

2016 ANNUAL REPORT

Utah Water Research Laboratory



Message from the Director



Mac McKee
UWRL Director

Last year we celebrated the 50th anniversary of the Utah Water Laboratory building dedication and Utah State University's Year of Water. That major milestone led us to look back and recognize the accomplishments of the past, the challenges we have met, and the progress we have made.

One thing that has changed over the years is the way we obtain, process, and manage data. Water resources research and management have become more and more data intensive. Over the next decade, science and engineering research could produce more scientific data than has been created over all of human history. Scientific breakthroughs in the future will depend on the ability of researchers to access, integrate, and analyze these large datasets. Our researchers are developing the computer infrastructure to handle the ever-growing volume of available hydrologic data.

And who could have imagined 50 years ago that we would have computers flying in the sky? Remote sensing has changed the way we approach water resources research. The AggieAir UAV platform, developed right here at the UWRL, allows us to collect scientific-grade multispectral images and other data then use high-performance computing to translate this imagery into information products that support precision agriculture and a host of other applications.

Even with the technological advances of the past 50 years, it has been and will continue to be the hard work and dedication of our students, faculty, and other professionals who make all the research happen. Looking toward the future, the UWRL will strengthen its leadership in the more traditional areas of water research—in fluid mechanics and hydraulics, in water quality and environmental engineering, in water systems analysis and management, and most importantly, in water education—by strategically investing in exciting new fields that will include remote sensing, cyberinfrastructure, information management, and "big data". We expect our next 50 years to be even more exciting than our first 50 years.

This report is only a brief snapshot of the wide range of research ongoing at the UWRL. For more information, please visit our website at:

<http://uwrl.usu.edu/>

Contents

UWRL Year of Water & 50 Year Celebrations.....	4
Project Highlights	5-10
Community Data: Hydrologic research becomes a team sport	6-8
HydroShare's national and local impact	9
AggieAir: 10 years of innovation in hydrologic remote sensing technology.....	10-13
Training the Next Generation of Engineering Experts	14-15
Austin Jensen.....	14
Manal Elarab	15
Focus on Utah.....	16-21
Life on the Edge: Understanding the spread of invasive <i>Phragmites australis</i>	16
Finding Water Waste: Testing the accuracy of Utah's flow management devices	18
Biofiltration: Exploring new ways to protect Utah's drinking water	20
FY 15-16 Financial / Academic Summary.....	22-23



UWRL Year of Water & 50 Year Celebrations

200+

visitors toured 34 displays and demonstrations at 21 stations in 2 buildings and on all 3 floors of the UWRL during the lab's 2015 'Year of Water' Public Open House



The 50th anniversary of UWRL building dedication in 2015 was a wonderful opportunity for us to celebrate our history and past accomplishments. Utah State University celebrated right along with us by designating 2015 as the 'Year of Water' at USU. Departments across campus joined in the celebrations and incorporated a water-related focus for speakers, research, music, art, and other events throughout the year. UWRL students and faculty welcomed many visitors to our facility and shared our passion for water resources and environmental research. Here are just a few highlights from our Year of Water celebrations.

Public Open House

More than 200 visitors toured the UWRL building, where students and faculty presented 34 different demonstrations and displays at 21 stations in 2 buildings on all 3 floors of the UWRL, where visitors were able to learn more about the UWRL's role in supporting water resources research and training in Utah and around the world.

