).

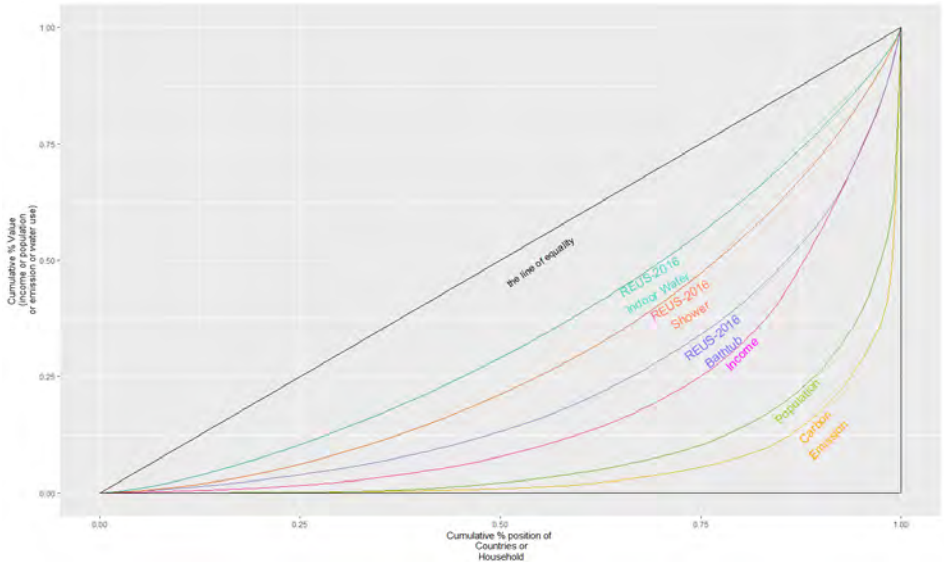


Figure 1. Differences in indoor, shower, and bathtub water use among households and differences in income, population, and carbon emissions among countries. Curves that bend closer to the bottom-right corner show a small number of households or countries use a very large fraction of the total resource. The black line of equity shows the situation where every household or country uses exactly the same amount of the resource

Work Plan FY20/FY21

- Group households by their water use and opportunities to conserve water.
- Develop messages specific to household groups.
- Estimate water saved if households follow messages.

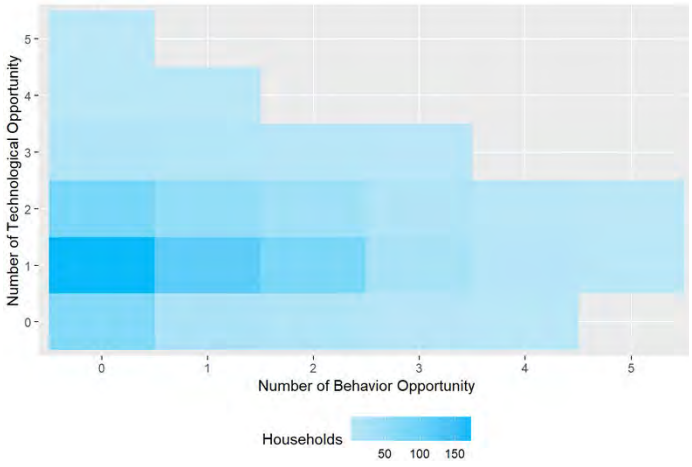


Figure 2. Number of behavioral (x-axis) and technological (y-axis) opportunities households have to conserve water. Darker blue indicates more households

Informational Resources

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

Publications:

James (2019). *Agent-Based Model to manage household water use through social-environmental strategies of encouragement and peer pressure*. Master's Thesis. Utah State University, Logan, UT. https://digitalcommons.usu.edu/etd/7581/.

Datasets: Aveek (2020). Data and Code repository. https://www.hydroshare.org/resource/eb77a88a5bfa4608a361e06b04fcf2ae/.

The Future Hydrology of the Colorado River Basin

Principal Investigators:
David G. Tarboton,
David Rosenberg
Jack Schmidt (Center for Colorado River Studies, and Watershed Sciences, Utah State University)
Homa Salehabadi (PhD Student)
Sara Goeking (PhD Student, Watershed Sciences)

Partners/Collaborators:
- *Eric Kuhn (retired general manager of the Colorado River Water Conservation District),*
- *Brad Udall (Colorado State University)*
- *Kevin Wheeler (Water Balance Consulting)*

Project Description:

- **Need and Purpose:**

  Long-range planning of the water supply provided by the Colorado River requires assessments of the impact resulting from continuation of the current drought that began in 2000, the impact of potentially extreme future droughts, and the long-term and progressive decline in watershed runoff that is caused by a warming climate. Water-supply managers want to know the maximum plausible stresses to water users so that plans for conservation, reservoir operations, and/or construction of new infrastructure can be properly developed. River managers want to know the implications of various water-supply plans on the flow-regime and water-quality characteristics of the Colorado River and its headwater branches in order to develop natural resource management plans that maintain desired attributes of river ecosystems.

