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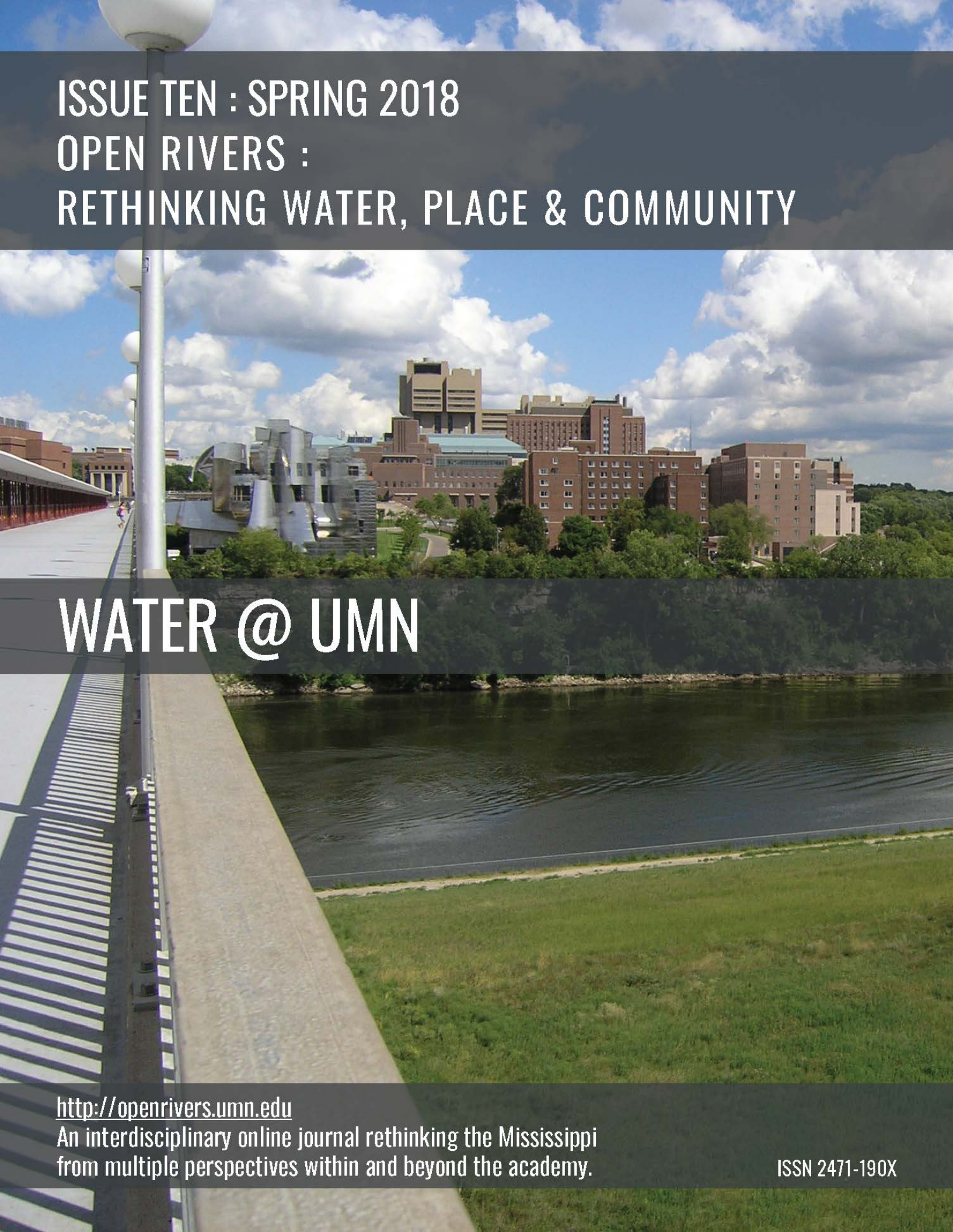
OPEN RIVERS : RETHINKING WATER, PLACE & COMMUNITY



WATER @ UMN

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The cover image is of The East Bank of the Minneapolis campus of the University of Minnesota and the Mississippi River from the Washington Avenue Bridge. Image courtesy of Patrick Nunnally.

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INTRODUCTION

INTRODUCTION TO ISSUE TEN

By Patrick Nunnally, Editor

Welcome to Issue 10 of *Open Rivers*, which serves as a milestone in at least two ways. First, we have achieved "double digits" in terms of issues, which many publications never achieve. Thank you to the many, many people who have made the journal happen over the years. Second, this issue focuses at home, at the University of Minnesota, where the breadth of work on water is simply staggering. The number of faculty affiliated with Water Resources Sciences numbers well over 100, and it seems that water is becoming part of many of the University's broad initiatives, such as Grand Challenges Research and MnDrive. This is truly an exciting time to be researching, teaching, and learning about water at the University of Minnesota!

Traditionally, people have thought about water through lenses shaped by scientific inquiry and engineering expertise. Of course, those perspectives are well represented in this issue with articles about the Large Lakes Observatory at the University of Minnesota Duluth, the Natural Resources Research Institute, also in Duluth, and the Minnesota Aquatic Invasive Species Research Center on the St. Paul campus.

Across the country, in the state of Minnesota, and at the University, the recognition is growing that water concerns pervade issues that have not been usually thought of as involving water. It wasn't too many years ago that discussions of agriculture did not have water at their center; as the article

The East Bank of the Minneapolis campus of the University of Minnesota showing the Washington Avenue Bridge and the Mississippi River. Image courtesy of the author.

in this issue by Ann Lewandowski and her colleagues makes clear, University researchers and educators are now involved in this conversation in several diverse ways.

While some research appropriately looks at solutions to well understood problems, other work redefines problems in terms we had not thought of by reminding us of perspectives that we can't overlook. Simi Kang's discussion of the challenges faced by Vietnamese fisherfolk in New Orleans should expand our considerations of all the regional water problems that are discussed in purely technical or broad policy terms.

There is much more to "Water @UMN" than can be contained in a handful of articles, though. In this issue we introduce a feature that we call "Roundup," which contains short pieces from over a dozen researchers, technicians, and program leaders addressing a very broad range of water concerns. See these pieces for insights into music and computer modeling, views from global perspectives and how one class is involved with a local national park, and for highlights from several community-engaged programs. We also have our usual range of columns in this issue: a book review and discussion of water-centered pedagogy, pieces that focus on "where" water comes to our attention most prominently, a discussion of a perhaps-unlikely source for new insights on water, and a summary of an exciting national water conference taking place this summer in Minneapolis.

Many writers across a number of genres and media are trying to make water problems simple: if we just do this, or value that better, then we'll "fix the water crisis." In fact, most issues involving water are complex and will remain complex and will require all the perspectives represented here, plus others, to address them successfully. For better or worse, university researchers and teachers are charged with revealing the complexities in matters that we often think of as simple. It's what we do, and, as the perspectives contained here illustrate, the contributions we make are both local and regional, exist at varying scales and diverse sectors of society, and affect all of us nearly every day.

When we began to plan this issue months ago, we involved the University's Institute on the Environment and the Water Council to help us spread the word and make sure we didn't overlook obvious perspectives. Through these two organizations, we were in touch with a number of people, laboratories, and institutes that we did not know of before. The issue is richer for those perspectives, and we thank all of the individuals who contributed.

Happy reading!

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About the Author

Patrick Nunnally coordinates the River Life Program in the Institute for Advanced Study at the University of Minnesota. He serves as editor for *Open Rivers* and was one of the lead scholars for the University's John E. Sawyer Seminar, "Making the Mississippi: Formulating New Water Narratives for the 21st Century and Beyond," funded by the Andrew W. Mellon Foundation.

FEATURE

NRRI'S SYSTEMS APPROACH TO MINNESOTA WATER CHALLENGES

By June Breneman

Water equals life, and in Minnesota especially, clean water equals quality of life. As one of our state's most prized resources, the Natural Resources Research Institute (NRRI) at the University of Minnesota Duluth (UMD) takes water seriously. Founded in 1983 by the state legislature, NRRI was established to balance economic development of natural resources with environmental sustainability. Applied research solutions for water challenges are part of almost every problem addressed. From dealing with excess rainfall to trying to minimize human impacts on water resources, the NRRI uses a "systems approach" to solving issues such as stormwater runoff, sulfate contamination, aquatic invasive species and climate change, then delivering tools

NRRI researchers sort through samples collected at Lake Mille Lacs last summer to understand how invasive species are impacting the food web of walleye. Image courtesy of the author.

and information needed for informed decision making.

NRRI's Water Initiative is keenly focused on these issues, while other initiatives support and inform the work. They are Minerals, Metallurgy & Mining; Renewable Energy; Forestry & Land; Wood Products & Bioeconomy; and Business & Entrepreneurial support. The interplay among the scientists, engineers, and geologists makes NRRI uniquely positioned to deliver solutions for resilient communities. Water-based problems are tackled from the watershed and followed to the end of the pipe, an approach that saves money and protects the environment.

"To fully understand and then develop appropriate solutions to the challenges facing Minnesota's water resources, we need controlled, small-scale experiments as well as large landscape-scaled experiments," says Lucinda Johnson, director of NRRI's Water Initiative. "What's great about NRRI is that we partner with colleagues from multiple scientific disciplines to develop new approaches to the challenges."

NRRI research and administrative staff is housed in a recycled Air Force air defense building in Duluth, Minnesota, with a second facility on the Iron Range in Coleraine, Minnesota, focused on minerals and renewable energy. Image courtesy of the author.

TACKLING STORMWATER

Green infrastructure

In 2012, Duluth received 10-plus inches of rain in just a few hours and the flooding caused over $100 million in damages to the city's infrastructure. It also triggered concern about how to develop community resiliency in the face of future storm events.

NRRI took the birds-eye view with computer modeling. How much rain could be absorbed by converting half of the city's buildings to green roofs, adding rain barrels and rain gardens? Once the green infrastructure was mapped out, the scientists brought the scenarios to a citizens meeting where they ranked them for feasibility.

"It was a great chance to educate people, too, and get down to the nitty gritty of cost and what is actually doable from their perspective, which is absolutely essential," said George Host, NRRI Forest & Land Initiative director. The University's Center for Changing Landscapes used the information to develop a fact sheet for climate preparedness and prioritize strategies.

Ditches 101

Other important, but often overlooked, players in stormwater protection are the county and state workers who build and maintain rural ditches. If the ditch banks are built incorrectly or not maintained, the roads can erode and won't shed rainwater efficiently. Ditches also carry water directly to streams and lakes, and the water is not treated or cleaned in any way. When asked what these maintenance professionals needed most to help them do this important job correctly the answer was simple. A guidebook.

But pulling it together was quite a project. NRRI Aquatic Ecologist Valerie Brady led the effort with Minnesota Sea Grant's Jesse Schomberg to develop the "Field Guide for Maintaining Rural Roadside Ditches," published in 2014.

The Field Guide addresses problems like beavers, preventing erosion, and managing vegetation, including invasive species. Workers can quickly reference when to change culvert size or when to involve an engineer. The format is straightforward, specifically written for northeastern Minnesota's county and township maintenance crews for easy reference in the cab of the excavator. An advisory committee provided input and engineering consultants made sure the technical details were covered.

In the front of the book is a "Ditch Problem Checklist" with drawings, photos, and clues making it user friendly. The guide even comes with a slope measuring template to visually guide the excavator in creating proper ditch bank slopes to prevent erosion.

"The goal is to do ditch maintenance in a way that is most protective of our aquatic resources while still protecting the road and traffic," said Brady. "We printed 1,100 copies and distributed to every township and road maintenance group in northeastern Minnesota and northwestern Wisconsin. We need to print more because we are still getting requests."

NRRI Field Technician Mary Heise inspects a large culvert in rural Duluth, Minn., as part of an effort to develop ditch and culvert best practices leading to protecting water quality. Image courtesy of Andrea Crouse.

Unique roadside filters

Even with stable ditches, there are pollutants running off the roads—salt, dirt and heavy metals—especially in the first flush of rain. In 2013, the Pollution Control Agency established a regulation requiring onsite treatment of the first inch of stormwater off roads. Since then, compost and sand have become standard filter materials. But a better idea is being tested at NRRI that uses local waste resources and helps the state meet regulations.

NRRI Scientists Kurt Johnson and Meijun Cai are experimenting with varying mixtures of three ingredients: 1) a clay and organic material mix called "muck," 2) peat that was stockpiled after a road construction project, and 3) taconite tailings waste rock. Each material has its advantages and disadvantages, so the researchers are experimenting with which "recipe" works.

"It has to support vegetation and it has to filter chemicals in the stormwater," said Johnson. "And, of course, they have to be native plants, so I'm looking at the biology and plant growth potential."

Cai is an environmental engineer, so she's working on the efficiency of the pollution removal. Another member of the team is David Saftner in UMD's Civil Engineering Department, who will develop the water storage requirements for the materials.

NRRI Researcher Meijun Cai filters water in her lab as part of an experiment to use local waste resources to remove pollutants from road runoff. Image courtesy of the author.

"We're comparing our mixes to the standard compost/sand mix," said Cai. "If it works and the performance is good, we can make use of these local waste resources for local projects."

Powerful peat

Another effort is underway to address parking lot runoff in a partnership with American Peat Technologies in Aitkin, Minnesota. NRRI Chemist Igor Kolomitsyn is helping them take advantage of the natural attributes of peat to remove heavy metals. Kolomitsyn developed a process to chemically alter the surface of granulized peat to increase its adsorption properties for target removal of cadmium, zinc, cobalt, copper, and sulfate.

A demonstration project to test its efficacy is in place in Aitkin at the far end of the Paulbeck's County Market parking lot. An underground vault is positioned to catch and filter out trash, and then two levels of the peat-based filters capture heavy metals before the water moves to a nearby wetland.

Peat resources are harvested at American Peat Technologies in Aitkin, Minn. NRRI is working with the company to develop unique, peat-based water filters that target specific heavy metals. Image courtesy of the author.

The "S" word: Sulfate

Sulfate in water systems is a statewide problem related to human activities. Innovation is needed to find low cost and efficient options to augment/complement more expensive reverse osmosis. NRRI is tackling this challenge with chemistry, microbes, and filtration aids.

Currently underway at NRRI are promising lab-scale tests of a process that transforms soluble sulfate into a dense solid that settles in a water system so that it can be removed with filters. The goal is to bring sulfate levels ranging from 60-300 parts per million – levels often associated with municipal wastewater treatment facilities – down to the current target of 10 parts per million, the current standard for areas with wild rice in Northeastern Minnesota. This lab work will be scaled up to a first generation pilot demonstration this summer.

Another process uses microbes that naturally convert sulfate to sulfides. NRRI is now working on a biological treatment that allows these sulfides to be permanently removed from the system as another compound.

"It's clear that we need to address with problem multiple approaches, which may or may not include reverse osmosis technology," explained Rolf Weberg, NRRI Executive Director. "These projects are directed at providing another set of tools to address sulfate and related water challenges in Minnesota."

PREVENTING AND MITIGATING AQUATIC INVASIVE SPECIES

Testing ballast technologies

It's well known that aquatic invasive species are a proliferating problem for Minnesota's native species. And we know that one way they're getting here is in ballast water transported by ocean-going vessels travelling through the Great Lakes. For the past decade, NRRI Senior Researcher Euan Reavie has been leading a project to take the guesswork out of finding technologies that kill off invasives before ballast water is released. The research is part of the Great Waters Research Collaborative at the Lake Superior Research Institute in Superior, Wisconsin.

The final step in this lab-to-pilot-to-onboard research was completed in 2017. Reavie and his crew chased a working commercial bulk carrier to ports around the world testing a promising technology, commercialized by JFE Engineering Corporation, in real world situations. The combined filtration and chemical injection treatment keeps species out of the ballast tanks while also killing any organisms that enter. NRRI systematically and scientifically tested the technology so that vendor and policy makers can deploy the equipment with confidence.

"The engineers who build equipment like this have good intentions," Reavie explained. "But they don't necessarily grasp the complex biology of water around the world. A vendor may have done preliminary testing in Europe, and then comes to Lake Superior and gets completely different results."

Fishing gear study

It is well documented that the half-inch barbed spine of the spiny water flea, a tiny invasive zooplankton, gets caught on fishing lines. The non-native species can then inadvertently be transported from lake to lake. But what other gear might it be catching on? NRRI Aquatic Ecologist Valerie Brady and UMD Biology's Donn Branstrator are studying the role of a variety of fishing gear in the spread of aquatic invasive species.

"Are the frayed anchor ropes a problem? What about the bait bucket? The downrigger? Are they hiding in the live wells in the boat? Would a different type of fishing line entangle fewer of them?" Brady said, explaining the project. Insights about the ways that invasive species are transported provide managers with tools for preventing their further spread.

NRRI researchers on Island Lake in northern Minnesota test three different types of fishing line, buoys holding anchor lines and a downrigger to see if spiny water fleas attach to them. Image courtesy of the author.

This research took place on Island Lake near Duluth in 2017 with funding from St. Louis County. In summer 2018, the research moves to Lake Mille Lacs, with funding from the Minnesota Aquatic Invasive Species Research Center and the Environment and Natural Resources Trust Fund. Mille Lacs water is much clearer than Island Lake, which may affect how spiny water fleas interact with fishing gear. Comparing results from both lakes will provide information to anglers to help stem the spread.

Using better information gleaned from this project, waterproof stickers will be made available at bait and fishing supply stores with best practices information for anglers.

On Island Lake in northern Minnesota, one boat of NRRI researchers pulls nets searching for spiny water fleas while a second boat trolls equipment through the water to see if the invasive species attaches itself to the gear. Image courtesy of the author.

What about walleye?

Even though anglers are being educated in checking and draining their boats, aquatic invasive species are still spreading to popular sport fishing lakes. NRRI Aquatic Researcher Katya Kovalenko is leading a team to understand the impacts of spiny water fleas and zebra mussels on walleye populations in Lake Mille Lacs.

"I'm interested in the entire food web and how the lakes are changing," said Kovalenko. "But walleye are especially interesting because they are the top predator. They can give you a picture of everything below them on the food chain."

The overall project is led by the Minnesota Department of Natural Resources (DNR) to understand the walleye food webs in the state's nine largest walleye lakes. Three lakes (Cass, Winnibigoshish, and Leech) have varying levels of zebra mussel invasions. Four lakes (Kabetogama, Lake of the Woods, Rainy, and Vermilion) have spiny water fleas. One lake (Mille Lacs) has both invaders. And another (Red Lake) has neither. Historical data collected by the Minnesota DNR will also allow for comparisons of walleye populations pre- and post-invasion.

NRRI Researcher Katya Kovalenko holds a water sample with amphipods (scuds) and caddisflies take from Lake Mille Lacs in July 2017. Image courtesy of the author.

And while the two unwelcomed critters are very different, they both reduce zooplankton, the tiny food source at the bottom of the food chain. That means less food for young walleye and for yellow perch, which is the food source of grown walleye. The question is: Are walleye adapting to the changes in the food web? If so, what are they eating?

ASSESSING THE IMPACTS

Indicators of environmental change

So how do all these challenges actually impact the environment? NRRI has a number of assessment projects underway to inform future decisions about protection and restoration.

At the turn of the last century, the complexity of the Great Lakes coastal zones was little understood. In 2000, the Environmental Protection Agency (EPA) tapped NRRI to develop indicators to assess the ecological condition and point to problem areas. The resulting labor-intensive and unprecedented report, Great Lakes Environmental Indicators, was delivered in 2015. It serves as a guide for comprehensive studies of the U.S. freshwater coastal zones from Lake Superior's North Shore to Lake Ontario in New York.

The EPA granted NRRI $6 million for the initial project, and the Great Lakes Restoration Initiative provided an additional $1.7 million in 2010 for more data and analysis.

Keys to a successful project of this magnitude were collaboration, tight coordination, and a way to collect data across all watersheds. Principal investigators were assigned to five different indicator groups: 1) Algae and Water Quality, 2) Fish and Macro-invertebrates, 3) Wetland Vegetation, 4) Birds and Amphibians, and 5) Chemical Contaminants.