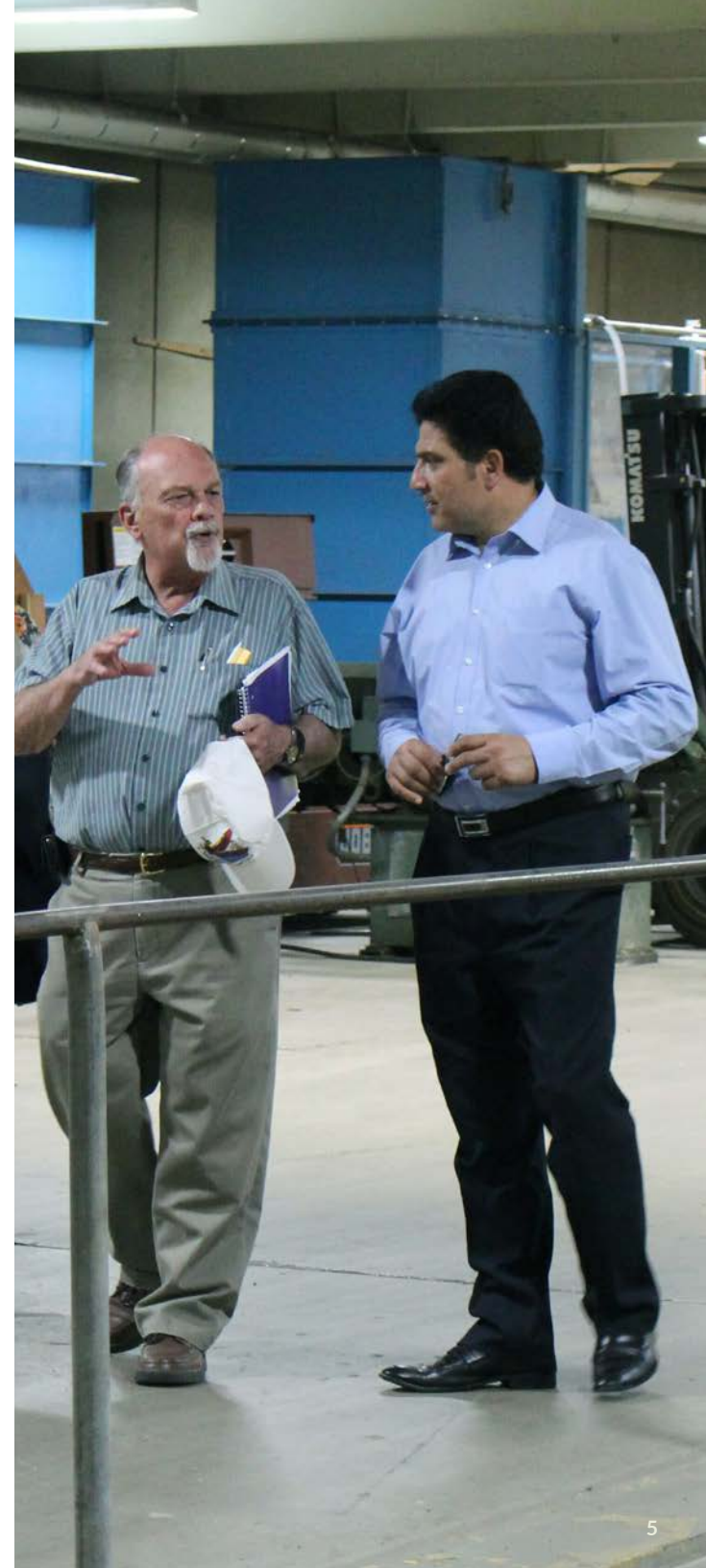
Alumni Get-Together

Alumni and current students gathered for a casual get-together to renew old ties and introduce new research. Some of our alumni were part of our history from the very beginning! The get-together was a great way to celebrate our past and future at the same event.

Other Events

UWRL Director Mac McKee welcomed numerous dignitaries and gave dozens of tours and presentations, including an invited tour for Utah legislators. We were pleased to partner with other USU colleges and departments to celebrate and re-emphasize the vital importance of water to all facets of society and the environment.

Now, as we move forward from this Year of Water into our next 50 years, our view remains solidly on the future of water research. ■