- **Benefits to the State:**

  Utah is one of the Upper Basin states included in the Colorado River Basin and has been apportioned a fraction of the Colorado River water under the Colorado River Compact and other elements of the Law of the Colorado River. Utah uses Colorado River water in the Central Utah Project and has planning studies under way for expansion of its Colorado River water use via the Lake Powell pipeline. It is important that these planning efforts consider the full range of droughts plausible in the Colorado River Basin, both due to natural variability and climate change. This study has identified plausible future hydrology drought scenarios for consideration in the planning and management of the Colorado River System to enable the development of management strategies that will secure water supplies and protect ecosystems facing the challenge of severe future droughts.

- **Geographic Areas:**

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

  Areas Benefited: Agricultural and Municipal water users and providers throughout Utah.

- **Findings/Results:**

  We evaluated the record of natural runoff at Lees Ferry based on analysis of historic observations and tree-ring streamflow reconstructions. To evaluate the severity of sustained droughts, we advanced a new methodology based on calculating sequence-average and cumulative depletions relative to the natural flow mean. We identified the most severe droughts of the past 600 years from observed and tree-ring reconstructed streamflow. Three past droughts stand out in the record of prior flows: The millennium drought from 2000 – 2018 (and ongoing), the mid-20th century drought from 1953 and 1977 and the paleo tree-ring drought from 1576 and 1600 that is based on tree ring estimates of streamflow. Guided by the principle that if it has happened in the past, it might happen again in the future, we developed a method for simulating future plausible droughts by randomly selecting sequences of low runoff years from the records of the three severe past droughts identified above based. This approach

assumed that years of low runoff that occurred in the worst of past droughts might occur again in the future, but that the sequence in which these years of low runoff occur in the future might differ from what occurred in the past. We also developed and implemented a scheme to incorporate our estimates of future drought at Lees Ferry into the Colorado River Simulation System (CRSS). This required development of a disaggregation method that estimates conditions at every input node of CRSS, and the results provide a rigorous quantitatively derived set of drought scenario inputs that can be used by any stakeholder proficient in CRSS, or in any other model of the Colorado system, who wishes to analyze current risks or alternative management paradigms that might be useful in confronting future drought. We also provided one example of the stresses that a severe sustained drought would place on the Colorado River system by using the CRSS model and our estimates of future droughts to evaluate 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 when Lake Powell pool elevations would fall below that which is required to produce hydropower. Thus, new strategies and plans will be necessary to confront the challenge of severe future droughts.

Work Plan FY20/FY21

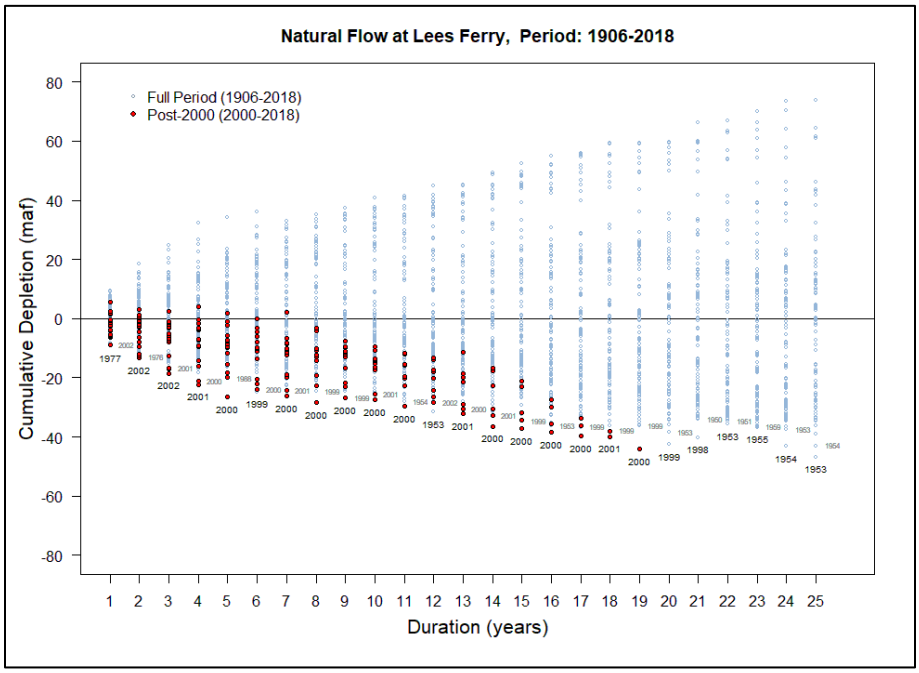
Develop and evaluate the results from alternative management paradigms for the Colorado River System, using the drought scenarios developed. Publish the results in the peer-reviewed literature to establish the credibility of peer review, refining as needed to address peer review comments.