Out of the terabytes of data collected, nearly 100 peer-reviewed papers and countless metrics and methodologies emerged indexes and benchmarks that provide the capacity to both postulate and confirm the condition of the entire Great Lakes shoreline.

"Basically, we wanted to know how the biological communities related with human disturbances across the Great Lakes coastal region," said Johnson. "Our final products provide a rationale for defining new approaches to solving problems on the Great Lakes and are being implemented in various forms in both Canada and the U.S."

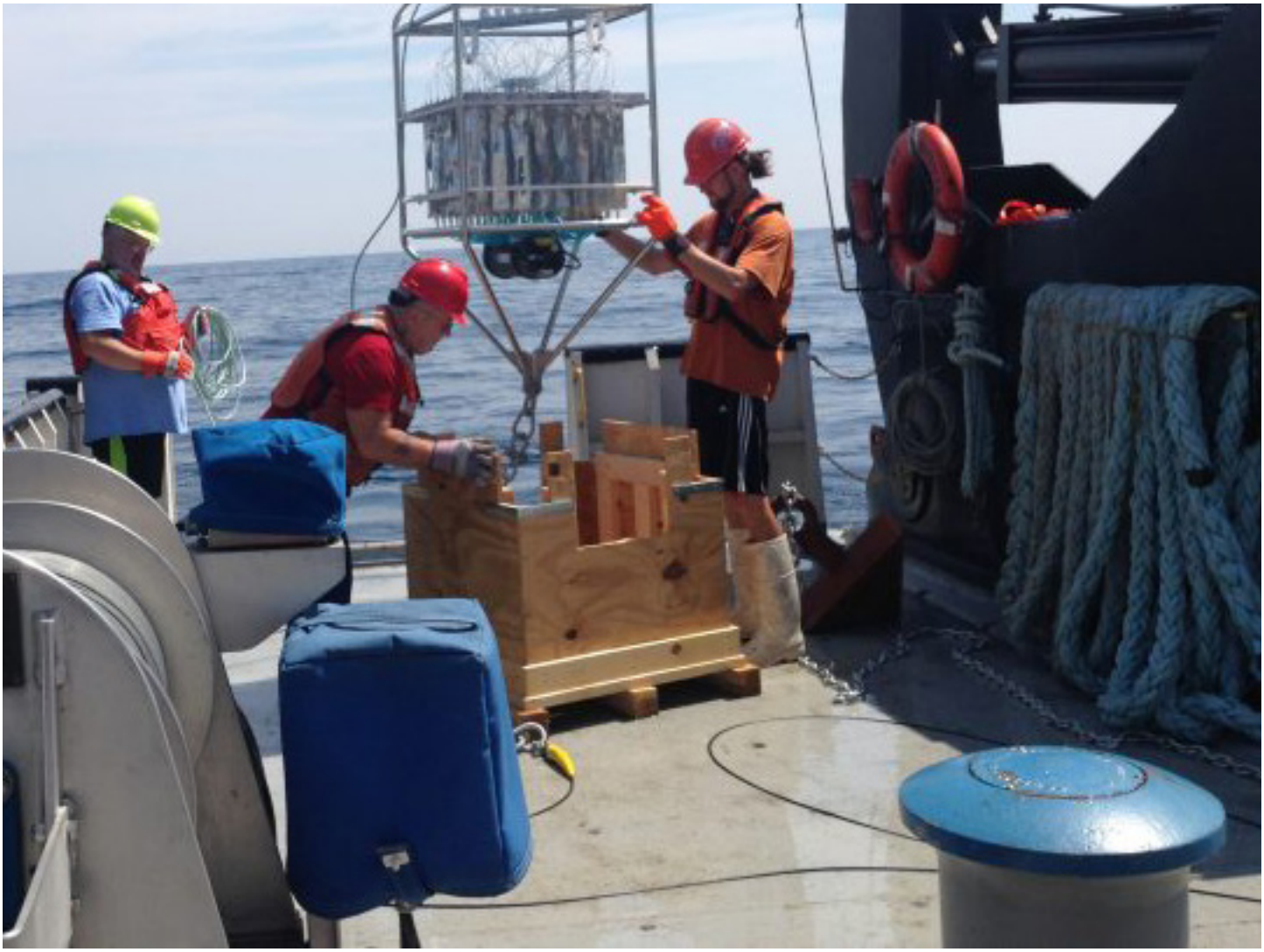
Focusing on the food web

Since 2007, NRRI scientists have been providing data to the U.S. EPA about the status of microscopic organisms at the bottom of the food chain in the deep, open waters of the Great Lakes. Then in 2016, NRRI received additional EPA funding to expand the data gathering to areas near the shore and to use robots that collect data year-round, including under ice in the winter.

"Because of the discoveries we've made so far revealing profound food web impacts, this is a natural progression for the research," explained

Euan Reavie, NRRI senior researcher and program lead. “We need data from more seasons, beyond spring and summer to make predictions, especially with climate change impacts.”

Two submerged buoys with remote sampling devices will be stationed in each of the lakes to collect and preserve phytoplankton samples and store them until retrieved a full year later. The winter data will identify what species are active under the ice and what happens as the ice thaws, a period that is little understood but critical as annual biological cycles begin. The nearshore area, which sits between the shallow coastal waters and the deep open waters, is a very poorly sampled zone that could tell us more about impacts associated with human activities on the land.



Deploying one of the buoy systems with remote sampling devices to collect year-round data on the Great Lakes. Image courtesy of Euan Reavie.

Keeping it cool for trout

The need to better understand North Shore streams that might stand the best chance of staying cool for trout resulted in funding from the Environment and Natural Resources Trust Fund in 2016.

Volunteers from Trout Unlimited and NRRI researchers teamed up to find cool groundwater inputs in about 120 stream segments from south of Duluth, up the North Shore and to the Canadian border.

In 2016 and 2017, researchers mapped cold water seeps and tributaries and correlated the data with each location's geology, creating a computer model to predict the probability of encountering cooler groundwater. Management agencies and fishing groups can then target trout habitat

NRRI Field Technicians Nick Pierce and Kari Hansen walk through rural streams to get temperature readings, documenting where cool water inputs might make them more resilient against climate change impacts. Image courtesy of the author.

restoration and protection efforts on locations where groundwater helps keep streams cool during hot summers.

Field surveys revealed 83 stream segments containing cool water locations, and the resulting computer model was accurate for predicting other groundwater locations. The Minnesota DNR considers warming water to be the greatest threat to trout and steelhead fisheries.

Where the river meets the inland sea

In addition to these many research efforts, NRRI is especially known for ongoing data gathering for long-term monitoring. A significant effort is informing restoration efforts on the St. Louis River estuary as the state works to remove its status as an Area of Concern. In all, more than $400 million has been invested with the goal to complete the work by 2025.

NRRI scientists with specialties in aquatic vegetation, macroinvertebrates, fish and wetland birds species, as well as toxicology and paleolimnology, are able to document change over time. Data showing both historical and pre-restoration condition are used to set goals for what the post-restoration estuary will look like.

The St. Louis River estuary is shown here as it joins Lake Superior. Image courtesy of the author.

Delivering solutions for resilient communities

NRRI was given a unique mission in 1983 when it was established through legislation by state leaders who understood the need for sustainable use of Minnesota's natural resources. Thirty-five years later, the staff of approximately 150 continues that important work with renewed vigor as new challenges emerge and the balancing act becomes more complex.

Large uncertainties exist with respect to the future of Minnesota's water resources. While Minnesota is generally a water-rich state, there are regions that are likely to experience stress as a result of climate and land use change.

"We are facing both threats and opportunities as society strives to adapt to changing conditions and become more resilient," said Johnson. "What is clear is that a systems approach will continue to be necessary to increase efficiencies, and where possible, prevent problems before they demand expensive remediation."

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About the Author

June Breneman is NRRI External Affairs Manager and has been telling the stories of this unique research institute for 18 years. June holds a master's degree in journalism and English from the University of Minnesota Duluth. Prior to her career at NRRI, she worked seven years in both print and television journalism, as well as some magazine freelance writing. She and her husband live on the Wisconsin side of the St. Louis River Estuary and enjoy canoeing and hiking.

FEATURE

STATES OF EMERGENCE/Y: COASTAL RESTORATION AND THE FUTURE OF LOUISIANA'S VIETNAMESE/AMERICAN COMMERCIAL FISHERFOLK

By Simi Kang

"The current environmental situation that has given rise to [Louisiana's] coastal restoration programs is not limited to the ecological, geological, and hydrological processes that produce land loss. Humans make the decisions, they design the projects, and cope with the consequences. Indeed, the combined processes of coastal land loss and coastal restoration will create conditions impelling residents to adapt once more." (Colten 2017, 2)

"If [we cannot shrimp] you take away the only economic opportunity [we] have here." (Vietnamese commercial shrimper, LA SAFE meeting in Buras, LA, June 5, 2017)

Louisiana's commercial shrimping fleet is threatened day in and day out by oil spills, a seasonal hypoxic dead zone, a flood of foreign imports, and, significant to all of these, the

Shrimp boat off Grand Isle, Louisiana. Image courtesy of Billy Metcalfe, (CC BY-NC-ND 2.0)

long-term institutional management of the coast's land, water, flora, and fauna. While all coastal entrepreneurs feel the strain of environmental and human-made crises, their consequences are borne more heavily by first-generation, 1.5-generation,[1] and second-generation Vietnamese/American[2] fisherfolk.[3] Language barriers, a lack of political representation, and cultural differences make Vietnamese/American (and other Southeast Asian/American) fisherfolk more vulnerable to projects that, well intentioned though they may be, promise to change the material and cultural landscape of Louisiana's coast.

State management of Southeast Louisiana's natural resources is historically a part of the region's

Shrimp boats. Image courtesy of the author.

colonial project,[4] which has long required residents to make watery marshland inhabitable (Campanella 2006; Morris 2017). In its current iteration, management threatens to hit shrimpers hardest in the form of a science-oriented suite of coastal restoration projects called the Master Plan for a Sustainable Coast (also referred to as the master plan). As one of the fishery's most vulnerable communities, Vietnamese/American shrimpers stand to lose one of their major industries, and with it, the community's economic bedrock, when a proposed large-scale Mississippi freshwater and sediment diversion is introduced into the nation's most productive and abundant shrimp habitat.

Unlike other Gulf states, Louisiana's coast is made up of muddy marsh, which gives these organisms places to cycle through their adolescence relatively safe from other actors, including oil, before reaching maturity in open water. That the BP oil catastrophe (2010) completely suffocated this vibrant ecosystem, making shrimp smaller and less abundant, killing whole oyster beds, suffocating the birds and other fish species who rely on both, and strangling the region's fauna in the process, is still evident in every trip commercial fisherfolk take. In the last five years, each brown shrimp season has been worse than the last, oyster beds are increasingly taking on too much fresh water from harsher hurricane seasons, and the industry as a whole is suffering.

For the last two years, I have worked with several community-based organizations[5] that provide social and economic support to Southeast Louisiana's residents. In light of changing ecological, industry, and restoration outlooks, many of these organizations work together, partnering with NGOs, non-profits, and other

Capt. Bean, Port of New Orleans. Image courtesy of the author.

community-based organizations to advocate for coastal residents and entrepreneurs at the state and federal level. Throughout the course of my research, I attended local and national government meetings, public comment sessions, and outreach opportunities with commercial fisherfolk, their families, and owners of other fishing-dependent businesses like processing docks and fuel stations. This has allowed me to observe what it means for them to survive the onslaught of ecological, policy-based, infrastructural, political, and cultural engineering they experience as both the state's first line of defense and concomitantly, its most vulnerable people. Using this first-hand knowledge and relying on the expertise of commercial fisherfolk, this article considers the political and cultural contexts of the master plan, then addresses local efforts to respond to and resist the extinction of not just an industry, but a way of life for Vietnamese/Americans in Southeast Louisiana.

DIVERTING DISASTER

"People are in crisis. Economies are in crisis....For policy, any crisis in the productivity of radical contingency is a crisis in participation, which is to say, a crisis provoked by the wrong participation of the wrong(ed)." (Harney and Moten 2013, 81)

Immediately following the catastrophic effects of Hurricanes Katrina and Rita (2005) on Louisiana's coast, the state passed Act 8. This established the Coastal Protection and Restoration Authority (CPRA), a state agency that partners with marine biologists, soil specialists,

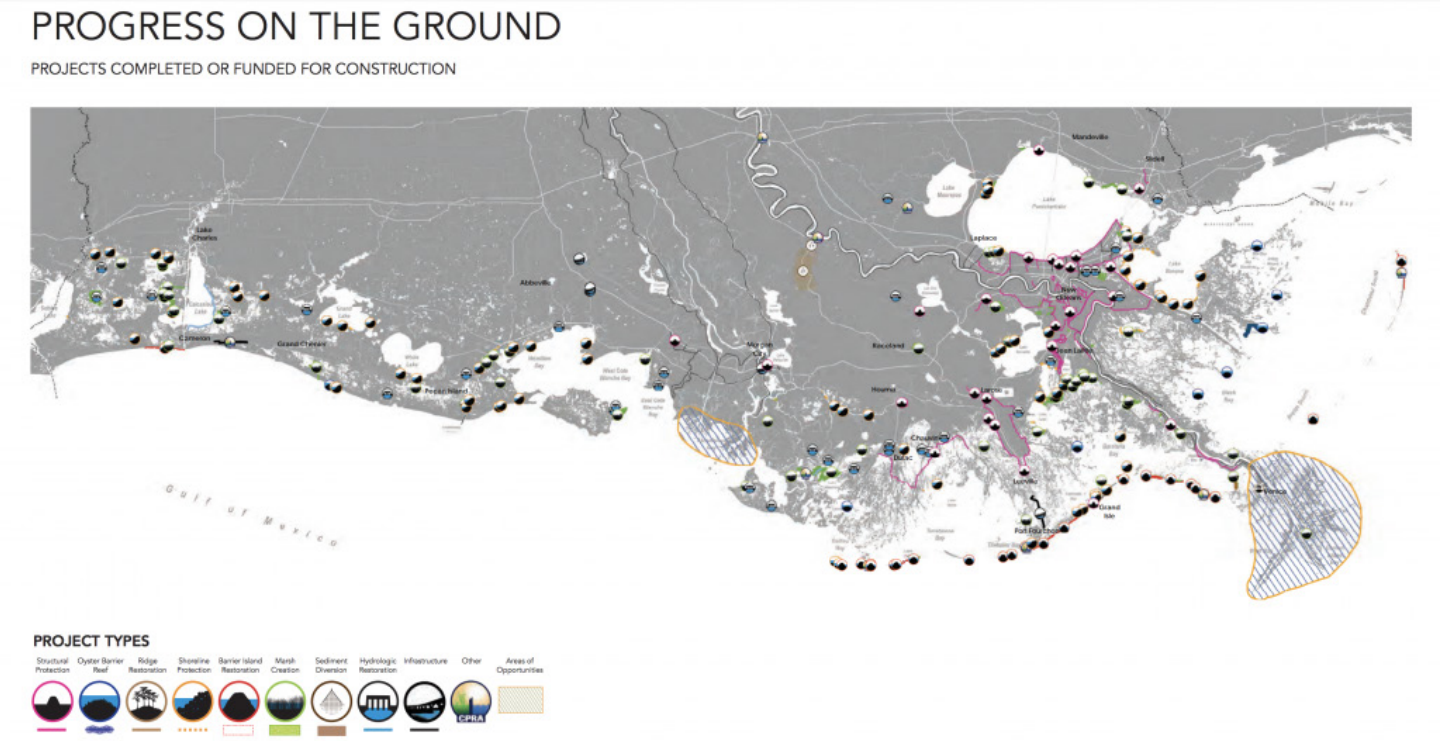

Figure 1. Projects completed or funded for construction as of the publishing of the 2017 Coastal Master Plan (CPRA 2017:ES-5).

and other scientists, non-governmental organizations, and industry heads to solicit and implement three types of restoration projects: structural, non-structural, and restoration. It has a dedicated budget largely comprised of federal- and state-allocated funds, and publicly releases a budget annually to identify how these funds are and will be directed. In creating this organization, Louisiana integrated hurricane protection and coastal restoration, formerly the purview of disparate local authorities and parish governments, under one agency. Tasked with developing a comprehensive, science-vetted plan to stop the coast from washing away, CPRA created the 50-year Master Plan for a Sustainable Coast which, "in its purest sense, is a list of projects that build or maintain land and reduce risk to our communities" (CPRA 2017:ES-2).

CPRA released its first master plan in 2007 and has revised and updated both the plan's projects and its short- and long-term goals every five years thereafter.

Over the lifetime of the plan, the authority has worked to grow its budget and resources in order to implement one of its key initiatives: a series of Mississippi River sediment diversions aimed at rebuilding land around the river's mouth in Louisiana's southeastern-most region, the Birdfoot Delta. According to CPRA, diversions are a direct response to over 80 years of land loss resulting from the U.S. Army Corps of Engineers' (USACE) leveeing of the river following the Great Flood of 1927. In protecting New Orleans and other river-adjacent communities from future

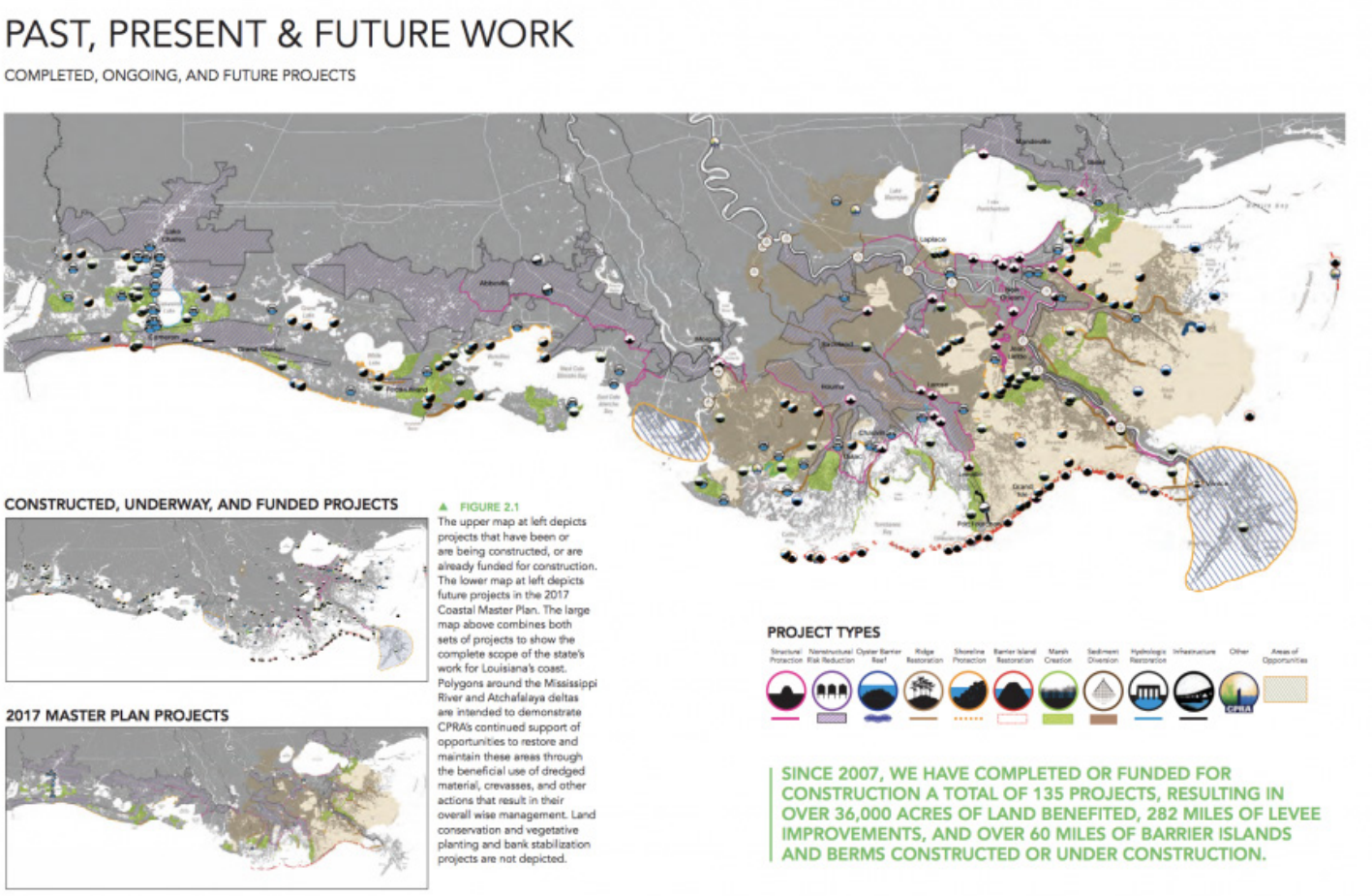

Figure 2. This map indicates which projects CPRA included in the 2017 Master Plan for a Sustainable Coast. Brown or tan areas indicate proposed sediment diversions, including in Mid-Barataria Bay, due south of Lake Pontchartrain (CPRA 2017:ES-15).

flooding, the Corps trained the Mississippi's land-building sediment away from the marsh that protected the region against gale-force winds and storm surge, instead sending it impotently over the continental shelf.