Community Data: Hydrologic research becomes a team sport

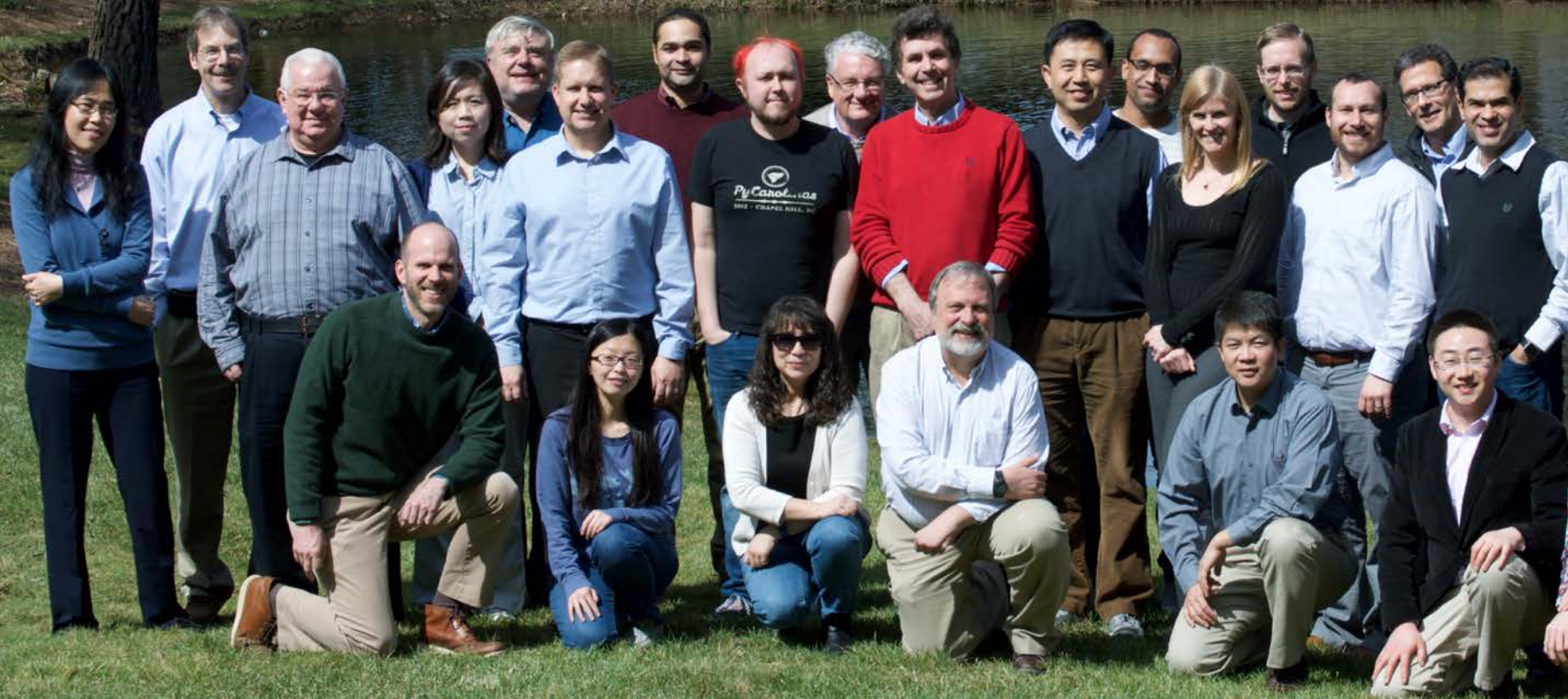




Photo by RENCI

Researchers across the country and around the world expend tremendous resources to gather and analyze vast stores of hydrologic data and populate a myriad of models to better understand hydrologic phenomena and find solutions to vexing water problems. Each of those researchers has limited money, time, computational capacity, data storage, and ability to put that data to productive use.

What if they could combine their efforts to make collaboration easier? What if those collected data sets and processed model outputs could help advance hydrologic understanding far beyond their original purpose?

That is exactly what a group of hydrologic researchers around the country is making possible through development of an Open Source hydrologic cyberinfrastructure platform called HydroShare.

In Search of a Solution

Seven years ago, Dr. David Tarboton and his team recognized the need for a platform that would allow scientists from around the world to upload and store a wide range of hydrologic information from multiple sources that could be shared and integrated to support collaboration, produce new hydrologic knowledge, and advance

11 universities and organizations collaborated to develop HydroShare, an Open Source web based platform for hydrologic collaboration and data management.

hydrologic understanding. Dr. Tarboton led the effort to assemble partners from 11 different universities and other organizations and propose a project to the National Science Foundation's Software Infrastructure for Sustained Innovation (SSI) program that would turn the vision of a web based system for hydrologic collaboration and data management into a practical reality.

The team was well acquainted with the challenges ahead. The continual flow of research data and model outputs from multiple sources would create a data deluge and require sophisticated computing power. The new system would need to incorporate datasets in different formats and ensure sufficient metadata to make the information useful for other applications.



1

Create Data

Collect your data using the same methods you use now. HydroShare supports a broad set of hydrologic data types.

2

Upload to HydroShare

Upload your data files to HydroShare through the web user interface. HydroShare will automatically extract as much metadata as it can from the files you upload.

3

Describe with metadata

Use HydroShare's simple metadata entry forms to finish describing your data so that your colleagues can find, access, and interpret it.