Informational Resources

Contact: Dr. David G. Tarboton, Telephone: (435) 797 3172, E-Mail: david.tarboton@usu.edu.

Publications:

Salehabadi, H., D. Tarboton, E. Kuhn, B. Udall, K. Wheeler, D. Rosenberg, S. Goeking and J. C. Schmidt (2020). *The Future Hydrology of the Colorado River Basin*, Center for Colorado River Studies, White Paper 4, Utah State University, https://qcnr.usu.edu/coloradoriver/files/WhitePaper4.pdf.



Cumulative Depletion plot of natural flow of the Colorado River at Lees Ferry 1906-2018. Each dot represents water year annual flow minus long-term mean summed over the duration. Each dot represents a sequence of the given duration (including overlaps) within the record. Negative numbers in the lower part of the graph depict the amount by which the sum of water year flow was less than the mean, i.e. a depletion. Dot labels indicate the start year of the largest (black) and second largest (gray) depletion. The spread of the dots for each duration characterizes how cumulative depletion may vary for different durations. The 19-year period starting in 2000 accumulates a depletion of close to 40 maf relative to the mean. For the majority of durations, the 2000-2018 period contributes the largest cumulative loss, highlighting the severity of the current drought

Websites: Center for Colorado River Studies, Future of the Colorado River Project, Publications. https://qcnr.usu.edu/coloradoriver/futures

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.

Weber Basin Drought Vulnerability Study

Principal Investigators:
David E. Rosenberg)
Jacob Everitt (Student)

Partners/Collaborators:
- ***Local**: Jon Parry Ashley Nay, Derek Johnson, Darren Hess, Weber Basin Water Conservancy District*
- ***State**: Candice Hasenvager, Scott McGettigan, Utah Division of Water Resources*
- ***Business/Institutions**: Seth Arens, Western Water Assessment; Court Strong, Paul Brooks, University of Utah*

Project Description:

- **Need and Purpose:**

Streamflow, demand, sedimentation in reservoirs, and evaporation from reservoirs are uncertain, and they affect the ability of the Weber Basin Water Conservancy District (WBWCD) to store and deliver water to agricultural and municipal customers. The Utah Water Research Laboratory used a bottom-up approach to identify the individual factors and combinations of factors that influence whether the water system succeeds or fails to meet delivery criteria. The bottom-up approach helps identify key thresholds that tip the system from more vulnerable to less vulnerable states.

The bottom up approach follows six steps (Figure 1). (1) Uncertain streamflow, demand, sediment buildup, and evaporation factors and subfactors are identified. (2) Next, scenarios of possible future states for each uncertain factor are developed. (3) Scenario combinations are simulated using the Utah Division of Water Resources (UDWR) Riverware model for the Weber basin system and a Riversmart extension we developed. (4) Vulnerability criteria are defined and evaluated using the simulation model results. (5) Contour and timeseries plots help to visualize when the water system transitions from performing satisfactorily to unsatisfactorily. (6) Finally, findings are discussed with water system managers.