Now in its third revision, the master plan is laying the groundwork for two major diversions. Passed by the Louisiana State Legislature in the spring of 2017, this plan proposed the largest, most costly projects in the Authority's history, with sediment diversions in Mid-Barataria Bay (due south of New Orleans and to the delta's west) and Mid-Breton Sound (northeast across the delta from Barataria) representing a significant percentage of its resources. As written, these projects would "reconnect and re-establish the natural or deltaic sediment composition process between the Mississippi River and the [basins], as a long-term resilient, sustainable strategy...[that] is needed to reduce land loss rates and sustain wetlands injured by the [Deepwater Horizon] oil spill through the delivery of sediment, freshwater, and nutrients" (Gulf Engineers & Consultants 2018:1).

At present, Mid-Breton is in research and development, while Mid-Barataria has advanced to the permitting phase. In August of 2017, the USACE began the Environmental Impact Statement (EIS) process for Mid-Barataria, conducting preliminary scoping meetings and soliciting public comments. While USACE originally planned for the EIS to take five years, Louisiana's Governor and CPRA successfully lobbied the federal government to speed the process along, arriving at a projected completion time of 2022. As the plan is currently designed, CPRA will use the natural flow of the river basin to determine when to open the diversion at what rate. Once the EIS is completed, CPRA plans to run the diversion primarily in the spring; as the river thaws up-stream, it will bring more sediment to the delta than at any other time of year. Spring, however, is when most of the Gulf's marine life is breeding and one catch in particular—brown shrimp, which, along with white shrimp, supplies 26 percent of the nation's demand—needs the brackish water along the coast to properly gestate and mature (Louisiana Sea Grant 1999). To introduce up to 75,000 cubic feet per second (cfs) of sediment and fresh water into a habitat whose survival requires a mix of salt and fresh means that either whole species will suffocate (particularly oysters, which are fixed in place) or species like brown and white shrimp will be forced further into the Gulf, just beyond the reach of small skimmer boats that hug the coast.

EXPERTISE AND ERASURE

"When you pose a problem, you present a problem." (Ahmed, February 17, 2014)

Brown shrimp are the lifeblood of small-scale commercial shrimpers who can only work in state waters, the narrow, three-mile strip of ocean that functions as Louisiana's aquatic buffer zone. These are also some of the most tenuous ecosystems in the state, where the oil catches and sticks and hulls are destroyed by abandoned drilling equipment; where the cypress and mangroves are dying or dead, and island after island has ceded to the ocean, no longer there for birds to rest on their long journey south. It is also where, like so many other vulnerable places, the workforce is overwhelmingly low-income members of underserved communities with little political or economic capital.

Vietnamese/American fisherfolk are a critical portion of this workforce, comprising almost 40 percent of the commercial shrimp fishery (Louisiana Sea Grant 2015:5). Most were

shrimpers in Việt Nam prior to the forced diaspora that followed the Fall of Sài Gòn in 1975. After their forced flight and resettlement in Louisiana, Vietnamese shrimpers transferred their skills to the Gulf, where they have become a driving force of the local economy over the last three decades. Like Cajun and other shrimpers in Louisiana, Vietnamese/American fisherfolk's knowledge of the industry and its relation to the land, water, and other species upon which it relies is generations deep, or as many will say, in their blood. In this way, the community's attachment to the industry is not solely labor- or income-centric, but a critical part of their relationship to personal histories and knowledges that deeply attach to the place wherein they animate both: Southeast Louisiana.

Popular storytelling often depicts commercial fishing as exploitative, pitting fishermen against initiatives meant to preserve and foster marine ecosystems. In truth, however, their social, cultural, and economic reliance upon the region require vulnerable commercial fisherfolk to act as the region's stewards. Each time they haul up a net, add gear to their boat, file their taxes, or start a college fund, Vietnamese/American fisherfolk are thinking about entire ecosystems, from the plankton to the pelicans, that make their industry possible.

Given this deep knowledge and attachment to place, commercial shrimpers—among many other coastal stakeholders including Indigenous Elders and other community leaders—are natural experts in the water, land, flora, and fauna of coastal Louisiana. While the diversion and master plan writ large rhetorically emphasize the value of coastal communities (see Figure 3, below), CPRA regularly disregards community needs and knowledge in its solicitation, research and design, and implementation processes. This is not simply because representatives reject or otherwise refuse to acknowledge community knowledge, however; in South Louisiana politics, so many decisions rely on a close consideration of oil and tourism revenue. In this way, dollars—not people—make a place. For example, the fact that CPRA is now trying to undo federal land and water management projects that effectively killed a large swath of Southeast Louisiana speaks not to their concern for the people who live there—people who have, over a few generations, been forced to adapt to that resource starvation to survive as fishers, hunters and trappers, and coastal residents—but to the fact that the area is now so degraded that New Orleans, the region's main attraction, has lost its storm buffer. What's more, when asked about the efforts the state is making to identify the possibly irreparable effects the diversion might have on shrimp, oysters, and other marine species and by extension, mitigate the impact to shrimpers and other fisherfolk, CPRA officials say that the former is too difficult to predict and so the latter is equally impossible to address.
With this understanding of CPRA's approach to project design and implementation, two things become clear: one, Louisiana's residents must be more resilient than the land they live on and, two, for the state to adequately control and re-design coastal Louisiana, it must carve up the coast in a different way. Through the master plan, CPRA has reduced coastal Louisiana to a series of projects, budgets, timelines, and lobbying efforts. As the state both rhetorically and materially dissolves through a scientific re-imagining of space as discreet problems and attendant solutions, so too does the very notion of a region of people, families, and communities. Look at Figures 1 and 2 (above) long enough and you realize that something truly telling is missing from CPRA's landscape: people.

Photos courtesy of Louisiana Sea Grant

While coastal Louisiana provides the state, region, and nation with important natural resources, here the greatest assets are not oil and gas, fisheries, or sugar cane, but the people.

Figure 3. A collage of photos representing coastal Louisiana residents, with a caption reading: "While coastal Louisiana provides the state, region, and nation with important natural resources, here the greatest assets are not oil and gas, fisheries, or sugar cane, but the people." The inclusion of these images and the accompanying caption in the 2017 Master Plan for a Sustainable Coast is an example of how CPRA identifies coastal communities as both an asset and a justification for the way it implements restoration projects (CPRA 2017:ES-3).

Figure 4. This infographic is captioned: "Together, the Louisiana coast and the Mississippi River create billions in economic value" in the master plan. Here, we see that while people matter in the prior image, it is in fact the economic value of the region that is central to CPRA's decision-making processes.

STICKY RESILIENCE

"I'm sick and tired of people saying 'y'all are so resilient;' resilient means you can do something to me. No! I'm not resilient. I have a right not to be resilient." (Washington, August 25, 2015)

The story goes that to survive along the Gulf, one must be resilient. To be resilient, then, one must bear anything as it comes; if the entire ecosystem of Barataria Bay changes because of the diversion, then so too must fisherfolk. If brown shrimp are suffocated or pushed beyond state lines, it is the job of fisherfolk, not the state, to mitigate that loss. Look at CPRA's maps again, and you see how surviving against the odds effectively erases whole communities; if they are resilient, they do not need the master plan. By relying on residents' resilience, CPRA both excises their vulnerability and gives the state the freedom to worry about more important things like building land.

While resilience silences every one of Louisiana's coastal residents, the way it is deployed against Vietnamese and other Southeast Asian fisherfolk is particularly damning. Under the harsh conditions they currently face, this community is in many ways trapped in the very industry they love. This is true because:

- First, the majority of other blue-collar industries in the Gulf, from oil work to shipbuilding, have English-only training and entrance exams, effectively barring all for whom English is not a first language;

- Second, because boat insurance is equivalent to almost a third of their take-home pay, most boat owners cannot afford it. This prohibits captains from using their boats for tourism or other income-generating endeavors and makes it impossible to secure loans (banks require proof of insurance); and

- Finally, small-scale shrimpers cannot earn enough liquid capital to expand their operations into federal waters, where the shrimp will be pushed when fresh water inundates the area.

In these ways, then, the state *forces* Southeast Asian and Southeast Asian American fisherfolk to continue fishing in the Gulf—one of the most vulnerable places in the nation—and calls them resilient for surviving ever more punishing economic, political, and environmental conditions.

That Vietnamese/American fisherfolks' survival tactics have been written into policy—thus normalizing resilience such that it is their socio-legal *duty*—shows that rather than creating new coastal futures, the state is instead using the coast as it always has: as critical space for producing infrastructure that protects tourism, shipping, oil, and other assets to the detriment of every human and marine community, home, boat, and processing dock in the way. That so many of these in-the-way peoples are Indigenous, refugee, and im/migrant[6] points to the insidious ways they have been made vulnerable by political decision making that, ironically, requires that same vulnerability to function.

EMERGENCE/Y

"Who is going to use the land they build if we aren't here no more? [If the shrimp disappear] we will disappear." (Vietnamese commercial shrimper, LA SAFE meeting in Buras, LA, June 5, 2017)

After the 2017 Master Plan for a Sustainable Coast was approved, CPRA began the process to approve the Mid-Barataria Bay diversion. Later that year, USACE began laying the groundwork to conduct an Environmental Impact Statement (EIS) of the project, which they believed could take up to five years (until 2022). Before USACE could begin the process, Louisiana's Governor, John Bel Edwards, declared a state of emergency for coastal Louisiana on April 19, 2017. In the official document, the governor urged Congress to fast-track five projects in the master plan, including the diversion, because "Louisiana and its citizens have suffered tremendously as a result of catastrophic coastal land and wetlands loss, and the threat of continued land loss to Louisiana's working coast threatens the viability of residential, agricultural, energy, and industrial development" (CPRA 2017). After a month without federal reply, the state of emergency expired. Keeping to its extended schedule, USACE began the EIS process three months later by conducting scoping meetings to solicit scoping comments, or comments intended to identify the positive and negative attributes of the project, from the public.

Over 200 commercial fisherfolk, many Southeast Asian/American, submitted comments, including the following:

> "I have a skimmer boat and fish inshore. If the diversion comes. It'll bring too much freshwater into the lake where I shrimp. Too much freshwater will push the brown shrimp out further into the Gulf and my boat is not big enough to go outside state lines. Right now, I can't make my existing boat bigger because shrimpers just aren't making any money. If the diversion comes then I'll have to stop shrimping and then I'll be out of a job." (Pheap Phon)
>
> "If the diversion happens, my job will be affected. I am a deckhand on a shrimp boat. If the owner of the boat does not go shrimping, I cannot go shrimping. I have no skill sets besides shrimping, that's why I want to continue shrimping. I am too old to learn new skills; my English is very limited so it will be hard to do anything else." (Phung Phu)
>
> "I do not agree with [the Mid-Barataria sediment diversion] for many reasons. My father will not make enough money to pay for our family. He is the worker of our family, meaning he is the only one who is paying for our financial bills and education for my brother and me. My mother cannot speak English, she stays home and takes care of the house and her children...If you decide to release the fresh water, keep in mind all the lives you would make more difficult and all the hard work you would put down the drain...Please don't release the fresh water. It [will] create a gruesome impact in our lives and many others who have worked extremely hard for the lives that we currently have [today]." (Lili Tran)
>
> "I am an older fisherman and if there are no shrimp then I will be out of a job. If the government would help me with making my boat bigger so that I could go out further [into federal waters to follow the shrimp,] then that would be a good thing. I'm open to getting a grant or a loan. I would even open a new

> business if I had help. I've lived many places, but I like Southeast LA the best." (Chhiet Lat)

Here, it is clear that commercial shrimpers experience their boats not just as material sites for producing capital—the system of which is skewed toward the top and rarely adequately or evenly compensates them for their labor—but as future-securing enterprises. Rather than being concerned about the shrimp per se, these deckhands and captains are worried about how, in CPRA's hands, the shrimp control their families' futures.

What the above comments make clear is that the barriers against Vietnamese/American shrimpers learning skills other than shrimping are not merely economic, but deeply social and political. They produce the consequences this story began with a disappearing coast within which its most vulnerable people—its experts and stewards—are disappearing. This disappearance is deliberate, maintaining a power imbalance that keeps Vietnamese/American commercial fisherfolk always in a position of lack. In this way, the Mid-Barataria Bay diversion and its likely impacts are not simply a fisherfolk problem; it is specifically a Southeast Asian/American fisherfolk problem.

PERPETUAL RESILIENCE

"Once refugees outlive their narrative usefulness they become disposable." (Patel and Tang, June 20, 2016)

In Southeast Louisiana, it is a matter of course that residents will adapt. Adaptation is most often demanded of the state's most underserved and underrepresented communities, who cope with the consequences of government-mandated projects that re-shape, create, and dissolve the land and water upon which they rely. As people who have been forced to bear the burden of U.S.-sanctioned violences for generations, Vietnamese/American fisherfolks' intimacies with adaptation and resilience are well documented, often by scholars and journalists who deploy racialized public health and sociological language, laying the groundwork for CPRA's own "resilience requirement" (Le and Nguyen 2013; Li et al. 2010; VanLandingham 2017). The consequences of Mid-Barataria Bay sediment diversion will be overwhelming for Vietnamese/American fisherfolk. Those who do not develop the language and technical skills to enter other industries will be left behind, struggling to support themselves or requiring a great deal of support from already under-resourced peers and family. The likelihood of forced displacement—moving from one's home against one's will—will only engender more distrust of a nation that, over and over again, claims its own injury in relation to the war that already forced them to leave many homes (Nguyen 2012; Ong 1999; Um et al. 2012). As detailed above, the diversion as it is planned is the result of preserving capital accumulation (oil, tourism) over privileging community survival. It excludes residents whose first language is not English from full participation in private and public life, excluding them from secure presents and futures. What's more, it refuses local, experiential knowledge of culture, ecology, and place in favor of "hard" science.

But the diversion will happen. In late January, 2018, the Trump administration agreed to accelerate the permitting process for the EIS from five to two years (Stole 2018). More recently, CPRA representatives told a roomful of fishermen that they must stop talking about "if," shifting the conversation to "when." With an understanding

of how the master plan dispossesses Vietnamese/American and other shrimpers who steward and rely on state waters, community-based organizations have used this moment to craft collaborative responses to the plan. Given that their work to uplift fisherfolks' place- and ecology-specific expertise has failed to materially change CPRA's approach to the diversion, these organizations are moving forward with their own independent programming. Community leaders hope that implementing new coastal education models for youth, testing industry-specific loans and grants, and creating other novel programming will provide a percentage of the support their constituents need to weather such definitive state erasure.

However, there are rarely perfect answers when capitalism and colonialism have been writing the story of a place for generations. What is implied but never made explicit in Colten's assertion that "Humans make the decisions, they design the projects, and cope with the consequences" is that for each action, the "humans"—decision-maker, project designer, and consequence coper—are vastly different. And here is the crux of the issue: the complexities of individuals' and communities' experiences of success and struggle are flattened and dismissed by state agencies whose relationship to place is one of management rather than stewardship. Instead of listening to the experts—those whose very lives rely on maintaining and cultivating the coast in spite of human-made disaster—state and federal actors push ever forward in a battle not toward a more secure future for all, but for state revenue. By making land stable, oil can consistently be transported on the region's highways and refined near its small towns; New Orleans retains its land buffer and can withstand the next 100-year storm; barge traffic flows in and out of South Louisiana, maintaining its place as a critical node of transnational trade.

Restoration re-makes place and space to solve a set of problems the state itself produced. In always seeking to manage, control, and create hierarchies of value—for ecologies, industries, and communities—Louisiana and CPRA redesign not only the region's current, but future possibilities. As some of the region's most economically and ecologically vulnerable peoples, Vietnamese/American fisherfolk have, as Patel and Tang gesture to above, become disposable. This happens in large part because of the double bind of resilience: while they are actively *being resilient* to a myriad of violences and circumstances, policymakers require fisherfolk to indefinitely *maintain resilience*. As such, Vietnamese/American fisherfolk at once pose a problem for and offer a solution to CPRA: those who survive can and must continue to do so. If they do not succeed, that is a communal failure, not a state one.

For CPRA to undertake the true work of helping the coast survive, they would need to cede political power and economic resources to the people, the true experts of the coast. If they quit calling an exorcism a survival and let those who have always been made to survive actually try to do so, maybe the coast could call itself home again.

Footnotes

[1] Refugees born in Southeast Asia and who fled to the U.S. as young children sometimes identify as between first- and second-generation, or 1.5.

[2] I use the composite term Vietnamese/America with a slash to indicate the myriad generations—first, 1.5, or those born in Viet Nam but arriving in the U.S. as children, and second—of peoples of Vietnamese heritage who work in the industry. Many first-generation fisherfolk prefer to call themselves "Vietnamese" or "Asian" over "Vietnamese American," a designation that sometimes feels more appropriate for later generations (who often vacillate between all three).

[3] I use the gender-neutral term "fisherfolk" when writing about the commercial fishing industry as a whole to acknowledge that it extends beyond the discreet spaces of fishing boats and processing docks to the home and family, the members of whom directly contribute to its economic and cultural success. As such, commercial shrimping relies on the labor of all genders.

[4] New Orleans is currently hosting a year's worth of public programming to celebrate its Tri-centennial as a city; among other things, this points to a failure to acknowledge that the space New Orleans occupies is extant, un-ceded Chikasaw land. While this programming acknowledges the city's economic contributions to the U.S. as a primary port, it largely fails to acknowledge that this also made New Orleans a central axis for the exchange of enslaved African and Caribbean peoples, a site of passage for Asian immigrant laborers, and the transit of bodies across French and Spanish colonies and, more recently, a place of resettlement for peoples made refugees of U.S. military engagements the world over, from Southeast Asia to Eastern Africa.

[5] While these organizations allowed me to observe and participate in their work during my research period, the views expressed herein are mine alone.

[6] I use the composite im/migrant to index the fraught relationship between migration and immigration in and to the U.S., particularly their contested and overlapping social and legal expectations, requirements, and lived experiences.

Works Cited

Ahmed, Sara. 2014. The Problem of Perception. feministkilljoys.com, February 17, 2014.

Colten, Craig E. 2012. An Incomplete Solution: Oil and Water in Louisiana. *Journal of American History* 99(1): 91–99.

Colten, Craig E. 2017. Introduction. In *A Louisiana Coastal Atlas: Resources, Economies, and Demographics*. Baton Rouge: LSU Press.

CPRA. 2017. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Baton Rouge, LA: Coastal Protection and Restoration Authority.

Foundation for Louisiana and Office of Community Development. 2017. LA SAFE Meeting Four. Buras, LA.

Gulf Engineers & Consultants. 2018. Mid-Barataria Sediment Diversion Project Final Scoping Report. U.S. Army Corps of Engineers.

Harney, Stefano, and Fred Moten. 2013. *The Undercommons: Fugitive Planning & Black Study*. New York: Minor Composition.