4

Share with colleagues

You choose who has access to the data and models you have uploaded to HydroShare. You can share with individual users or publish your resources for everyone to access.

www.hydroshare.org

Now, seven years later, HydroShare is accomplishing its goal of advancing hydrologic science by enabling the scientific community to more easily and freely share products resulting from their research—not just the scientific publications summarizing a study, but the data and models used to create the scientific publications. HydroShare is open and available to all hydrologic researchers on the internet.

Making It Happen

Each partner organization (see next page for full listing) has contributed valuable

expertise to advance the program's development. The full HydroShare platform is housed and maintained by RENCI at the University of North Carolina, Chapel Hill, and is operated as a facility of the CUAHSI Water Data Center.

The USU team includes UWRL faculty members (David Tarboton and Jeff Horsburgh), a software engineer (Pabitra Dash), and two graduate students (Tian Gan and Mauriel Ramirez). Dr. Tarboton is the overall project lead and coordinates all work on the project. Collectively, the USU team has designed the overall functionality of the system; determined the way content resources,

time series, and geographic raster and multidimensional data are represented in the system; and styled the front end user interface appearance; along with lots of work under the hood on many aspects of the system.

The HydroShare platform allows users to access and operate on its resources through the HydroShare website and web programming applications program interface (API) and save results back to HydroShare, while preserving the original resources. This access is helping the entire hydrologic community to be on the same team. ■

HydroShare's national and local impact

HydroShare already houses hundreds of different data resources, with more added continually. The two examples below show how HydroShare is making a difference nationally and right here in Utah.



The National Water Model (NWM) from NOAA is a powerful new tool that simulates and forecasts river and stream flow parameters for 2.7 million stream locations across the United States at a higher resolution than ever before. The

HydroShare team at RENCI created a system that captures and stores the NWM outputs at the RENCI facility. Apps enable users to manage, archive, and share this important water science data through the HydroShare platform for applications such as flood control. Read more at:

<http://renci.org/news/hydroshare-extends-the-reach-of-breakthrough-national-water-model/>



iUTAH is an interdisciplinary research and training program funded through the National Science Foundation that aims to strengthen science for Utah's water future. The HydroShare team are among the statewide network of researchers, universities, governmental agencies, industry partners, and non-profit organizations that make up iUTAH. Some of the lessons learned from iUTAH's original data management efforts informed the design of the HydroShare platform, and now developers from both teams are working

together to archive, publish, and share previous and future iUTAH datasets to be widely available on HydroShare. Learn more at:

<http://iutahepscor.org>



The HydroShare team is led by UWRL faculty member David Tarboton and includes collaborating scientists from:

- ▶ Utah Water Research Laboratory at Utah State University
- ▶ The Renaissance Computing Institute (RENCI) at University of North Carolina, Chapel Hill
- ▶ The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)
- ▶ Brigham Young University
- ▶ Purdue University
- ▶ University of Texas
- ▶ Tufts University
- ▶ University of Virginia
- ▶ San Diego Supercomputing Center
- ▶ University of Washington
- ▶ Cactus Group

The system is hosted at RENCI and operated as a facility of the CUAHSI Water Data Center.

HydroShare was developed with support from the National Science Foundation collaborative awards ACI-1148453 and ACI-1148090.

An aerial photograph of Fish Lake, Utah, showing a mix of water and submerged vegetation. The water surface is a mix of light and dark green, with some brownish patches. The surrounding land is covered in dense green and yellow vegetation. A road is visible in the upper left corner.

AggieAir:

10 years of innovation
in hydrologic remote
sensing technology

25 mile
range
45 min. airtime
6 ft. wingspan
8 lb. weight
RETIRED



Flying Wing

4 mile
range
15 min. airtime
4 ft. frame size
20 lb. weight



Ark

37 mile
range
60 min. airtime
9 ft. wingspan
18 lb. weight



Minion

200 mile
range
200 min. airtime
10 ft. wingspan
26.5 lb. weight



BluJay



<http://aggieair.usu.edu>

SELECTED DATA PRODUCTS based
on AggieAir RGB 10-cm imagery in Lodi, CA

AggieAir has come a long way over the past decade. Starting out as nothing but an idea, AggieAir has grown to become an exceptionally capable, scientific-quality, small unmanned aerial data collection system with a 10-year history in support of scientific research and a wide range of practical applications.