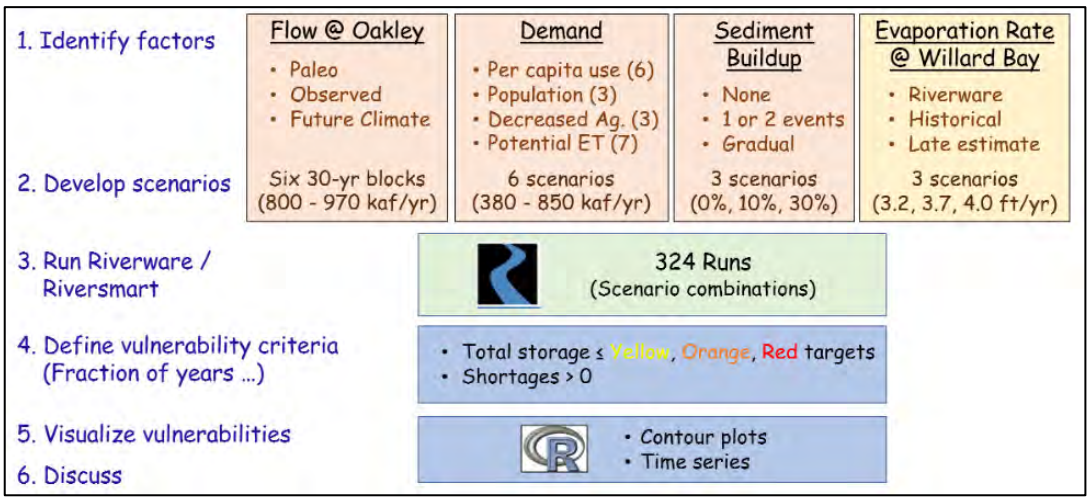


Figure 1. Bottom-up vulnerability method

- **Benefits to the State:**

The project is benefitting Utah by identifying how a major state water system is vulnerable to climate, stream flow, demand, reservoir, operations, and other factors.

- **Geographic Areas:**

  Study Areas: Bear and Weber River basins; Rich, Cache, Weber, Morgan, Summit, Davis, and Box Elder Counties, Utah.

  Areas Benefited: Weber Basin. Methods can also be applied to other basins throughout Utah that are served by large water systems.

- **Accomplishments:**

  Major Findings and Results
  - Strength: The system maintains total reservoir storage above the 380,000 acre-feet moderate (yellow) target defined in the drought contingency plan for historical inflows and demands, no sedimentation, and 3.2 feet per year evaporation from Willard Bay (Figure 2, blue square).
  - Strength: Demands must increase by about 160,000 acre-feet per year and/or inflow decrease by about 80,000 acre-feet per year from historical conditions for total reservoir storage to drop below the 380,000 acre-feet target in 10% to 20% of modeled years (Figure 2).
  - Strength: Reservoir evaporation rates of 3.2 to 4.0 feet per year minimally impact storage.
  - Vulnerability: Reservoir drought contingency plan targets of 380,000, 320,000, and 280,000 acre-foot are violated more frequently when sediment fills 30% of active reservoir storage.
  - Vulnerability: A unit volume reduction in inflow leads to more violations in storage targets than the same unit volume increase in demand.
  - More major findings available at the informational resources listed below.

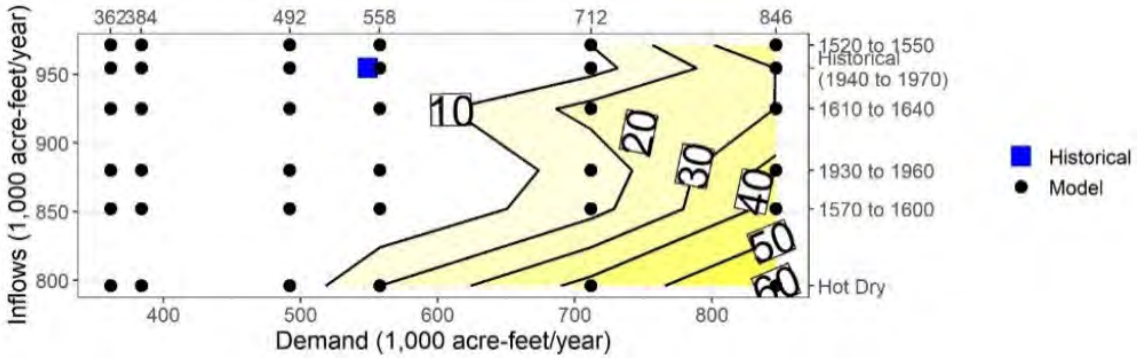


Figure 2. Percent of time (contours) Weber Basin June 1st system storage fell below the moderate drought criteria of 380,000 acre-feet total system storage for different demands (x-axis) and inflows (y-axis) with 0% reservoir sedimentation and 3.2 feet/year reservoir evaporation. Right axes shows years for inflow scenarios

Work Plan FY20/FY21

The Western Water Assessment will include this study as part of a Climate Vulnerability Report given to the Weber Basin Water Conservancy District.

Informational Resources

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

Publications: Everitt, Jacob (2020). Masters thesis. https://digitalcommons.usu.edu/gradreports/1474.

Datasets: Project repository https://github.com/jacobeveritt/WeberBasinVulnerability.

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