Houck, Oliver A. 1983. Land Loss in Coastal Louisiana: Causes, Consequences, and Remedies. *Tulane Law Review* 58: 3.

Ko, Jae-Young, and John W. Day. 2004. A Review of Ecological Impacts of Oil and Gas Development on Coastal Ecosystems in the Mississippi Delta. *Integrated Coastal Management in the Gulf of Mexico Large Marine Ecosystem*, issue of *Ocean & Coastal Management* 47(11): 597–623.

Le, Mai-Nhung, and Tu-Uyen Nguyen. 2013. Social and Cultural Influences on the Health of the Vietnamese American Population. In *Handbook of Asian American Health*, edited by Grace J. Yoo, Mai-Nhung Le, Alan Y. Oda, 87–101. New York: Springer-Verlag.

Li, Wei, Christopher A. Airriess, Angela Chia-Chen Chen, Karen J. Leong, and Verna Keith. 2010. Katrina and Migration: Evacuation and Return by African Americans and Vietnamese Americans in an Eastern New Orleans Suburb. *The Professional Geographer* 62(1): 103–118.

Nguyen, Mimi Thi. 2012. *The Gift of Freedom: War, Debt, and Other Refugee Passages*. Durham, NC: Duke University Press Books.

Ong, Aihwa. 1995. Making the Biopolitical Subject: Cambodian Immigrants, Refugee Medicine and Cultural Citizenship in California. *Social Science & Medicine* 40(9): 1243–1257.

Patel, Raj, and Eric Tang. 2016. Commentary: For refugees, awkward truths about U.S. asylum. *Reuters*, June 20, 2016.

Stole, Bryn. 2018. Trump administration pledges to speed up permits for the Mid-Barataria sediment diversion. *The Advocate*, January 26, 2018.

Um, Khatharya, Mimi Thi Nguyen, Fiona B. Ngo, and Miriam Lam. 2012. Exiled Memory: History, Identity and Remembering in the South East Asian Diaspora. Southeast Asians in Diasporas. positions: east asia cultures critique 20(3): 831–850.

VanLandingham, Mark. 2017. *Weathering Katrina: culture and recovery among Vietnamese Americans*. New York: Russel Sage Foundation.

Washington, Tracie. 2015. What Does It Mean to Know New Orleans? Presentation at New Orleans: Ten Years Later. The Atlantic (conference), New Orleans, Louisiana, August 24, 2015.

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About the Author

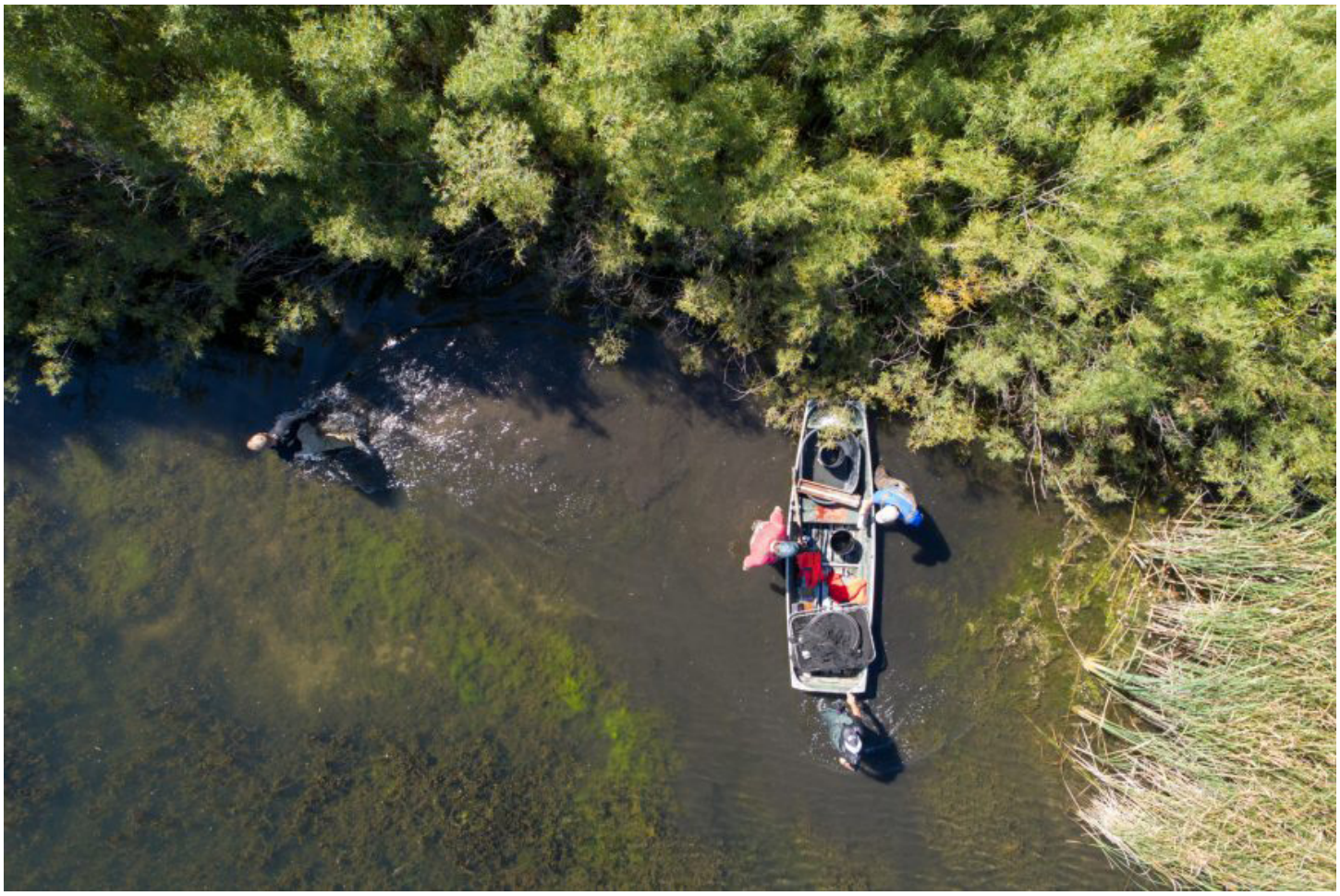
Simi Kang is a scholar, artist, educator, and community advocate who engages Asian American collaborative resistance as a site for imagining ecologically and economically just futures. Simi works with Vietnamese and Vietnamese American fisherfolk to understand how state policy impacts their communities at the intersection of resistance, resilience, and displacement. She is currently a Ph.D. Candidate in the Feminist Studies program at the University of Minnesota, Twin Cities. Her work has appeared in *The Asian American Literary Review, Kartika Review, Hyphen Magazine, Jaggery: A DesiLit Arts and Literature Journal, Gravy Quarterly,* and *Gastronomica*.

FEATURE

MINNESOTA AQUATIC INVASIVE SPECIES RESEARCH CENTER

By Christine Lee and Nick Phelps

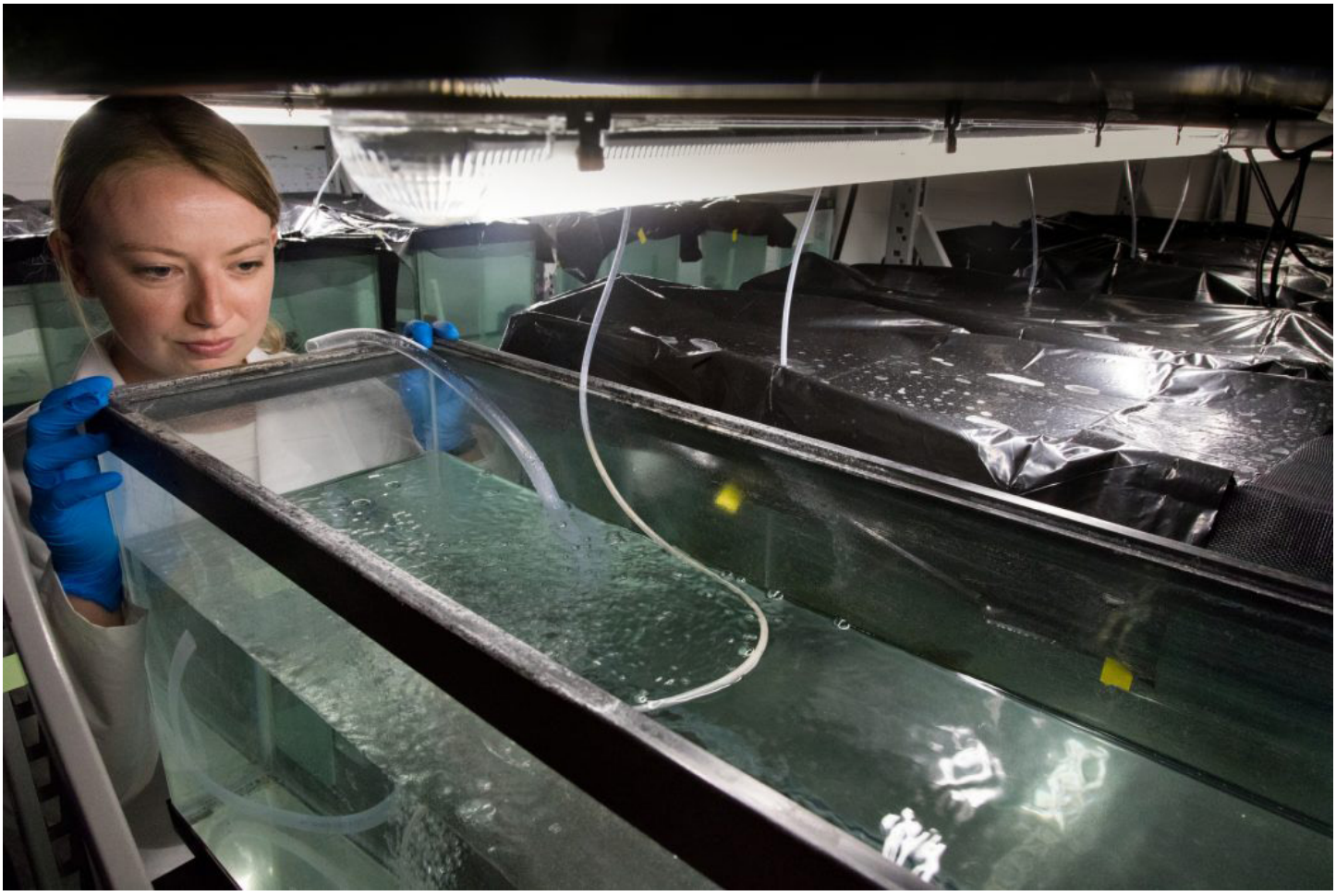
The Minnesota Aquatic Invasive Species Research Center (MAISRC) was founded in late 2012 when the Minnesota legislature and the University of Minnesota took a leadership role in the fight against aquatic invasive species (AIS) and created our interdisciplinary, innovative, and forward-thinking Center. This initiative was led by Dr. Peter Sorensen, a well-known invasive carp researcher who is still working with the Center on several projects. Our initial funding was provided by the Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources and the Clean Water Fund.



MAISRC researcher Przemek Bajer and his team studying the use of bluegills as a biological control for common carp. Image courtesy of Dave Hansen, University of Minnesota.

The Center's mission is to develop research-based solutions that can reduce the impacts of aquatic invasive species in Minnesota by preventing spread, controlling populations, and managing ecosystems; and to advance knowledge to inspire action by others.

We strongly believe in the value of collaboration and coordination, which is why operating as a Center instead of funding individual research projects is important to us. Although we are housed at the University of Minnesota, we support projects across the state. We currently have projects led by researchers at the U.S. Geological Survey, the Minnesota Department of Natural Resources (DNR), and the University of Minnesota—Duluth and Twin Cities campuses; and we also partner with researchers around



MAISRC graduate student Megan Tomamichel in the newly renovated Minnesota Aquatic Invasive Species Containment Lab. Image courtesy of Dave Hansen, University of Minnesota.

the world. We have spent considerable effort in these early years of MAISRC to develop a species prioritization process, an inclusive and systematic research needs assessment, and a competitive and peer-reviewed funding process to ensure that the most-needed research is being addressed.

Thanks to funding from the Minnesota legislature, we recently completed renovations to our lab and holding facility. What was once a tractor garage built in 1911 is now one of the most state-of-the-art labs in the country, at which AIS research of all kinds can be safely conducted.

MAISRC researcher Ray Newman holds a jar of invasive plants. Image courtesy of Dave Hansen, University of Minnesota.

What the Center does

To date, MAISRC has supported over 40 projects on 11 different species. Our research focuses on the control and management, early detection, and prevention of key invasive species that are either already in Minnesota or considered to be high-risk to arrive in the state. Research varies greatly by the species, its life cycle, and its invasion status.

MAISRC currently conducts research on invasive plants, fish, invertebrates, and pathogens. Find out what we've learned so far and what the next steps are below.

MAISRC researcher Peter Sorensen and his team take measurements of common carp. Image courtesy of Dave Hansen, University of Minnesota.

Invasive plants

Species	Accomplishments so far	What's next?
Eurasian watermilfoil	MAISRC researchers have established best practices for treating this invasive plant using chemicals and biocontrol through milfoil weevils. We've also identified hotspots where Eurasian watermilfoil is most likely to be found next, in order to prioritize prevention efforts.	Researchers are quantifying the genetic diversity of Eurasian, hybrid, and northern watermilfoil across the state to establish, develop, and prioritize management strategies. We're also identifying pathogenic microbes associated with Eurasian watermilfoil to possibly use for biocontrol.
Starry stonewort	When this species was first found in Minnesota in 2015, MAISRC quickly convened a group of international experts to develop a strategic and collaborative research plan. Since then, we've evaluated the efficacy of mechanical and algaecide control methods in the field, identified hotspots for invasion and provided technical assistance to lake associations and agencies on managing this invasive alga.	Researchers are learning more about the phenology of starry stonewort to guide the timing of management, conducting lab experiments to test different algaecides, and creating a decision-making tool to prioritize resources for optimal prevention and intervention of starry stonewort.
Curlyleaf pondweed	Research on this invasive plant has focused on creating best management practices, including when and how to treat without negatively impacting the native plant community.	Research is ongoing to analyze the best time of year to apply herbicide treatments and how to enhance the recovery of the lake community by transplanting native plant populations.
Phragmites	In 2017, MAISRC collaborated with citizen scientists all over the state to identify and report non-native populations of *Phragmites*. These samples are now being genetically confirmed.	Once population distribution is understood, researchers will establish whether it is sexually or asexually reproducing. Then, management protocols for responding to different invasion scenarios will be developed.

Invasive fish

Species	Accomplishments so far	What's next?
Common carp	MAISRC research has progressed from laboratory to field experiments and informed the effective control of carp in multiple Minnesota watersheds. Control methods that have been successfully implemented include seining, removal at barrier sites in streams, and winter aeration. Researchers are also exploring using native predators for biocontrol.	Researchers are currently developing a species-specific toxin delivery system to control populations, harnessing naturally occurring carp viruses for biocontrol, introducing a synthetic barrier to reproduction that will lead to sterile offspring, and adapting stream barriers to remove carp during seasonal migrations.
Bigheaded carps (Asian carp)	MAISRC researchers installed the first acoustic deterrent system for carp in a lock and dam in the U.S. and are providing ongoing recommendations to the U.S. Army Corps of Engineers for adjusting spillway gate operations in ways that will reduce carp passage while still meeting their standards. MAISRC also conducted a collaborative risk assessment to determine high-risk watersheds and potential impacts, and to prioritize management efforts.	To further refine the lock and dam prevention strategies, researchers are evaluating the acoustic deterrent system using high-resolution imaging sonar to track movement of fishes. We're also conducting virus discovery and culturing potential pathogens for biocontrol.

Invasive invertebrates

Species	Accomplishments so far	What's next?
Zebra and quagga mussels	MAISRC set out to sequence a draft of the zebra mussel genome for the first time ever in 2015. Other genetic approaches have allowed researchers to identify relationships between zebra mussel populations across the state, which has helped to inform management strategies. In addition, connectivity networks have been created to understand boat movement and water connectivity to determine the optimal locations for decontamination units and inspection checkpoints. Research has also focused on limiting spread through residual water, establishing best practices for using commercially available molluscicides, and developing rapid response tools.	Researchers are working to identify markers in the genome that can be targeted for control using gene drive technologies. Researchers are also developing underwater population survey protocols, and quantifying the impacts of zebra mussels on walleye growth rates and food webs. MAISRC is also identifying pathogenic viruses and bacteria to evaluate their specificity and effectiveness as biocontrol for both zebra and quagga mussels.
Spiny waterflea	MAISRC launched its first spiny waterflea project in 2016. Since then, field work has been conducted on several lakes across the state, and two additional projects have launched.	Researchers are determining what gear on boats is most likely to spread spiny waterflea, quantifying their impacts on walleye-producing lakes, and analyzing lake sediments to identify the changes that occur to lakes after spiny waterflea invade.

Pathogens and harmful microbes

Species	Key Accomplishments
Viral hemorrhagic septicemia (VHS)	MAISRC researchers developed a new diagnostic assay for this virus that is 1,000 times more sensitive, lowered turn-around time from 28 days to 4 hours, and reduced cost by 40% compared to the previous test. We also developed risk management recommendations that have been implemented by the DNR to prevent the introduction and spread of VHS.
Heterosporis	MAISRC formally named and described the appearance, genetics, and pathology of *Heterosporis sutherlandae*, the causative agent of Heterosporosis. Researchers also conducted surveys of Minnesota fish populations to estimate current distribution and identify long-term and seasonal infection variability. We also developed an infection model to understand the disease over time in live fish and determined that it may have short-term impacts on yellow perch harvest, but long-term impacts are unlikely.

Zebra mussels, a major AIS challenge in Minnesota

There are numerous factors to consider when judging the urgency and impact of an invasive species threat, including:

- Whether it is already found in Minnesota and if so, how widely established it is
- How quickly it's moving around the state
- The level of ecological and environmental damage it can cause
- Whether good options for control are available.

Considering these benchmarks, zebra mussels are particularly troubling for Minnesota. The Minnesota DNR currently considers 180 bodies of

A SCUBA diver holding adult zebra mussels, which are covered by juveniles. Image courtesy of Naomi Blinick.

water to be infested with zebra mussels. They are moving quickly around the state, and can often travel undetected on boats, trailers, docks, and lifts. By filtering the water, they disturb the food web and can re-engineer the entire ecosystem. Their sharp shells can cut swimmers' feet when they wash up on shore, and they can cost millions of dollars in damage at water intake systems. Although some molluscides—like EarthTec QZ and Zequanox—have been developed, they are often prohibitively expensive and have been met with limited success, especially in the relatively cold waters of Minnesota lakes.

Because of this, we focus a lot of research effort on zebra mussels. MAISRC researchers are approaching this problem from many different angles, including:

- Detecting zebra mussels early using a new molecular assay
- Predicting their spread in order to prevent it
- Establishing whether they are spreading in the residual water of recreational boats—the water that is left after boats are drained
- Testing and evaluating commercially available molluscides to develop best practices for Minnesota lakes
- Sequencing the genome in order to find weaknesses that may be targeted for control.