In 2006, UWRL director Mac McKee and his students recognized the value of aerial imagery and remote sensing data for agriculture, but manned aircraft and satellite data were either too expensive or not flexible enough.

These challenges inspired Dr. McKee to look for other sources, but ultimately he allocated funding to initiate development of a low-cost unmanned aircraft that could return scientific-grade remote sensing data, and AggieAir took to the skies.

The Fleet

The Flying Wing, now retired, was AggieAir's first generation unmanned aerial vehicle (UAV). Even as the Wing launched a UAV Service Center at the lab to collect multispectral data for a wide range of applications, development of the next generation was already underway.

Minion moved to a conventional fixed-wing design to increase platform stability, and an improved payload that includes a thermal camera, vital for agricultural applications.

Ark added vertical take-off and landing (VTOL) capability.

BluJay, the newest platform, has enabled additional sensors and has attained the capacity for beyond line of sight operation.

The current fleet includes ten aircraft that have flown missions in nine western states and one foreign country. BluJay can now fly 200 miles, remain airborne for 200 minutes, and image 20,000 acres on a single battery charge. To date, AggieAir has flown further than any other similarly sized scientific UAV on the market.

Sensors & Safety

Sensors in the aircraft payloads can include visual, near-infrared, infrared, "red-edge", and other spectra. At 13-cm resolution, AggieAir imagery contains about 53,000 times as much information per unit of land area as Landsat 30 m imagery (see left).

Safety is essential for flight. AggieAir incorporates ADS-B, RADAR, and UAV metadata in real time, meets and exceeds the 2020 regulations for ADS-B, and is far safer than ultralights and small sport aircraft.

Most FAA COAs only allow flights up to 400 ft. above ground level (AGL), but AggieAir has COAs across the US that give permission for flights up to 3,000 ft. AGL.

Practical Science

The potential and actual beneficial uses of AggieAir continue to grow. Applications range from precision agriculture to atmospheric ozone sampling, vegetation mapping, stream and river applications, invasive species monitoring, hydrologic water quality investigations, fish and wildlife tracking, and much more. The following are just a few of the projects AggieAir is making possible:

- ▶ Evaluating the use of high-resolution imagery to monitor multiple agronomical parameters for row-type crops (vines)—evapotranspiration (ET), soil moisture, biomass, yield, vines and interrow crops (grass)—and integrate with satellite agriculture products.
- ▶ Examining ozone formation, transport, and transformation over the Great Salt Lake, Utah.
- ▶ Determining the linkages between Arctic landscape processes and the surface water response, particularly the influences of climate variability on instream temperature regimes.
- ▶ Mapping wetland flow path and consumptive use in the San Rafael River, Utah, as part of a larger restoration program.
- ▶ Developing digital surface models along the Duchesne River, using UAV imagery to assess levels of streambank erosion/ degradation.



- ▶ Mapping the progress of a non-native aquatic plant species, *Eurasian watermilfoil*, for State agencies interested in mitigating this habitat threat to Fish Lake in Utah.
- ▶ Comparing and integrating satellite and UAV imagery for on-farm agricultural water application using the available irrigation technology (center pivots) in Scipio, Utah.
- ▶ Improving emergency response and disaster mitigation with UAV imagery after the 2011 earthquake in Christchurch, New Zealand.
- ▶ Evaluating the use of high-resolution imagery for estimating agricultural parameters for typical Western US crops such as evapotranspiration, soil moisture, and plant chlorophyll.
- ▶ Identifying critical river habitat for the Northern Leather Side Chub along the Yellow Creek during periods of low flow for state and local agencies.
- ▶ Investigating the role of beaver dam complexes on instream temperature, groundwater/surface water interactions, and instream flow in western mountain streams. ■

Training the next generation of engineering experts

10 years of student driven research and development has led to exciting employment opportunities for AggieAir alumni

Adept Technologies
Airinov
The Aerospace Corp.
Amazon
Boeing Phantom Works
Blue Origin
Compass Systems
Facebook

General Electric
Google
Hill AFB
IBM
Icon Fitness
iMSAR
Juniper Systems
Lockheed Martin

MicaSense
Navitaire
Northrop Grumman
Panasonic Avionics
POWER Engineers
Qualcomm
Samsung
Sandia National Lab
Scaled Composites
Synopsis
Teal Drones
U.C. Merced
U. of Virginia
Vayu
Vialight Comm. GmbH
US Dept. of Defense
Virginia Military Institute
WECC

Austin Jensen

As an electrical and computer engineering graduate student at USU, Austin was involved in AggieAir's earliest development. When the technology was ready to be deployed, his experience and drive made him the obvious choice to take the reins of the fledgling AggieAir Remote Sensing Service Center at the UWRL. Austin tackled the challenges of making the technology fly, managing projects and teams of researchers, working to meet client needs, and navigating FAA regulatory requirements. In a very real sense, Austin helped get AggieAir off the ground.