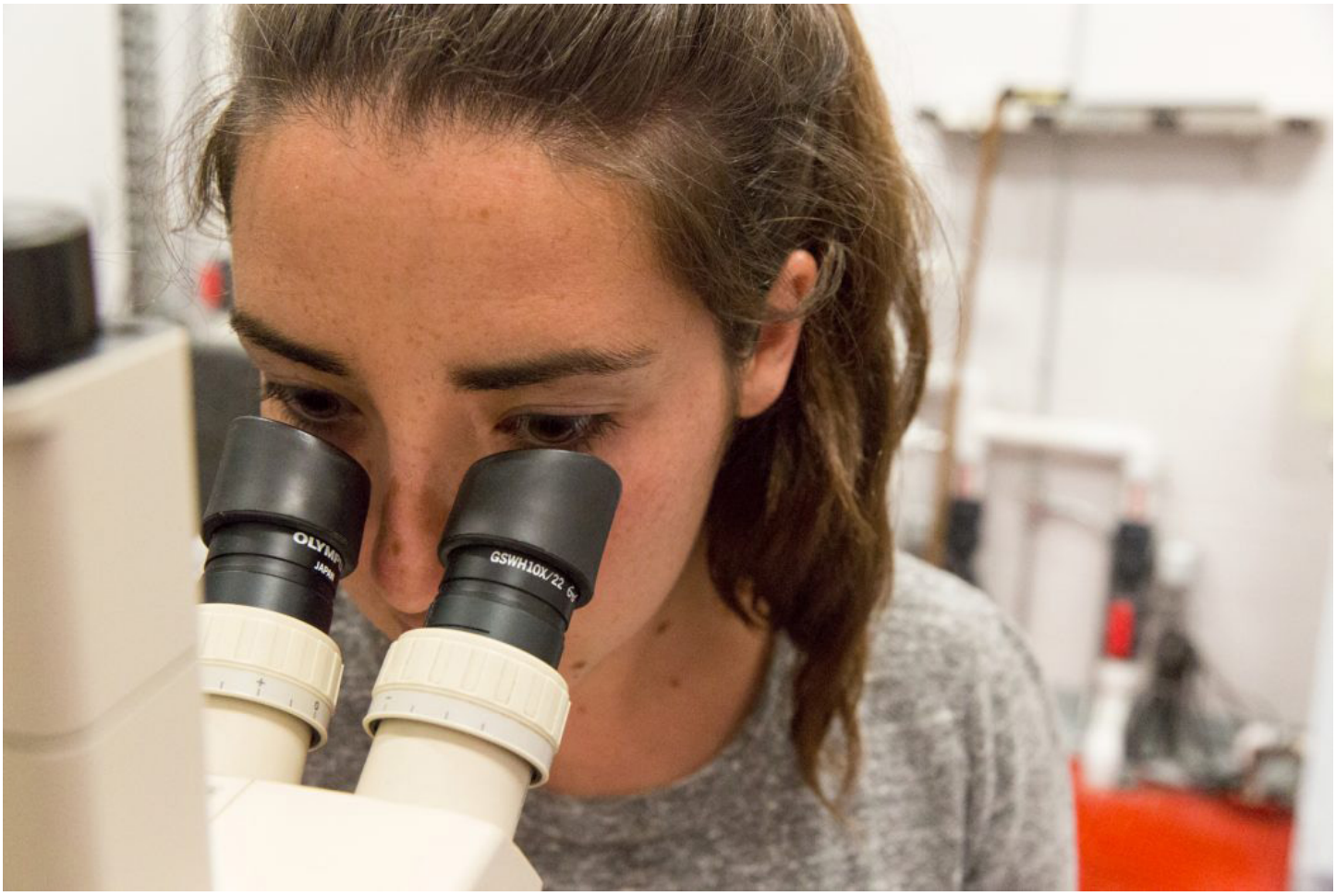
As more research is developed, the next significant challenge for AIS in Minnesota becomes changing behaviors and adapting to new norms.

MAISRC researchers Mike McCartney and Sarah Baker paddle to a zebra mussel research site on Lake Minnetonka. Image courtesy of Dave Hansen, University of Minnesota.

Opportunities for breakthroughs

Scientific discoveries are often made in incremental steps towards the big breakthrough; we need the endurance to see good ideas through to the end. This is particularly true for problems as complicated as AIS. That said, we have two areas of research that are showing great promise, both in the short-term and in the long-term: creating a sophisticated model that will help prevent the spread of AIS, and using genetics to control and suppress AIS.

A diverse team of MAISRC researchers is working together to create a decision-making tool that will help AIS managers, counties, and other agencies prioritize their resources for optimal prevention and intervention of AIS, specifically for zebra mussels and starry stonewort. The tool will answer two main questions: whether a species can get to a lake by assessing its proximity to other infested lakes, boater movement, and water connectivity; and whether it could survive there, based on lake and landscape variables such as temperature, precipitation, and pH. When complete, this one-of-a-kind model will help managers to efficiently utilize funding for AIS and improve prevention outcomes statewide.



A MAISRC researcher looks at zebra mussel veligers through the microscope. Image courtesy of Dave Hansen, University of Minnesota.

Field work on Red Lake. Image courtesy of Gretchen Hansen.

MAISRC researcher Przemek Bajer releases a fish at a study site near Lake Phalen. Image courtesy of Dave Hansen, University of Minnesota.

Researcher Dan Larkin and graduate student Carli Wagner look at starry stonewort on Lake Koronis. Image courtesy of Dave Hansen, University of Minnesota.

Longer-term, we're looking to the growing field of genetics research, which presents numerous promising opportunities. MAISRC currently supports two projects that use genetic tools: sequencing the zebra mussel genome in order to find weaknesses that could be targeted for control, and using genetics to introduce a synthetic barrier to reproduction in common carp.

A similar technology—a genetic modification that causes offspring to die—has been deployed in mosquitos and is undergoing trial in areas of Florida struck by the Zika virus.

Genetic technologies show promise to be very species-specific and cost-effective. However, we are taking seriously the environmental, ethical, and regulatory concerns posed by the application of genetic modification research.

MAISRC researcher Przemek Bajer and his team studying the use of bluegills as a biological control for common carp. Image courtesy of Dave Hansen, University of Minnesota.

The status of invasive Asian carp research

Silver and bighead carps—often referred to as Asian carp or bigheaded—were introduced to the U.S. nearly 50 years ago and have been moving up the Mississippi River ever since. There is not yet evidence of an established, breeding population in Minnesota, although some 30 fish have been captured in Minnesota waters between 1996 and today. Asian carp pose threats to aquatic vegetation, food webs, and commercial and recreational fishing. Silver carp pose an additional threat to human health due to their propensity to leap out of the water when disturbed.

Asian carp research has been the biggest recipient of funding at MAISRC since our inception, and this investment has allowed us to move research from the lab to the field. After discovering that these fish are relatively weak swimmers at their peak, researchers developed and optimized a plan to increase water velocity by adjusting spillway gate operations at locks and dams, the details of which have been recommended to the U.S. Army Corps of Engineers.

MAISRC researchers have also installed the first acoustic deterrent system for carp in a lock and dam in the U.S., in order to capitalize on the

This image – not taken in Minnesota – shows how invasive Silver ("Asian") carp jump out of the river when startled. Image courtesy Asian Carp Regional Coordinating Committee. (CC-BY 2.0)

carps' exceptionally sensitive hearing ability. The sound will deter most of the carp from moving upstream, while native fish will travel through unimpeded. Additionally, MAISRC researchers conducted a thorough risk assessment to understand the watersheds at risk for invasion in Minnesota, as well as the types of threats these invasive fish pose—both important to know when making management decisions.

Going forward, researchers are testing promising lab studies on various types of deterrents in the field, using high-resolution imaging sonar to track the movement of fish and evaluate the acoustic deterrent system that's installed at Lock and Dam 8, and conducting virus discovery using Next Gen Sequencing to culture potential pathogens that could be used for biocontrol.

If you are interested in learning more about Asian carp work, check out the Asian Carp Regional Coordinating Committee at www.asiancarp.us, a group that released an Asian Carp Action Plan in 2017.

MAISRC's key programmatic and research partners

Aquatic invasive species issues are massive; solutions will require not only scientific advancement but also personal responsibility, adaptation of norms, informed policy, and effective agency management. MAISRC is one piece of this puzzle. We partner with numerous stakeholder groups, including members of the academic community, agencies, and the public. We also receive guidance from an advisory board which includes members from the Minnesota DNR, U.S. Fish and Wildlife Service, National Park Service, local government, lake associations, tribal representatives, and sportsmen's groups.

Universities

We are pleased to partner with University of Minnesota Extension for two citizen science programs: AIS Detectors and AIS Trackers. AIS Detectors launched in 2017 and certified 121 Detectors in its first year. It provides participants with high-quality training that's been developed by AIS experts and equips volunteers to identify, respond to, educate about, and manage AIS. AIS Trackers is being piloted in summer 2018 and will train volunteers to contribute data to help understand how AIS can be controlled while minimizing non-target impacts and informing ongoing research at MAISRC. Elsewhere on the University of Minnesota–Twin Cities campus, we are working with researchers in the College of Food, Agriculture and Natural Resource Sciences, College of Veterinary Medicine, School of Public Health, BioTechnology Institute, and the College of Biological Sciences.

We also have research partners at several universities around the country and the world, including University of Minnesota–Duluth, Minnesota Sea Grant, Southern Illinois University, University of Wisconsin, Wayne State University, Carleton College, Cornell University, Michigan State University, Montana State University, University of Regina, and the Chinese Academy of Sciences.

Agencies

The Minnesota Department of Natural Resources is a critical partner that we closely work with to understand the problems posed by AIS and to create and promulgate the knowledge needed to solve them.

We partner with numerous other agencies, including the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the National Park Service, Chicago Botanic Garden, New York Botanic Garden, and many others. We also work closely with watershed districts around the state, including Minnehaha Creek, Ramsey Washington, Rice Creek, and Riley-Purgatory. Counties around the state are also incredibly valuable partners.

The public

Lake associations and their members are critical stakeholders: they are on the front lines of the aquatic invasive species invasion. They have been essential partners from the very beginning to inform and support our research efforts.

AIS Detectors. Image courtesy of University of Minnesota Extension.

Additional opportunities for growth and collaboration

Aquatic invasive species are affecting ecological and human systems; AIS research cannot be confined to one department or college. We need an all-hands-on-deck approach to solve these problems. We see very few groups on campus that wouldn't have something to bring to the table. In the coming years, we are hoping to build capacity in the social sciences by partnering with the Carlson School of Management, the School of Journalism and Mass Communication, and the Humphrey School of Public Affairs, to name just a few.

A volunteer throws a plant rake. Image courtesy of Megan Weber.

Engaging with citizens on AIS issues

MAISRC is a statewide center with projects all across the state, from Lake of the Woods on the Canadian border to the Mississippi River at the Iowa border. It's difficult to pick one project that encapsulates all of our work. But, one particularly exciting project that brings together lots of diverse stakeholders, while also informing research, is the work of our AIS Detectors and Trackers programs. Not only do these programs introduce hundreds of engaged citizens to AIS issues, they also greatly help our research. They've already had one big win: at the annual Starry Trek event, a statewide search for starry stonewort, volunteers found a new infestation in Grand Lake. This led to the lake association and the DNR rapidly mobilizing to hand-pull the infestation, and initial results from this early intervention are very promising! Save the date for this year's Starry Trek: Saturday, August 18.

The Minnesota Aquatic Invasive Species Research Center is working diligently to solve the state's AIS problems. We're working closely with stakeholders at all levels, and have become a trusted resource and an independent voice to inform decision-making.

Sue Galatowitsch, head of the Department of Fisheries, Wildlife, and Conservation Biology and MAISRC researcher, leads an aquatic plant identification course at the annual AIS Research and Management Showcase. Image courtesy of Christa Rittberg.

We work hard to be inclusive of many voices, and invite you to make your voice heard through our upcoming research needs assessment. We conduct this assessment biannually to ensure we are meeting the needs of Minnesotans and funding the best research possible. This is the best opportunity to inform our work—visit www.maisrc.umn.edu for details in a few months. Readers can also sign up there to receive our e-newsletter, or find us on Facebook and Twitter to stay up to date on our research, events, and other announcements.

Anyone who wants to hear from our researchers, try hands-on demos, and get an inside-peek into our lab is invited to attend our annual AIS Research and Management Showcase. The 2018 Showcase will be held on the UMN–St. Paul campus on Wednesday, September 12 (details and registration available on the MAISRC website).

When we took on this fight, we knew that developing much-needed science to solve our AIS problems would not be fast or easy, and that expectations were high. However, after only five years, we are finding successes. Incremental steps are beginning to lead to big wins. Research will always be a long-term investment, but progress is being made. We're deeply grateful to our funders—especially the Environment and Natural Resources Trust Fund—as well as each and every lakeshore association, foundation, corporation, and private citizen who has showed their support for us along this journey. We envision big things coming out of the research center in the next five years, so stay tuned!

Recommended Citation

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Dr. Nicholas Phelps is Director of the Minnesota Aquatic Invasive Species Research Center and Assistant Professor in the Fisheries, Wildlife, and Conservation Biology Department at the University of Minnesota. His research broadly focuses on emerging threats to aquatic ecosystem health and sustainability, including aquatic invasive species, infectious diseases of farmed and wild fish, and risk assessment. His work with MAISRC has consisted of risk assessments for Viral Hemorrhagic Septicemia Virus, invasive pathogen discovery, biological control of carp species, understanding the impacts of Heterosporosis, and predicting the spread and establishment of a variety of AIS.

FEATURE

THE FUTURE OF AGRICULTURE IN A WATER-RICH STATE

By Ann Lewandowski, Axel Garcia y Garcia, Chris Lenhart, David Mulla, Amit Pradhananga, and Jeff Strock

In 1920, Minnesota held 2.4 million people and 132,744 farms. Corn production was near 100 million bushels per year. By 1929, 18.5 million acres were under cultivation. Nearly 100 years later, the state has 5.4 million people, 74,500 farms, and 26 million acres of farmland. Annual production of corn is about 1.5 billion bushels and soybean is about 380 million bushels.

Over that century, agricultural technology and infrastructure changed profoundly. Equally transformed are the threats to streams, lakes, and

Protecting water quality requires integrated thinking about agricultural "working lands" and conservation. Image courtesy of David Hansen.

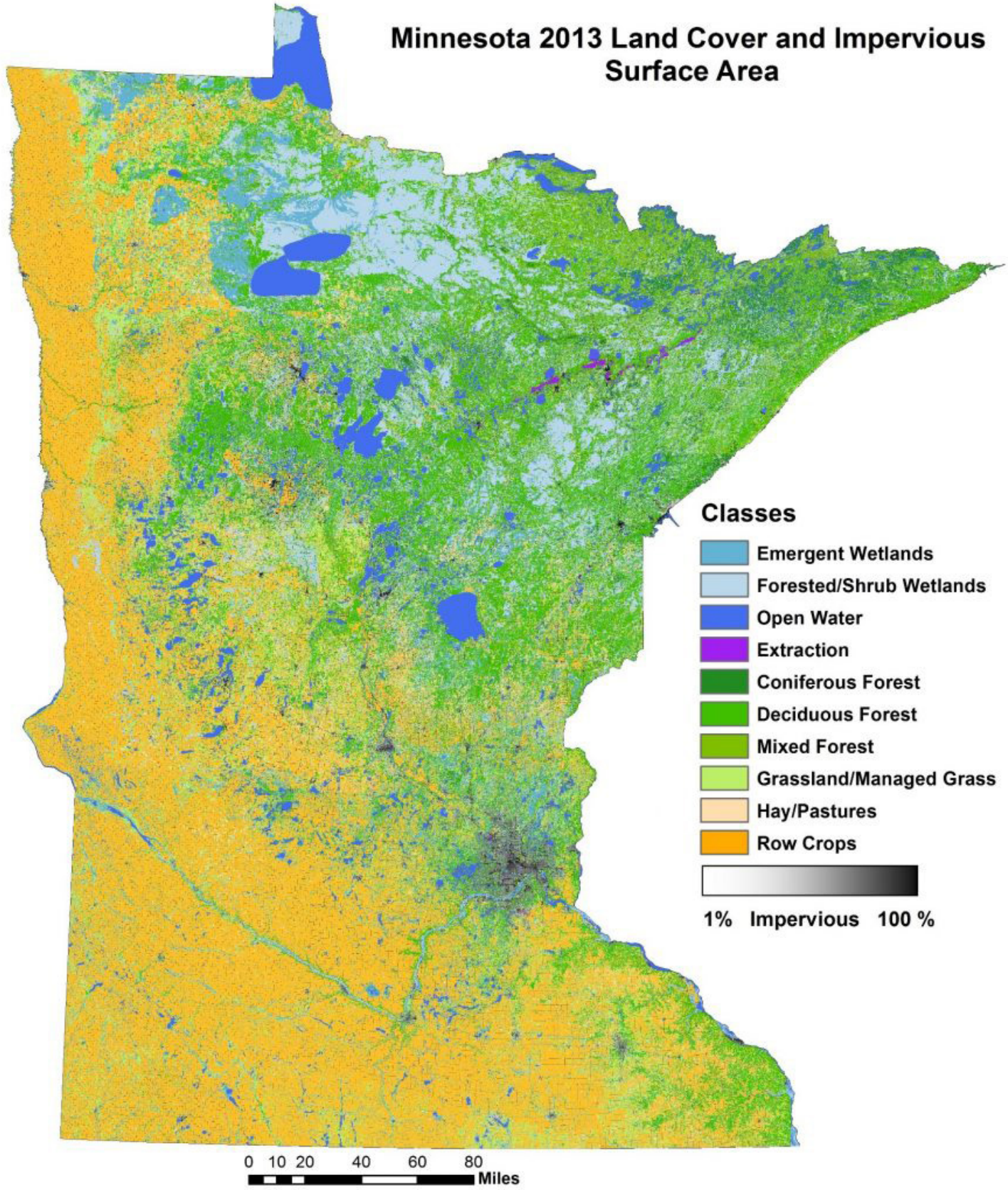
drinking water. Population, urbanization, and chemical production and use have exploded. The result is a growing tension between agriculture and water quality. Hydrology—where rainfall flows and pauses on the landscape—has also changed dramatically. In this new context, protecting a healthy future for both agriculture and water requires deliberate work from both the agricultural community and the university research community. This article is about the cutting edge work at the University of Minnesota (UMN) that is helping transform farming and water resource management.

Water runs through all our land and vegetation; it cannot be protected adequately by simply setting aside key refuges. We also need "working lands conservation" where we manage water quality and habitat in concert with farming. Half the land in Minnesota is managed by farmers, most as cropland, but interlaced with grazing land, woodland, stream buffers, farmsteads, and so on. For this reason, it is essential that farmers and non-farmers equally participate in the water conversation. Farmers are essential because they directly manage the land and bear much of the costs and benefits. Non-farmers are important because they also influence land management, benefit from the agricultural economy, and help pay for water management. Participating in the conversation means learning about unfamiliar topics, including how farmers farm and why, how climate is shifting, the unique character of Minnesota landscapes and soils, the impacts of urban development, and how individuals and communities make choices that impact water. All of those topics influence how we manage contamination of drinking water, algae-choked ponds, sedimentation of Lake Pepin, the hypoxic zone in the Gulf of Mexico, small-scale flooding and ponding, and more.

At the University of Minnesota, faculty and students in several colleges and countless departments are studying agriculture and its relationship to water. This article will highlight some of that work and what it means for agriculture in the next decade or two.

First, we want to highlight the work being done across rural Minnesota. Throughout the agricultural community, many individuals, businesses, and organizations are proactive and creative in finding ways to strengthen the sector while preserving the water and land resources they depend on. For example, the agricultural co-ops, equipment suppliers, private agronomists, and other professionals who guide farmers' decisions are increasingly providing conservation services. They are designing stream buffers and water detention structures; advising on cover crop mixes; analyzing detailed soil, pest, and crop data; and more. The implementation of the 2015 Minnesota Buffer Law highlighted examples of poor stream edge management, but also demonstrated that most streams were already protected. For decades, many farmers have been using water-friendly practices, including reduced tillage, grassed waterways, stream and ditch buffers, and fertilizer and manure management best practices. Hundreds of farmers have attended Nitrogen Smart training, a UMN Extension program supported by agricultural commodity organizations to improve the agronomic and environmental effectiveness of farmers' nitrogen management strategies. Major agricultural organizations are providing significant research funding and are collaborating with agencies and market-based initiatives to make Minnesota agriculture more water-friendly.

The remainder of this article will introduce a small sampling of the many agricultural research efforts around UMN, most of which rely on the support and engagement of individual farmers and agricultural organizations. We highlight four key trends that are transforming the relationship between food production and water resources.



More than half of Minnesota's land area is managed by farmers. Based on 2013 Landsat data. Image courtesy of Remote Sensing and Geospatial Analysis Laboratory, University of Minnesota.

These are arenas of opportunities for more productive agriculture and healthier water.

1. Minnesota hydrology is changing, and has been changing dramatically for decades. UMN researchers are studying how to respond to these shifts by developing practices to strategically store and retain more water on the landscape.

2. Cropping systems are the interdependent package of crops and management practices. UMN researchers are developing new cropping systems aimed at improving farmers' bottom line and risk management while improving agriculture's impact on water.

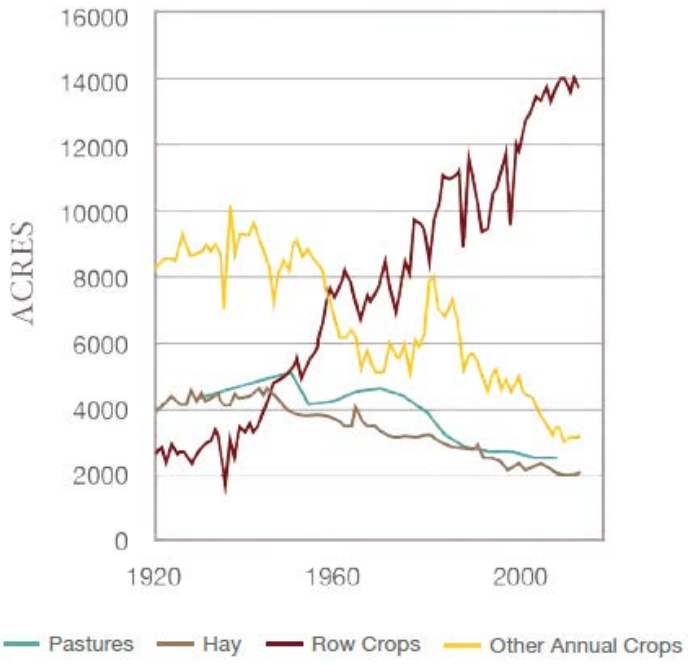
3. Robots, big data management, and other cutting-edge technologies have moved into rural Minnesota in a big way and are changing the look of agriculture, conservation work, and job opportunities.

4. In the end, managing water is about managing people. UMN researchers are active in addressing this people puzzle and changing how we frame water problems and solutions.

For this discussion, we are focusing on Minnesota, even though we are directly linked to global food supply and water issues (e.g., see Foley et al. 2011). We are also leaving many important themes for a future discussion, including the growing prominence of water quantity concerns in the face of irrigation demands and climate change, and increasing demand on groundwater aquifers and contamination of them.

Changing How Water Flows

The water cycle is often seen as an unchanging feature of the natural world, yet Minnesota has experienced dramatic changes to streamflow and rainfall amounts over the past few decades. The causes of these changes have been the subject of, at times, intense debate. We know that changing climate, land-cover and agricultural drainage have all contributed to increases in streamflow—both at small local scales and large river basin scales. Streamflow increases have been especially large in southern and western Minnesota streams and rivers. Some rivers have had a doubling of the average yearly flow since 1980, including the Yellow Medicine and Des Moines Rivers (Lenhart et al. 2011). These increased flow levels have led to greater rates of stream bank and bluff erosion with some rivers widening by as much as 50 percent compared to the widths observed in 1938 aerial photos (Lenhart et al. 2013). Some researchers (e.g., Gupta et al. 2015) have demonstrated that streamflow increases can be attributed primarily to climate change, as



Agricultural land cover has shifted dramatically over the past hundred years. Source: L. Schmitt-Olabisi. Image courtesy of Ann Lewandowski.

we've had increased annual rainfall and a greater frequency of large (greater than 2 inches per day) rainfall events. At the same time, agricultural drainage (ditches and subsurface tile) has expanded and intensified, and agricultural land cover has shifted dramatically away from pasture, hay crops, and small grains to corn and soybean. Both the changes in agricultural drainage and land cover tend to promote greater water yield from fields and increased annual flow to streams (even while subsurface drainage can reduce or slow flow of water after some rain events).

While the linkage between agricultural management practices and field erosion or nutrient export are fairly well established, the influence of agricultural management practices on farm- and landscape-scale water budgets remains poorly understood. The topic of agricultural drainage generates lively debate about the agronomic, environmental, and hydrologic impacts of drainage. The supporters emphasize the potential benefits of increased crop growth and productivity, reduced risk of crop loss from excess water stress, earlier planting, reduced crop susceptibility to pests and disease, reduced sediment and phosphorus in runoff, and the addition of soil water storage. In contrast, detractors of agricultural drainage tend to focus on the loss of wetlands, hydrologic alteration, and loss of soil nitrate to

A three-cell treatment wetland on a Martin county farm removes nitrogen and phosphorus from tile drainage before it flows into Elm Creek. Image courtesy of David Hansen.

surface and groundwater. The processes and mechanisms that control the volume and quality of drainage water leaving agricultural land is very complex. Land use, manure and nutrient management practices, drainage system design, antecedent soil moisture, soil properties, climate, rainfall intensity, watershed size, the location of drainage improvements in relation to the point of impact assessment, and characteristics of the pollutants are involved in complex interactions that impact water quantity and quality (Drury et al. 1996; Skaggs et al. 1994; Wesström et al. 2004; Zucker and Brown 1998).

Jeff Strock with Joe Magner and PhD student Lu Zhang are conducting research at the UMN Southwest Research and Outreach Center to better understand the role of agriculture and subsurface tile drainage in the observed changes to streamflow. Accurately identifying the relative contribution of agricultural management practices to basin-scale changes in hydrology is challenging because year-to-year weather variability can be much greater than the relatively small changes expected from changes in agricultural management, and further impacted by longer-term climate trends. Using a combination

A storage pond on a western Minnesota farm collects tile runoff in the spring to be used for supplemental irrigation during summer dry spells. Image courtesy of Jake Hicks.

of field research and systems analysis (modeling), Strock et al. (2014) designed an ongoing research project to quantify the water balances of corn production systems, with and without the presence of subsurface drainage, along a precipitation gradient from eastern South Dakota to south central Minnesota. Understanding the hydrologic response of drainage and crop water consumption at both the field and watershed scale will help corn growers be economically competitive, while also informing development of tools and management approaches that can minimize their environmental impact. Results from this work will provide important information to enable farmers to design water management infrastructure that is effective for crop production and environmentally responsible. Further, results from this work are expected to provide insight into the linkage between field-scale management decisions and watershed-scale hydrologic responses.

More information about this work in Minnesota and other states can be found at https://transformingdrainage.org/.

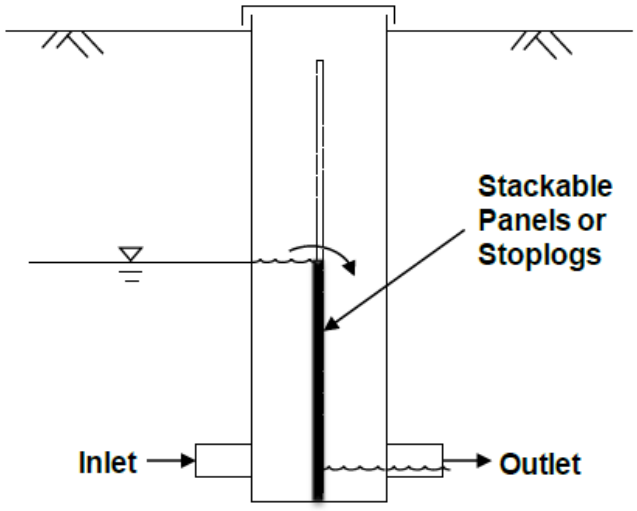
On a farm next to the Cottonwood River, patterned drainage tile is installed with drainage control structures that allow a farmer to raise the water level for parts of the year when a higher water table does not restrict crop growth or field operations.
Image courtesy of Jeffrey Strock.

While the debate continues over the relative importance of historical causes of increasing streamflow, there is widespread agreement that we need to better manage the water on our landscape to reduce downstream erosion and pollutant loading. This can be accomplished by slowing water down as it moves through a watershed, by building water and sediment ponds or restoring wetlands. This surface water storage is proven to reduce downstream flows, but it is impractical to restore large areas of wetlands, given the high value of farmland, particularly in southern and western Minnesota. We need alternative water storage practices, as well as better drainage water management approaches. Research into alternative wetland design has been done by PhD student Brad Gordon with Chris Lenhart and Dean Current, with funding from Minnesota Department of Agriculture (Lenhart et al. 2016). In Martin County, an edge-of-field tile drainage treatment wetland was built and successfully incorporated into a farming system and continues to remove nitrogen and phosphorus from entering Elm Creek. The project shows that small constructed wetlands can help address some of our water management problems, but are insufficient alone.

Another approach to reducing flow is the use of drainage water management where water control structures are used to manage water levels in tile drain outlets to reduce outflow from fields in the winter or spring when soil drainage is not necessary for crop growth. On-farm research conducted by Jeff Strock at the Nettiewyynnt Farm in western Redwood County, a fifth-generation farm owned and operated by Brian and Michelle Hicks, showed an annual average reduction in nitrate loss of 24 percent when using controlled drainage compared to conventional free-drainage between 2006 and 2014.

While we can't go backwards in time to a pre-development landscape of abundant wetlands across southern and western Minnesota, we can mimic the functions of wetlands and prairie grasses by working with farmers to strategically place management practices in the landscape. Towards that end, numerous management practice placement tools have been developed. For example, Dave Mulla, Jake Galzki, and others developed a tool to help farmers select alternative practices to provide equivalent water quality treatment as riparian buffers (MN Corn Growers 2017). In the long term, the technical challenges can be met, but it is the adoption of these management practices by landowners and alignment of economics with environmental values that will be key for success.

The examples above address hydrology at several points on the landscape, including the stream edge and floodplains, water storage features, edge-of-field water management features, and in-field drainage water management. The final piece of this puzzle is in-field crop and soil management—practices that impact what happens when rainfall first hits the land. The importance of vegetation and related research is discussed in the next section on "Innovations in Cropping Systems." In addition, the Office for Soil Health was recently created by the UMN Water Resources Center and the MN Board of Water



Schematic of the controlled drainage concept, using an in-field water control structure. Diagram courtesy of Jeffrey Strock.

and Soil Resources. The goal of MOSH is to strengthen the university's work in understanding and communicating how farming practices impact soil organic matter and other soil characteristics that determine how much water enters into the soil and is stored in it. The arena of soil health is widely seen as a "win-win" for agriculture and the environment, helping farmers improve the productivity of their soil while improving water quality in the streams, lakes, and wetlands receiving drainage from farmland.

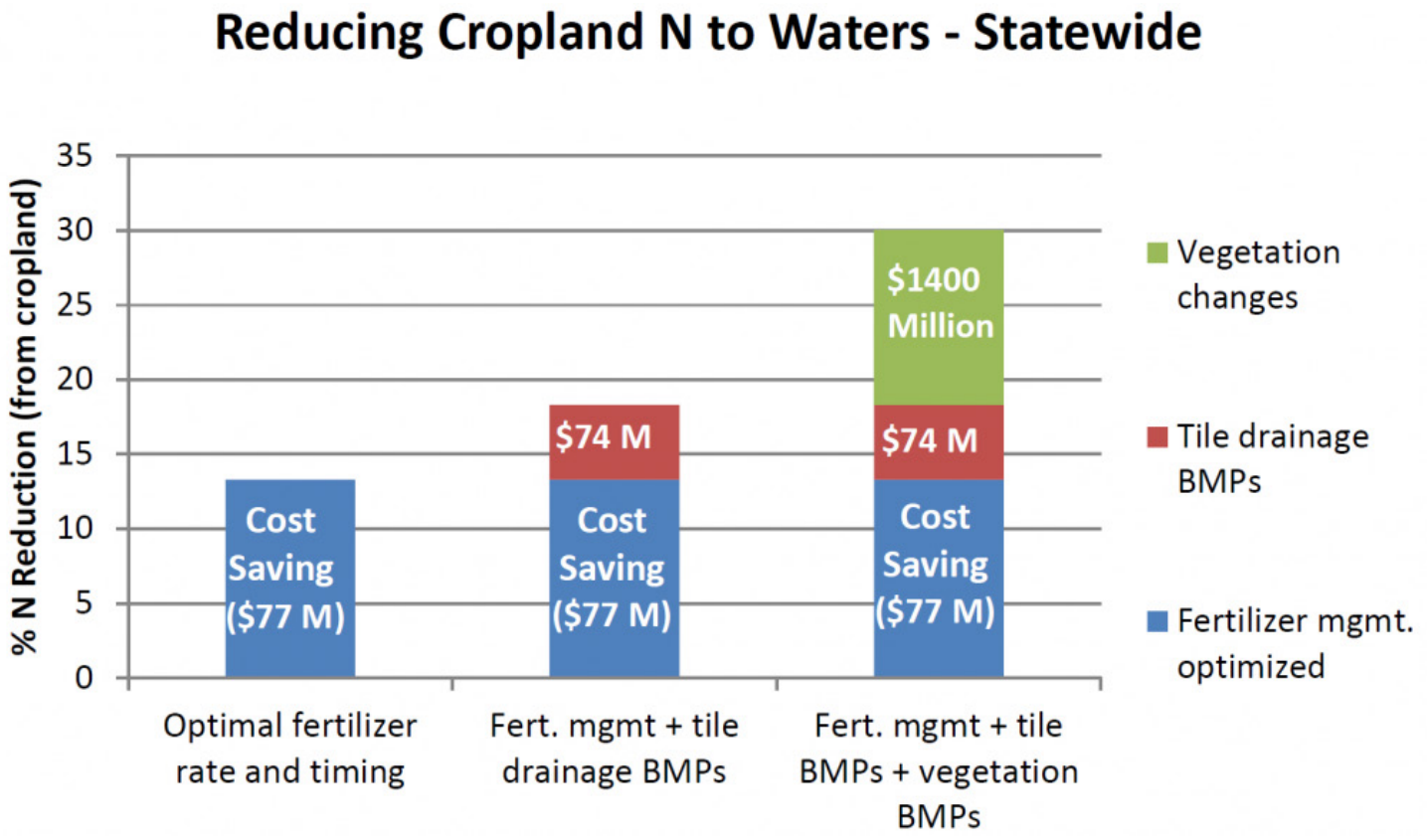
More about hydrology in rural Minnesota is explained in the UMN publication, *Fields to Streams*. Part 1 explains how land management, climate, geography, and drainage affect the water cycle and stream changes. Part 2 describes the agricultural land management practices that impact hydrology.

Double cropping with camelina at the Southwest Research and Outreach Center at Lamberton. "Relay crops" are planted before the first crop is harvested. "Sequence crops" are planted after the first crop is harvested. Image courtesy of Axel Garcia y Garcia.

Innovations in Cropping Systems

Minnesota cropland is a story of contrasts. Some of the most productive soils in the world are found here, yet our featured crop commodities are necessarily produced with high external inputs (e.g., fertilizer, crop protection chemicals, and direct energy). Our weather is highly variable and winters are extremely cold and long, but annual crops are grown successfully. We are famous for our quantity of fresh water, but water quality problems threaten human health, society's recreational places, and the ecosystems. Both water and nutrients are fundamental to crop yield increases, but many of our water resources (rivers, streams, and lakes) are reported to have quality impairments due to nitrogen, phosphorus, and sediments. Notable improvements have been made to reduce nonpoint source pollution related to agriculture, but more progress is needed to achieve Clean Water Act goals of fishable and swimmable waters, and the Minnesota Nutrient Reduction Strategy goal of 45 percent reduction in nitrates by 2045.

Cropping systems are managed ecosystems; as such, options to reduce negative impacts to the environment should be part of that management. For example, soil health, pests, and diseases must be integrated into a systems approach for



Nitrogen fertilizer management is important, but will not be enough to reach the state's nitrogen reduction goal of 45%. Current innovations will dramatically reduce the cost of vegetation BMPs such as cover crops and double cropping.
MPCA. 2013. Nitrogen in Minnesota Surface Waters. Page F1-18.

sustainable management, because in the end, cropping systems will be as sustainable as their capacity to provide environmental benefits like clean water.

With few exceptions, most cropping practices directly or indirectly impact the quantity and quality of water. Mainstream agriculture is based on mono-cropping utilizing practices like tillage, heavy use of synthetic fertilizers, and dependence on pesticides. Environmental pollution and its association with human health issues are the major concerns of this approach, but arguably, it has fed our hungry world. Crop production in temperate and humid regions like Minnesota is extremely complex. Water impairment is of major concern due to the delicate balance among water resources and societal interests. The prospects of climate change in the region bring further challenges to this complexity. Rivers, the natural link between crop fields and the different destinations of water, along with a network of thousands of miles of ditch and tile drainage, ultimately expand the water quality issues to a society that is more aware and concerned about the environmental impacts of current cropping practices than ever before. The question, though, is whether twenty-first century cropping systems can protect our water resources for generations to come.

The importance of a systems approach.

Agricultural research is conducted using both reductionist and systems approaches. The former separates the system into its individual components so they can be analyzed separately. The latter uses the whole system so the complex interactions between components are analyzed. Commonly, systems approach-based production has been the realm of smaller and niche farming operations; however, technological innovations, including the development of sustainable cropping systems, remote sensing, and big data science, is opening the doors for large-scale agriculture to embrace a systems approach, as well. Regardless of the size of the enterprise, the prospect of a widespread systems approach is great news for sustainable production and a cleaner environment. In fact, options to reduce water quality impairments will not succeed if we do not understand the whole system.

Research at the University of Minnesota has explored two different approaches to systems-based intensification of agriculture: 1) Sustainable intensification, a concept based on increasing productivity from existing land with minimum environmental disturbance, which loosely characterizes the practices of mainstream and larger scale agriculture, and 2) Agroecological intensification, a concept based on ecological principles to reduce the use of external inputs (usually associated with the reduction in water quality), while increasing productivity, which loosely characterizes smallholder and organic producers. In both cases, the challenge is not simple: increase production in the same or less farmland while enhancing the quality of the environment, in which water plays an essential role. Our research efforts on diversified cropping systems have been gaining attention, in particular the Forever Green Initiative (FGI), which advocates for a greener landscape in the region through crop diversification and cropping practices that include the integration of cover crops and promote soil health. Should the concept of the FGI work, gains in the quality of water and the environment as a whole could be immense for the state and the region. More on the FGI work can be found at www.forevergreen.umn.edu, as well as in Issue Six of *Open Rivers*.

Promising technologies.

Options for a more diversified agriculture in the region include expanding our crop portfolio with winter annual oilseed, perennial cereals, and cover crops. Winter annual oilseed crops allow producing two crops in one year while covering the landscape during periods vulnerable to soil erosion and nutrient loss. Such crops can be seeded into standing corn and soybean the end of summer to the beginning of fall, resume growth

early in the spring, and harvested for grain yield in mid-June. For perennial cereal grains, the focus in Minnesota is on Kernza®, which was developed from a close relative to wheat called intermediate wheatgrass. So far, Kernza® is highly productive for the first two years after planting, and research is advancing to secure one to two more years of highly productive perenniality. Cover crops are crops planted between two cash crops to provide agro-ecological services. They are not intended to be harvested and are terminated before the next cash crop is planted. Cover crops store and cycle nutrients for the next crop, improve soil health, and impact weed, pest, and nutrient inputs.

What do winter annuals, perennial grains, and cover crops have in common? They all positively impact water quality due to their ability to uptake and immobilize residual and applied nitrogen, therefore reducing nitrate-nitrogen (NO3-N) leaching out of the active root zone of crops. Research results from the University of Minnesota show considerable reduction of NO3-N concentration in the leachate when we diversify with a third cash crop like winter annual oilseed crops, and when cover crops or perennial cereal crops are used.

Cropping systems impact water quality by changing how rainfall is partitioned between runoff, infiltration, and evaporation/transpiration. The changes to the soil surface determine, in part, how much water enters and moves through the soil. Living plant cover during the springtime allows for transpiration of water out of the soil during a season when annuals are not yet growing. A recent modeling study from Brent Dalzell and David Mulla (2018) attempted to quantify the impact of vegetation on streamflow, showing that upland management practices can impact streamflow, and, in turn, impact the in-stream sources of sediment.