After 8 years leading AggieAir, Austin has now moved on to Amazon, where he is a technical program manager in the automation group for Amazon Fulfillment Technology. His group develops and supports software for automation in the order fulfillment process.

At Amazon, Austin is employing many of the same skills he honed while leading the AggieAir team: understanding client needs; gathering requirements; scoping projects; developing timelines; dealing with risk, ambiguity, and external dependencies; and communicating.

Austin says his of AggieAir experiences, "They helped me get this job and have helped me with decisions I have had to make since. Things move really fast here at Amazon." Just like at AggieAir. ■



Manal Elarab

Manal first came to the UWRL from the Bekaa Valley, Lebanon as a PhD student working under UWRL Director Mac McKee. Four years later, and only 3 weeks after her graduation, Manal landed her dream job at MicaSense, a Seattle-based company that manufactures multi-spectral cameras (RedEdge Sensor) and provides a cloud based platform (ATLAS) for processing, storing, managing, and analyzing multispectral data.

“The time I spent at the UWRL uniquely prepared me for the challenges within the nascent industry and technology of precision agriculture,” says Manal, “I was surrounded by world-class researchers and mentors that taught me how to be an effective scientist in both technical and interactive settings. The practical experience I gained as part of the AggieAir team gave me confidence, field experience, and industry exposure.”

As a Remote Sensing Scientist in research and development, Manal creates analytics capabilities for the MicaSense cloud platform and simultaneously develops powerful sensors to address the needs of precision agriculture. She also collaborates with researchers from across the world to develop remote sensing models.

“My job is taking me to exciting places, says Manal, “I never would have imagined such possibilities!” ■





20 *Phragmites australis* patches in the Bear River Migratory Bird Refuge are revealing secrets that can help managers improve Utah wetlands.

Focus on UTAH:



Photo by Karin Kettenring

Life on the Edge: Understanding the spread of invasive *Phragmites australis*

Utah wetlands, particularly along the Great Salt Lake, provide critical wildlife habitat, resting grounds for migratory birds, and important social and economic services such as water purification, stormwater retention, and recreation for hunters. However, invasive plant species, such as *Phragmites australis*, can edge out diverse native vegetation and dramatically alter and degrade critical wetlands habitats and ecosystems.

For the past several years, researchers from the UWRL and the USU Quinney College of Natural Resources have worked with wetlands managers at the US Fish and Wildlife Service's Bear River Migratory Bird Refuge (BRMBR) in northern Utah where the Bear River flows into the Great Salt Lake to examine ways to control the spread of this invasive species and improve habitat for priority bird species.

One of the research objectives has been to understand the primary modes of reproduction (by seeds or by underground stems called rhizomes) for these invasive plants, from initial colonization through patch expansion. In this project, the researchers studied 20

Phragmites australis patches in wetland impoundments at the (BRMBR)uge.

Researchers took leaf samples every 0.5 m around the periphery of each patch and, in the lab, used genetic assessments to determine if the leaves came from the same clone (evidence of spread by rhizomes) or if samples were genetically unique (resulting from seed spread). At the same time, multispectral AggieAir remote sensing imagery was used to estimate the rate of *Phragmites* patch expansion.

The combination of methods produced a detailed description of the mechanisms that make *Phragmites* one of the most successful invasive plants in North America. Most of its spread is by rhizomes, while seedling recruitment, which facilitates rapid expansion, occurred occasionally.

Armed with this detailed biological knowledge, wetland managers can employ targeted management tactics toward both forms of patch expansion—seeds and rhizomes—to combat this persistent threat to Utah's wetlands environments. ■

Finding Water Waste: Testing the accuracy of Utah's flow management devices

In Utah, as in other semi-arid states, the potential beneficial uses for water far exceed the available water supply. Managing those limited water resources for the various stakeholders in the state is an ongoing concern. Here in Utah, agriculture alone accounts for approximately 85% of water allocations. Flow measurement devices such as flumes, gates, and weirs help facilitate water management. But what happens when those devices are not as accurate as they claim to be?

Factors such as installation errors, uneven settlement, sediment and moss buildup, damage to the device, uneven flow, and improper construction can contribute to device measurement errors. Over

time, small contributing errors in flow measurement can add up to very large errors that either prevent water users from receiving their true allocations or support overuse of a water right.

UWRL faculty member Steven Barfuss and his team have spent the past nine years testing the accuracy of hundreds of *in situ* flow measurement devices throughout the State of Utah and generating a database that identifies flow measurement structures most in need of remediation, repair, or recalibration.

Only 31.3% of the 259 devices tested thus far have measured flow within manufacturer design specifications; 68.7% of the devices were measuring

flow less accurately than the design manufacturer specifications claim.

Water owners and managers have been using the calibration data to make changes to their structures that improve flow measurement accuracy. In many cases, UWRL researchers have returned to the same location the following season to evaluate the effect of those changes and improvements on flow measurement accuracy.

The UWRL continues to report the findings from this research to the Utah Division of Water Rights with encouragement to improve and maintain degraded or inaccurate flow measurement devices throughout the state of Utah. ■

Photo by Division of Water Rights



Devices tested by UWRL

- 4 cutthroat flumes
- 5 magnetic meters
- 6 sluice gates
- 12 ultrasonic meters
- 23 ramp flumes
- 27 rated sections
- 29 weirs
- 153 Parshall flumes

68.7%
of the 259 flow devices
tested as of August 2016
exhibited errors in excess
of the design specifications



Photo by DebraLamb



2 Utah drinking water treatment plants are testing beneficial bacteria as a safe and economical water disinfection alternative.

Biofiltration: Exploring alternative ways to protect Utah's drinking water

Have you ever thought about what it takes to ensure that your tap water is safe? Probably not. But those in charge of making it happen think about it all the time. Water managers must protect against potential unwanted disinfection byproducts and minimize the possibility that unwanted microorganisms will regrow in the system after treatment.

Disinfection byproducts occur when chlorine is used to disinfect drinking water (to kill or suppress microorganisms that can cause disease). While chlorine is very effective and economical, its use is not without problems, particularly when water supplies contain small amounts of harmless, naturally-occurring organic matter, such as the decay products of leaves and algae. Under the right conditions chlorine will react with that organic matter and produce contaminants that are known or suspected carcinogens.

Biofiltration, on the other hand, uses naturally occurring bacteria that remove the organic matter before it has a chance to react with chlorine and offers several desirable benefits:

- ▶ Significant potential cost savings since fewer to no chemicals are added to the water supply;

- ▶ Removal of the precursors to undesirable disinfection byproducts; and
- ▶ An operationally simple transition process because traditional plants can be adapted for biofiltration simply by stopping the addition of chlorine to certain parts in the process.

Biofiltration isn't a new idea; in fact, it's been around for decades, but water managers have been reluctant to adopt it as their primary disinfection technology.

UWRL faculty member Dr. David Stevens has designed and helped to implement biofiltration systems at two Utah drinking water plants hoping to gain additional understanding that may just change the minds of plant managers. The plants were chosen in consultation with project partners from the Utah Division of Drinking Water and the Utah Water Quality Alliance.

Pilot Study: Duchesne, UT

Weekly samples from influent (before treatment), intermediate (during treatment) and effluent (after treatment) water at three pilot-scale biofilters with slightly

different operational protocols were collected and assayed for general water chemistry, heterotrophic plate count (HPC), dissolved and total organic carbon, UV₂₅₄, ATP, nutrients (N and P), and other measures. Biofiltration media samples were also collected and assessed through microbiological analyses to monitor the development of the biological consortia.

The pilot biofiltration system produced water suitable for drinking, and with lower levels of organic matter (the cause of harmful disinfection by-products) as compared to the traditional system.