Certainly, we cannot depend solely on these cropping system options to reduce nitrogen losses and streamflow, but diversification could provide a myriad of benefits not only to clean water but also to soil health, including enhanced soil structure, increased soil organic matter, improved water holding capacity, reduced runoff, and enhanced biological activity.

What makes these technologies attractive?

In Minnesota, around eight million acres of land are used to produce corn, slightly less for soybeans. One can imagine a future with a massive adoption of cover crops, as well as a widespread use of perennial cereal grains, and a third crop in the corn-soybean rotation. This may sound utopian, but these practices could be part of Minnesota's landscape in the future because we have the powerful voice of the new generations asking for a better and "greener" environment and we have our farmers who are well-informed and embracing sustainable practices for a better future.

What is the range of research underway?

The University of Minnesota is well positioned with breeding programs for the development of alternative annual and perennial crops tailored to our unique environment, as well as for the development of technological innovations like sustainable cropping systems. The social and economic dimensions of possible changes in the agricultural landscape are just emerging. An interdisciplinary team led by the Water Resources Center, and including the Center for Changing Landscapes, the Department of Agronomy and Plant Genetics, the Department of Bioproducts and Biosystems Engineering, and the Department of Computer Science and Engineering, recently received support from the National Science Foundation through its Innovations for Food, Energy and Water Systems program (NSF-INFEWS). The team is starting a study with strong social and economic components to investigate innovative approaches to supporting sustainable supplies of food, energy, and water in intensively cultivated regions. This is extremely

important because mitigation measures to our water quantity and quality issues need integrated, systems-based approaches. Similarly, the Minnesota Department of Agriculture, through its Clean Water Funds, is supporting research led by the Department of Agronomy and Plant Genetics and the Department of Soil, Water, and Climate to investigate the nexus of cover crops with water and nitrogen as well as to assess an integrated landscape management for agricultural production and water quality, respectively.

Researchers from the University of Minnesota continue assessing double-cropping approaches like relay and sequence in corn and soybean production. "Relay cropping" refers to planting a second crop before harvesting the first; the growth of the first is not affected since the second grows marginally during the intercropping period, but resumes its growth rate after harvesting the first. "Sequence cropping" refers to two or more crops in succession, where the second crop is planted after the first crop is harvested. Winter camelina (Camelina sativa [L.] Crantz) and field pennycress (Thlaspi arvense L.) are excellent candidates for this technology in the temperate climate of the region. Both crops are considered bioenergy crops, overwinter, and require lower inputs than other crops. In fact, winter camelina and field pennycress have been successfully grown with double-cropped (relay and sequence) soybean; preliminary results with corn are encouraging. Double-cropping provides a temporal diversification intended to increase resources use efficiency and yield per unit of area while enhancing ecosystem services.

Robots and Big Data

Robotics is poised to become an integral part of agriculture, thereby improving the efficiency of agriculture and protecting water quality. The first large-scale adoption of self-driving vehicles occurred in agriculture over ten years ago, when farmers started buying attachments that enabled auto-steer on their sprayers, harvest combines, and other large farm machinery. Auto-steer allows large farm machinery to drive along straight paths and turn around without a human driver. Straight paths are particularly important when applying fertilizer or spraying crop protection chemicals. Auto-steer reduces overlap of adjacent passes, reducing double application of fertilizer or herbicides from one pass to another. This helps reduce contamination of water.

In the broader context, robotics are an integral part of precision agriculture. Precision agriculture is one of the major revolutions in agricultural history (Crookston, 2006). Scientists in the College of Food, Agriculture and Natural Resource Sciences (CFANS) were and still are at the forefront leading this revolution. The first Center for Precision Agriculture in the world was established at the University of Minnesota in 1995. Pioneering agricultural robotics research occurs at the University of Minnesota through collaboration between the Precision Agriculture Center and the Department of Computer Science and Engineering or the Department of Aerospace Engineering and Mechanics.

With precision agriculture, farmers can apply fertilizer or herbicides at the right rate, at the right time, at each location in a field. This precision management allows large fields to be subdivided into many small areas that each receive customized management. Each small area is termed a management zone. The benefits of precision agriculture are increased efficiency of fertilizer and pesticide use, increased profitability for the farmer, improved crop yield or quality, and reduced water quality pollution. In contrast, uniform conventional management of farms involves a single rate of fertilizer or pesticide

applied across the entire field, despite a variety of soil types, landscape slopes, and crop yield potentials.

There are several examples of how robotics is applied in precision agriculture. These include managing crop stresses due to nutrients, water, weeds, insects, or disease. Crop nutrient deficiencies result when the soil is unable to supply enough nitrogen, phosphorus, or potassium to the crop, causing crop yield to suffer. Crop nutrient deficiencies can be identified using remote sensing with cameras mounted on aerial robots, commonly known as drones. Cameras on drones can be used to map crop nutrient deficiencies on a weekly schedule. These maps can be relayed to ground robots, which can travel through crop rows spreading just the amount of fertilizer needed to correct the deficiencies. This approach to managing crop nutrients provides the nutrients needed by the crop at each location in the right amount at the right time, thereby reducing excess use of fertilizer and protection water quality.

Research at the University of Minnesota on variable rate nitrogen management showed that this technique reduced annual losses of nitrates to surface water by an average of about 15 percent over many years of study.

Similarly, aerial drones with cameras can be used to identify weeds, insects, or crop diseases early enough to treat the problem with crop protection chemicals. Precision weed, insect, or disease management helps reduce the use of herbicides, insecticides, and fungicides in agriculture, thereby protecting water quality.

Precision agriculture also involves better management of irrigation water. Over irrigation leads to falling water tables and leaching of nitrates and herbicides to groundwater. Farmers can improve their pivot irrigation systems through adoption of variable rate irrigation techniques. With variable rate irrigation, farmers can vary the amount of water and nitrogen applied by each nozzle along the irrigation boom as it circles through a field.

A controller in the tractor cab is used to vary the amount of fertilizer applied across the field. Image courtesy of Aicam Laacouri.

The rate can be adjusted based on information supplied by wireless soil moisture sensor networks or by crop water stress maps obtained using cameras on drones. Crop evapotranspiration (or water use) rates often vary considerably within a field due to changes in soil depth, sand and clay content, or landscape elevation. Drones outfitted with thermal infrared cameras can detect hotter and colder areas of a field that arise due to differences in evapotranspiration. These measurements indicate which locations have crops that are experiencing water stress (hotter areas), thereby requiring more irrigation.

Precision agriculture involves collection of massive amounts of data, or big data. Data needed includes spatial and temporal variations in soil properties, landscape elevation, crop yield, crop reflectance, and precipitation for example. Processing big data is often achieved using Geographic Information Systems (GIS), geostatistics, data mining, and machine learning algorithms. Strong expertise for data mining and machine learning algorithms exists at the University of Minnesota in the College of Science and Engineering (CSE). The objectives of this processing include detecting spatial anomalies, finding unusual changes over time, data clustering and pattern recognition, identifying the causes of crop stress, and mapping areas that require customized management practices. A single field could require storage of 100 GB of data in one growing season.

Robotics is becoming an integral part of agriculture, leading to better efficiency in using crop inputs such as fertilizer and herbicides, and leading to better protection of water quality. We have come a long way from managing agricultural fields with a uniform rate of fertilizer, herbicide or irrigation water. Now, application of fertilizers, herbicides, and irrigation water can be varied across a field and with time, so that just the right rate is applied at the right location and right time using concepts from precision agriculture. The adoption of robotics in agriculture is growing rapidly, leading to new business, different types of jobs, and additional revenue in Minnesota.

At the same time, the history of agriculture in the U.S. shows that technology cannot solve all our problems without proper consideration of rural values and culture (Berry 1977). Understanding the human component is the final thread in our exploration of agriculture and water.

The People Puzzle

Nonpoint source (NPS) pollution is commonly defined as a technical, hydrological problem requiring engineering solutions. However, reducing NPS pollution also requires the action and commitment of multiple stakeholders including farmers, landowners, and urban residents. A fundamental shift in approach to water management is needed to redefine NPS pollution as a social problem. Using this lens, we begin to reimagine solutions beyond the biophysical, and delve into social causes and consequences of water resource problems. We refocus our efforts on understanding communities, developing programs that are locally relevant, building trusting relationships with farmers, and collaborating with farmers and other community members in conservation (for more, see Inspiring Action for Nonpoint Source Pollution Control).

From a social perspective, two types of actions are needed to resolve NPS pollution problems: i) individual actions such as conservation practice adoption, and ii) collective actions of multiple individuals and groups. For a long time, social scientists have examined how to motivate individual actions. Far less attention has been given

to collective action, which involves understanding relationships, networks, and institutions—or what is being called social capital and social capacity.

The quality of Minnesota's waters depends on individual and community-level decisions about land use practices and policies. Farmers and other landowners are resource users and plan implementers. Individual farmers' decisions to take conservation actions can have profound impacts on the resources on which many depend. If planners and resource managers are to develop targeted conservation programs that speak to farmers' unique needs, concerns, and values, they need to understand how farmers farm, how they interact with natural resources, and how they make decisions about integrating conservation practices on their land and what motivates them to become more engaged in conservation initiatives. Further, farmer decision making does not happen in a vacuum. Their decisions are also shaped by various external factors (e.g., social networks, organizations, conservation programs, market forces). An understanding of community-level capacities is also necessary to address complex problems such as NPS pollution.

Researchers at the Center for Changing Landscapes (CCL) study how and why individuals make conservation decisions and how communities manage natural resources. CCL has collaborated with several state agencies (e.g., Pollution Control Agency, Board of Soil and Water Resources, Department of Natural Resources), counties, and watershed districts to conduct community assessments in more than a dozen Minnesota watersheds. Research findings from these projects have already informed conservation programming and civic engagement efforts across multiple watersheds. One study in particular, conducted in 2011, inspired a substantial change in Scott County's approach to conservation programming. Study results highlighted the importance of personal moral obligation and community support in motivating individual conservation actions. This spurred Scott County natural resource leaders to refocus their efforts on building better relationships with farmers and landowners to achieve water conservation goals.

University of Minnesota scholars are also conducting research to evaluate intervention strategies aimed at behavioral change. As part of the NSF-INFEWS project mentioned above, CCL will evaluate the effectiveness of benchmarking as a behavior change strategy. Benchmarking is an approach of providing social feedback about environmental conditions—for example, giving individuals information about their nitrogen management practices compared to others'—to motivate landowners to make management changes.

Interdisciplinary collaboratives that integrate social sciences with biophysical and geospatial sciences have also emerged at the University of Minnesota. For example, the New Agricultural Bioeconomy Project is a transdisciplinary research collaborative that examines the sustainability of economic, environmental, and social systems. Scientists apply participatory research processes to explore new "win-win-win" opportunities to enhance economy, environment, and community vitality in Minnesota's agricultural communities.

Protecting water resources, while maintaining or increasing agricultural productivity, requires solving the people puzzle. This means taking a people-centric approach to conservation and working side-by-side with farmers and communities to protect water resources. Improving our understanding of the social system drivers of conservation can help natural resource and policy leaders to fundamentally reshape water resource planning and programming.

The Future of Minnesota Agriculture

The health and resilience of Minnesota agriculture and water resources are interdependent. We see a future where both farmland and water resources are managed more sustainably as UMN researchers increasingly integrate the two efforts in collaboration with farmers, government agencies, and citizens.

The sample of research described in this article, along with other, equally significant work at UMN, is transforming how the landscape will look in upcoming decades. We are moving towards building soil health, instead of slowly mining it. We expect to see a more diverse set of profitable crops growing across the state and less bare soil in the springtime. We will increasingly find ways to store water and slow its movement between the time precipitation hits the ground and when the water leaves the state down the Mississippi, Red, and other rivers. In seeming contrast to the growing size of fields and field equipment, we will see farming of smaller units as management becomes customized to subfields, allowing more effective use of water, fertilizer, and other inputs. This precision agriculture is built on an innovative research and technology sector that is advancing development of sensors and decision-support systems, Big Data management, automation, and land analysis. These tools have been equally valuable for transforming the cost effectiveness of conservation activities.

Critical to all these advancements is the transformation of relationships and building capacity of communities to more effectively manage natural resources. Healthy water arises out of the dispersed involvement and networks of all types of citizens and organizations. Researchers at the University of Minnesota are becoming more sophisticated at integrating across disciplines and engaging all the varied stakeholders who are responsible for building the future of agriculture and water resource management. Together we can make a difference and conserve and preserve our valuable land and water resources for future generations.

References

Berry, Wendell. 1977. *The Unsettling of America: Culture and Agriculture*. San Francisco: Sierra Club Books.

Crookston, R. 2006. A Top 10 List of Developments and Issues Impacting Crop Management and Ecology During the Past 50 Years. *Crop Science* 46(5). 10.2135/cropsci2005.11.0416gas.

Dalzell, B.J., and D.J. Mulla. 2018. Perennial vegetation impacts on stream discharge and channel sources of sediment in the Minnesota River Basin. *Journal of Soil and Water Conservation* 73(2):120-132; doi:10.2489/jswc.73.2.120.

Drury, C.F., C.S. Tan, J.D. Gaynor, T.O. Oloya, and T.W. Welacky. 1996. Influence of controlled drainage-subirrigation on surface and tile drainage nitrate loss. *Journal of Environmental Quality*. 25:317–324. doi:10.2134/jeq1996.00472425002500020016x.

Foley, Jonathan A., Navin Ramankutty, Kate A. Brauman, Emily S. Cassidy, James S. Gerber, Matt Johnston, Nathaniel D. Mueller, Christine O'Connell, Deepak K. Ray, Paul C. West, Christian Balzer, Elena M. Bennett, Stephen R. Carpenter, Jason Hill, Chad Monfreda, Stephen Polasky, Johan Rockström, John Sheehan, Stefan Siebert, David Tilman, and David P. M. Zaks. 2011. Solutions for a cultivated planet. *Nature* 478:337–342 (20 October 2011). doi:10.1038/nature10452.

Gamble, J.D., G. Johnson, C.C. Sheaffer, D.A. Current, and D.L. Wyse. 2014. Establishment and early productivity of perennial biomass alley cropping systems in Minnesota, USA. *Agroforestry Systems* 88(1):75–85.

Gupta, S. C., A. C. Kessler, M. K. Brown, and F. Zvomuya. 2015. Climate and agricultural land use change impacts on streamflow in the upper midwestern United States. *Water Resources Research*, 51:5301–5317. doi:10.1002/2015WR017323.

Lenhart, C.F., H. Peterson, and J. Nieber. 2011. Increased streamflow in agricultural watersheds of the Midwest: implications for management. *Watershed Science Bulletin*, Spring 2011, pp.25–31.

Lenhart, C.F., M.L. Titov, J.S. Ulrich, J.L. Nieber, and B.J. Suppes. 2013. The role of hydrologic alteration and riparian vegetation dynamics in channel evolution along the lower Minnesota River. *Transactions of the ASABE*, 56(2):549–561.

Lenhart, C., B. Gordon, J. Gamble, D. Current, N. Ross, L. Herring, J. Nieber, and H. Peterson. 2016. Design and hydrologic performance of a tile drainage treatment wetland in Minnesota, USA. *Water* 8(12):549.

MN Corn Growers Association. 2017. New tool helps farmers choose alternative practices to buffers. Retrieved at http://www.mncorn.org/2017/08/30/new-tool-helps-farmers-choose-alternative-practices-buffers/.

Skaggs, R.W., M.A. Breve, and J.W. Gilliam. 1994. Hydrologic and water quality impacts of agricultural drainage. *Critical Reviews in Environmental Science and Technology* 24(1):1–32.

Strock , J.S., B. Dalzell, C. Hay, J. Kjaersgaard, J. Magner, G. Sands, and T. Trooien. 2014. Quantifying hydrologic impacts of drainage under corn production systems in the Upper Midwest. This is an ongoing project at the University of Minnesota, most recently funded by the Minnesota Corn Research & Promotion Council, http://www.mncorn.org/research-item/quantifying-hydrologic-impacts-of-drainage-under-corn-production-systems-in-the-upper-midwest/.

Wesström, I., G. Ekbohm, H. Linnér, and I. Messing. 2004. Application of recession analysis on subsurface outflow from controlled drainage. Pp. 398-408 in *Drainage VIII Proceedings of the Eighth International Symposium*, 21-24 March 2004 (Sacramento, California USA). ASAE Publication Number 701P0304, ed. R. Cooke.

Zucker, L.A., and L.C. Brown. 1998. Agricultural drainage: Water quality impacts and subsurface drainage studies in the Midwest. *Ohio State University*

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FEATURE

EYES ON LARGE LAKES

By Erik Brown, Sergei Katsev, Sam Kelly, Ted Ozersky, Doug Ricketts, Kathryn Schreiner, Cody Sheik, Robert Sterner, and Lisa Sundberg

A lake is a landscape's most beautiful and expressive feature. It is Earth's eye; looking into which the beholder measures the depth of his own nature." So said H.D. Thoreau in *Walden*, conjuring an image of human eyes peering intently into Earth's eyes, and learning something profound in the process. Indeed, who among us hasn't gazed into one of these watery eyes of Earth, into a lake's mysterious depths, and had their souls stirred, their curiosity piqued? How deep is it? How long has it been here? Where did the water come from and where does it go? What creatures live here? Is it safe to drink? On the western shore of Earth's largest lake, there is a

View of Duluth on the shores of Lake Superior, showing the Aerial Lift Bridge and the Great Lakes Aquarium.

century-old brick building, a former elementary school, where you can find a team of investigators whose job it is to be curious beholders of the largest of these "eyes" of Earth. Their studies of large lakes look into the past and help us project into the future. This story is about them and what they've done.

The Large Lakes Observatory (LLO) is a research unit at the University of Minnesota Duluth. It has a unique mission: to perform scientific study of the largest lakes of Earth. It is one of the largest water-centered research units at the university and its impact has been felt all over the world. The faculty, staff, and students of course use their human eyes to observe, but their senses also are extended in fascinating ways by the use of specialized observational platforms and techniques, some of which we will encounter here. Indeed, unusual skills and uncommon equipment often are needed to explore these large, sometimes remote, lake environments. Coordinated teams

Figure 1. The bottom of Lake Superior is below sea level! To measure certain parameters and to collect water from hundreds of meters below the surface, scientists can deploy this "CTD rosette." The gray vertical tubes are water sampling bottles that can be closed at chosen depths so that water from that location is brought back on board. Below the gray tubes is a package of instruments that measures such things as temperature, salinity, oxygen, and other parameters, giving LLO scientists a "vertical profile" of lake conditions. Photo credit: Blue Heron crew.

of investigators may take advantage of remote or autonomous sensors that extend their vision beyond what a single human alone can take in at a given moment. They use specialized equipment to make measurements of the chemistry, biology, and physics of large lakes. Such tools of the trade are not available everywhere, but they are central to the scientists of LLO.

Advancing human knowledge about large lakes isn't just fascinating for researchers; it has real value to society. Human welfare depends uniquely on these large lakes. It is sometimes said that clean freshwater is society's most valuable resource, something we can't live without. If you total it up, there is about 125,000 km3 of liquid, surface freshwater on Earth, covering about 9 million km2, roughly the area of Europe. Perhaps that seems like a lot of water. However, if all this freshwater was brought into a single spherical drop of liquid freshwater, its diameter would be only 62 km. This is really tiny on a global scale. One could barely see such a drop on an image of Earth from space, hardly what the iconic "blue marble" image of Earth or the nickname "the water planet" suggest. The lesson of this thought exercise is this: Only a small fraction of all the water on Earth is liquid and fresh, and it is spread thinly, with much greater breadth than depth, so the total volume is not impressive on a global scale. Just as remarkable and meaningful is where exactly this water is actually found on the planet. Just a handful of Earth's largest lakes hold a disproportionate amount of global freshwater. Lake Baikal, in Siberia, has 20 percent of the total, as do the five Laurentian Great Lakes

Figure 2. The university's 86' R/V Blue Heron is a critical piece of infrastructure, a floating field station, that provides scientific access to even the most remote parts of the Great Lakes. The Blue Heron is a Swiss Army knife of boats: it can be configured to perform a wide variety of scientific investigations. Image courtesy of the LLO.