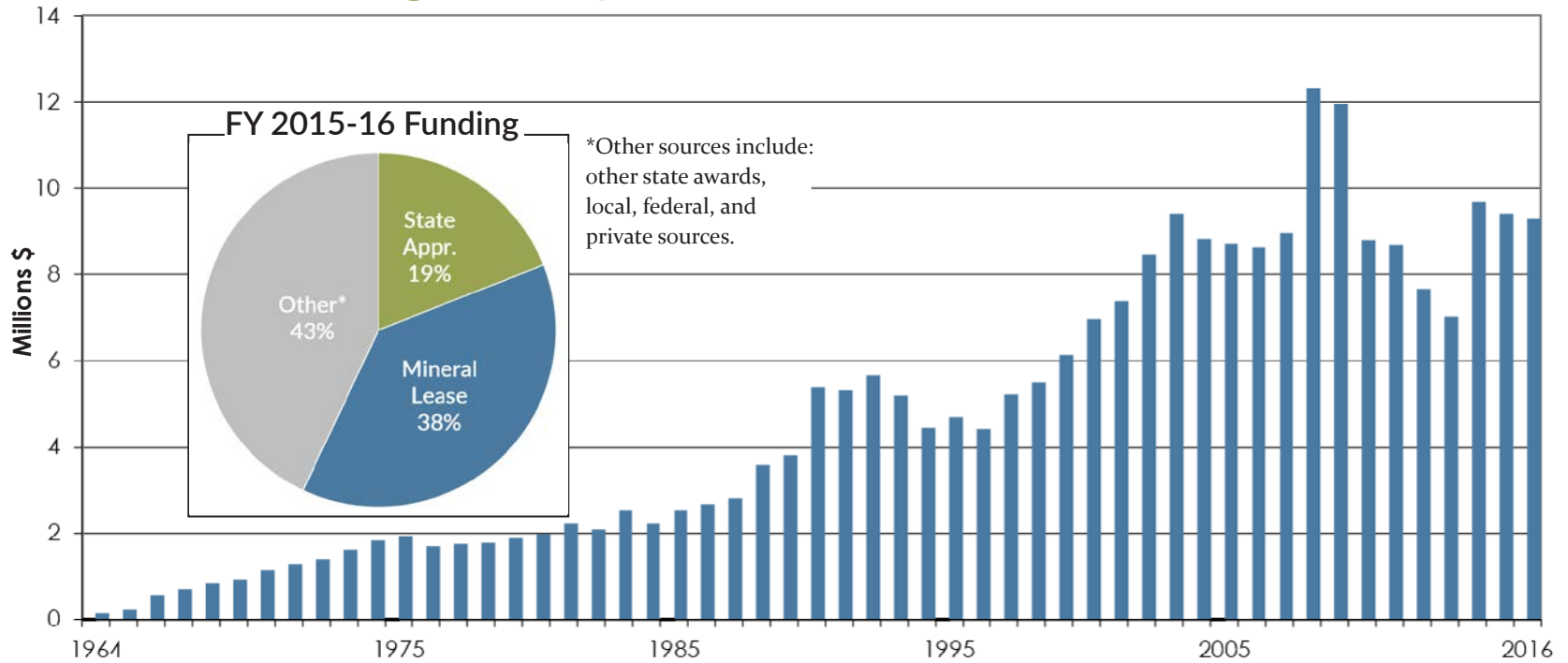
Full-scale Study: Hurricane, UT

In this full-scale project, Washington County Water Conservancy District's (WCWCD) Quail Creek water treatment plant converted half of their operation to biofiltration for one year in a way that does not compromise the quality of the drinking water delivered to their customers.

With the help of these forward-thinking water treatment plants, the State Drinking Water Division will have more information to help promote biofiltration as a safe and potentially cost-saving drinking water treatment option. ■

FY15-16 Financial/Academic Summary

UWRL Funding History:



\$9,277,880

Total Annual Expenditures FY 15-16

Research and Training Products:

263

Active projects

138

Scholarly presentations at professional conferences

81

Scholarly publications in peer reviewed journals

6

Short courses

Student Outcomes:

51

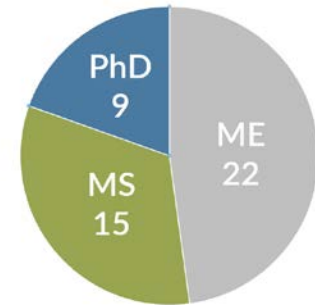
Graduate research assistantships funded

122

Undergraduate students supported

46

Degrees granted





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Photo by Tyler King