(HOMES, or Huron, Ontario, Michigan, Erie, and Superior) together. These two lake systems thus hold four of every ten drops of liquid surface freshwater on Earth. Further, just five lakes (Baikal, Tanganyika, Superior, Malawi, and Vostok, in that order) hold more than half of this resource. Large lakes are significant reservoirs of freshwater. To sum up, we can't live without freshwater, there is a very limited supply, and it is very unevenly distributed on the planet. How valuable these reservoirs of freshwater, these large lakes of Earth, are! We clearly need to care for places that hold such huge percentages of one of society's most valuable resources. We care for them because future generations need us to. To do this, we need to understand how these lakes function, how they are changing, and how we can make use of them without jeopardizing them for future generations. And for that, we need a solid scientific foundation. That's where LLO comes in.

What is it like to work on large lakes? Some of the work at LLO takes place on the largest university-owned research vessel (R/V) in the Great Lakes, the *R/V Blue Heron*. The *Blue Heron*, owned by the university, is managed as part of the University National Oceanographic Laboratory System (UNOLS), and it is chartered by research scientists near and far to explore any of the Great Lakes. Built in 1985 for fishing on the Grand Banks, and closely resembling the *Andrea Gail* from the movie *The Perfect Storm*, the *Blue Heron* was purchased by the University of Minnesota in 1997, and converted into a limnological research vessel during the winter of 1997–98. The *Blue Heron* is outfitted with state-of-the-art instrumentation and is capable of up to three-week long expeditions to any of the Great Lakes when up to 11 scientists and crew eat, sleep, and work on board. She has supported work that has looked in detail at Lake Superior's bottom for clues about its past, work that has helped scientists better understand the cycling of carbon and nutrients in the Great Lakes, and helped government scientists keep an eye on the status of the fisheries.

See a three-minute video on the Blue Heron here.

LLO prides itself on its rich interdisciplinary atmosphere. Hardly any environmental investigation relies on a single academic subject. A physicist is needed to explain the currents and waves; understanding the water quality requires a chemist; and a biologist would find a lifetime of work studying the creatures big and small, from microscopic algae to fish. And understanding how the lakes evolve and respond to climate change is impossible without geologists and climate scientists. LLO brings all of these kinds of scientists together under one roof, serving as a long-standing, successful model of interdisciplinary scholarship. Its 12 faculty members all have roots in individual disciplines and teach in their respective departments, but they spend their research time at LLO. At LLO one can often see a biologist discussing science with a physicist, and both asking advice from a chemist. It is this interdisciplinary nature of the place that makes its science strong and relevant.

While the windows of LLO offer an impressive view of Lake Superior, the largest lake in the world and the headwaters of the Laurentian Great Lakes, the team often finds itself looking well beyond the region. LLO scientists have carried out major expeditions to the great lakes of the East African Rift Valley, Lake Baikal in Russia, Lake Nicaragua, Lake Issyk Kul in central Asia, Great Slave Lake in the Canadian Arctic, and many smaller lakes throughout the world. This global perspective, combined with an aptitude for carrying out large-scale oceanographic work, makes LLO unique among limnological research institutes in the world.

Today one may find LLO scientists and graduate students working on a dizzying array of tasks.

They operate autonomous underwater robots that are gliding for months on end in the depths of Lake Superior, study organisms under deep winter ice, trace different pollutants, and study the effects of invasive species. They investigate sediment cores that allow them to peek deep into the geologic history of lakes and the contemporary climate, and they look at some rare unusual modern lakes that may help unravel some mysteries in the Earth's ancient history. They also educate some of the next generation of scientists. Here are some of these stories, telling what LLO has learned by closely looking into the great eyes of Earth.

Figure 3. Children are always curious. Here, some LLO scientists working on Lake Malawi came to shore near a fishing market via a dinghy and attracted a crowd.
Photo credit: Sergei Katsev.

Peering into the Past

Earth's climate is changing. What that means for the future is still largely unknown, but knowledge of past climate helps us to understand ongoing and future climate change so we can better prepare and make effective plans to mitigate the social and economic impacts of a changing climate. Records from marine sediments and polar ice cores have yielded key information on global changes in climate. Lake sediments complement those records by providing sharper focus on local to regional histories that are directly relevant to places where people live. LLO researchers study sediments that have accumulated year after year on lake floors, faithfully recording chemical and biological signals of changing climate and environmental conditions. Unravelling the stories

Figure 4. Aerial view of the 160′ drilling barge Viphya on Lake Malawi, where 26 members of the drill team, science team, and ship's crew lived for six weeks. This fuel barge was converted to accommodate a 100 ton geotechnical drilling rig (capable of recovering sediment from >1 km below lake surface) and a dynamic positioning system to maintain the position of the drilling barge in waters too deep for anchoring. Photo credit: Isla Casteneda.

preserved in these archives provides knowledge of past climate change that forms a basis for evaluating impacts of ongoing and future climate change.

LLO research on paleoclimate archives has extended across the planet, with field programs on six continents. These range from coring operations using small inflatable rafts to major drilling operations taking advantage of technologies developed for the petroleum industry; from studies focused on sediments deposited over the past few thousand years to million-year long records; from drilling ancient lake beds now on land to recovering sediments from hundreds of meters of water depth. We highlight here two international collaborative projects where LLO scientists had leading roles, The Lake Malawi Drilling Project and MexiDrill: The Basin of Mexico Drilling Program.

The Lake Malawi Drilling Project collected sediments at 600m water depth to recover a continuous record of past climate in the continental tropics over the past ~1.3 million years. This region over this time tells us about the conditions where and when humans evolved. Major findings include evidence that over the past million years, climate in this part of eastern Africa, in contrast to northern Africa, shifted from arid conditions with high-frequency variability to generally wetter conditions with more prolonged wet and dry intervals. This finding has significant implication for understanding the evolution and migration of early hominids in east Africa that we are beginning sort out as we obtain records from other areas on the continent.

Mexico City (then called Tenochtitlán) was established by the Aztecs in the 1300s on an island in the center of a closed-basin lake system, which at that time was shallow, marshy, and relatively saline. These lakes, which had existed for some 350,000 years, have been heavily modified through lowering of the water table to improve flood control, accommodate agricultural expansion, and provide water for urban development, and only a small remnant remains in the agricultural lands at the southern outskirts of Mexico City. However, the underlying sediments contain a rich record of past climate conditions. In 2016, LLO scientists were part of an international team (Mexico, Spain, Germany, UK) that drilled and recovered a sedimentary record, which we are now analyzing with the goal of recovering a 350,000 year record of environmental change directly relevant to the 25 million inhabitants of Mexico City.

Witnessing the Present

Large lakes sometimes change fast. As an example, consider how the introduction of new species may change the whole character of a lake ecosystem. Over the past two centuries, more than 180 invasive species have become established in the Laurentian Great Lakes and their watershed. Of those, among the most recognizable and damaging are two species of closely related bivalved mollusks (relatives of clams): the zebra and quagga mussels, together known as dreissenid mussels. After being accidentally introduced into Lakes Erie and St. Clair in the 1980s, dreissenids spread throughout all five of the Great Lakes and to numerous other water bodies in the U.S. and Canada, including many dozens of lakes and rivers in Minnesota.

The establishment of zebra and quagga mussels led to many changes in the functioning of aquatic systems and their ability to provide essential ecosystem services. As filter feeders, dreissenids can increase water clarity, stimulating growth of benthic (bottom-dwelling) plants and competing with zooplankton and the fish that rely on

Figure 5. Explosively growing dreissenid mussels have greatly altered lake environments. Here, a cluster of zebra mussels has encrusted a native, larger clam. Dreissenids affect lake environments in a variety of ways but those pathways are still being actively investigated. Photo credit: Ted Ozersky.

the zooplankton for food. These changes can result in modification of the food webs and fish communities of invaded systems. Dreissenids can also overgrow native mussels, leading to their localized extinction and to other changes in the diversity and abundance of benthic animals. Dreissenids attach not only to other mussels, but to artificial structures as well, including water intake pipes, boats, and buoys, leading to clean-up costs in the millions of dollars annually.

We know these invasive mussels have dramatically changed some large lakes, but we still don't understand well how they have done this. One aspect of zebra and quagga mussel impacts that is not well understood is the effect their establishment has on nutrient dynamics in invaded systems—that is, the cycling and distribution of phosphorus and nitrogen, elements that control the biological productivity of lakes and rivers. Changes to nutrient dynamics can lead to undesirable consequences such as excessive algal blooms, proliferation of toxin-producing cyanobacteria, or changes to the productivity of food webs, including abundances of commercially and recreationally important fish species. Researchers at LLO are conducting studies to better understand and predict the effects of invasive mussels on nutrient dynamics in both inland Minnesota lakes and in the Laurentian Great Lakes.

In the summers of 2014 and 2015, scientists from LLO sampled 10 dreissenid-invaded lakes throughout Minnesota, characterizing the distribution and biomass of mussels and making measurements on the turnover and storage of nutrients by the mussels. This was the most comprehensive study of the impacts of dreissenids on nutrient dynamics in lakes to date, and showed that invasive mussels can redirect large amounts of nutrients from the water to the bottom of lakes. Some of these nutrients become locked up in the soft tissues and shells of mussels, while another portion is returned to the water in dissolved form through metabolic excretion activity of the mussels. It appears that although dreissenids may be able to slightly alleviate the effects of excessive nutrient loading in some lakes by storing nutrients in their tissues, in unproductive lakes they may further reduce productivity and starve other organisms. This work lies at the interface of biology and chemistry, or "biogeochemistry."

LLO researchers are scaling up what they learned from work on small Minnesota lakes and are starting a research project to characterize the effects of dreissenids on nutrients in the entire Great Lakes ecosystem. Over the next three years, LLO researchers and students will sail aboard the *Blue Heron* and other research vessels to Lakes Superior, Michigan, Huron, and Erie; they will use a combination of field sampling, lab experiments, and mathematical models to study the effects of invasive mussels on the Great Lakes. These studies will help uncover the causes behind some poorly understood recent changes to the water chemistry of the Great Lakes and will enable researchers and ecosystem managers to better predict how the Great Lakes will respond to future changes in the abundances of dreissenid mussels, the loading of nutrients from the watershed, and the interaction of these processes with other environmental changes happening in the system.

LLO scientists are always interested in discovering new things. In some cases this means studying something familiar in a new way. For example, the vast majority of lakes studies in seasonal environments have taken place in the ice-free season, especially in the summer. It is beginning to be recognized though that lakes remain active in the winter and we cannot understand what lakes do in the summer without understanding what they do in the winter. This means leaving the comfort of warm offices and venturing out on the ice. In other cases, new things are learned by applying brand new tools and techniques. An example of that is in unlocking the vast storehouse of information that is present in the genetic material in organisms in lakes. The majority of the genetic diversity found in lakes is in the

Figure 6. Scientists are discovering that lakes do not rest in the winter. Here, LLO faculty member Ted Ozersky is using a net to sample winter populations of zooplankton, small crustaceans (related to shrimp) that consume algae and in turn are consumed by fish.
Photo credit: Steve Kuchera, Duluth News Tribune.

microbial populations that we understand are key in nutrient cycles and which form critical links in aquatic food webs. Advanced genetic sequence techniques together with ever more powerful statistical tools are opening new windows into this biodiversity.

Other LLO studies of lakes as they exist today concern lake physics. The laws of physics govern the temperature and circulation of large lakes. In turn, these physical properties affect weather, fisheries, shipping, water quality, and coastal engineering. Physics "sets the table" for all other in-lake processes. Physical research at LLO spans a range of activities, from monitoring long-term trends and providing context for multidisciplinary projects, to investigating fundamental aspects of large-scale fluid dynamics.

Researchers at LLO provide a large amount of practical real-time data to the public and scientific community. As part of the Great Lakes Observing System, LLO maintains buoys in the western arm of Lake Superior that report air and water temperature, wind speed, and wave height. These measurements are not only viewed by anglers and hobbyists, but are also integrated into national weather forecast models. LLO also provides "nowcast" predictions of Lake Superior, using current weather data to estimate

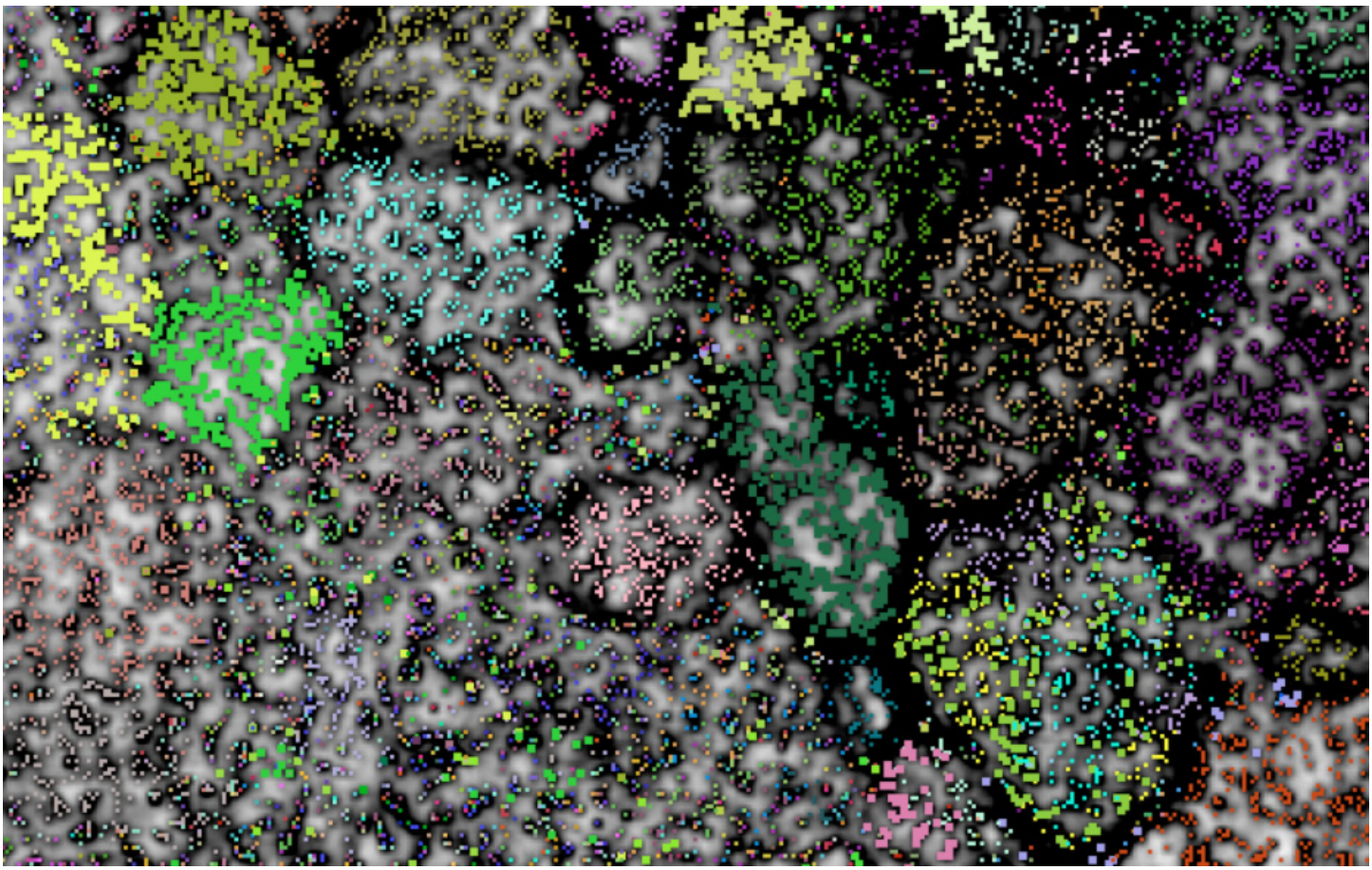

Figure 7. LLO scientists are using unique DNA fingerprints to discover new forms of biodiversity in large lakes. In this image, ESOM (Emergent Self Organizing Maps) shows the genetic relatedness of distinct microorganisms found in Lake Superior sediment using color and spatial position. Each point represents a DNA fragment which has been colored according to its taxonomy. Applying advanced genomic tools such as this can yield unique insight to cycling of elements like carbon and nitrogen in natural environments. Computer image by Cody Sheik.

the temperature, velocity, and water-level across Lake Superior.

Researchers are also collecting long-term records of Lake Superior. An array of sub-surface moorings have logged temperature and currents nearly continuously for the last 13 years. These moorings consist of a steel float 10 m below the surface (safe from ship propellers and the deepest projecting ice "keels"), which is tethered to an anchor by a steel rope. Instruments, which are attached to the rope every few meters, measure temperature and currents from top to bottom. These instruments can't report real-time data because they are inaccessible, except when they are serviced once a year. However, over time these measurements have revealed subtle long-term warming trends and some surprising discoveries, such as an 11-m (36-ft) deep ice keel during the extremely cold winter of 2013–14.

For process-studies, which investigate specific aspects of fluid dynamics in detail, LLO researchers have also collected a diverse set of cutting-edge measurements from lakes around the world. These measurements have targeted processes, such as eddies tens of kilometers across, dye spreading, turbulence, and sound propagation. Most of the measurements were taken from research vessels, such as the *Blue Heron*, but others were collected using autonomous underwater vehicles, known as "gliders." These gliders

Figure 8. One of LLO's solar-powered buoys on a calm, sunny Lake Superior day, sending data concerning air and water conditions to shore. During the open water season, data from LLO's two buoys (LLO1 and LLO2) are available from http://d.umn.edu/buoys/.
Photo credit: Jay Austin lab.

slowly move from the surface to the bottom and back again by increasing or decreasing their density. As they rise or fall, they glide horizontally toward programmed GPS coordinates. In a single deployment, these gliders can travel thousands of kilometers over the course of many weeks. These observational tools extend observable conditions greatly, providing data where and when direct human observation would be impractical or even impossible. Scientists have effectively developed "new eyes" in their pursuit of knowledge.

Looking to the Future: Preparing the Next Generation

At the Large Lakes Observatory, we combine our research mission with the education of graduate students and outreach to the local community. During scientific expeditions, generally half of the *R/V Blue Heron's* science party is made up of University of Minnesota Duluth undergraduate or graduate students, giving the students a full immersion in a field research experience. Along those lines, we at the LLO have embarked on a complete redesign of our graduate curriculum in order to better prepare our students for twenty-first century careers. Based on surveys of previous students and interviews with current employers, we defined some specific goals for our new curriculum. In order to succeed in their careers, they are required to have an interdisciplinary understanding of the field; an ability to work closely and converse with social scientists, policy makers, and the public; and an understanding of the professional skills required for their career. We have therefore redesigned our curriculum to include professional skills, field skills, and communication skills well integrated into the first-year graduate interdisciplinary scientific curriculum.

In the first half of this year, our students design a scientific project, carrying out a field campaign, sample analysis, data analysis, and writing up and presenting their results both individually and as a group at the end of the first semester. This allows the students to practice and implement designing a complete scientific project from start to finish, focusing on both the science they are most interested in carrying out and also working with other students in the course to design joint field campaigns and group papers. They must both complete a project from start to finish individually and also work to make sure they collaborate well with their colleagues.

Our students interact with local professional limnologists and environmental scientists in smaller venues throughout the year, and in a more in-depth way through an end-of-the-year Capstone project. This Capstone project is led by a local professional, either in a private consulting company or governmental lab. Previous organizations we have partnered with for the Capstone project include TetraTech consulting, LimnoTech consulting, and the Duluth Environmental Protection Agency laboratory. Through these Capstone relationships, student groups are given an authentic problem, work through a data set, and prepare and lead a presentation for industry professionals and interested stakeholders at the end of the project. They gain a professional network, meet potential employers, and practice important professional skills like project management, time management, and scientific communication. Our Capstone partner organizations have the opportunity to train potential new employees and have low-cost but educated students dedicated to their projects for

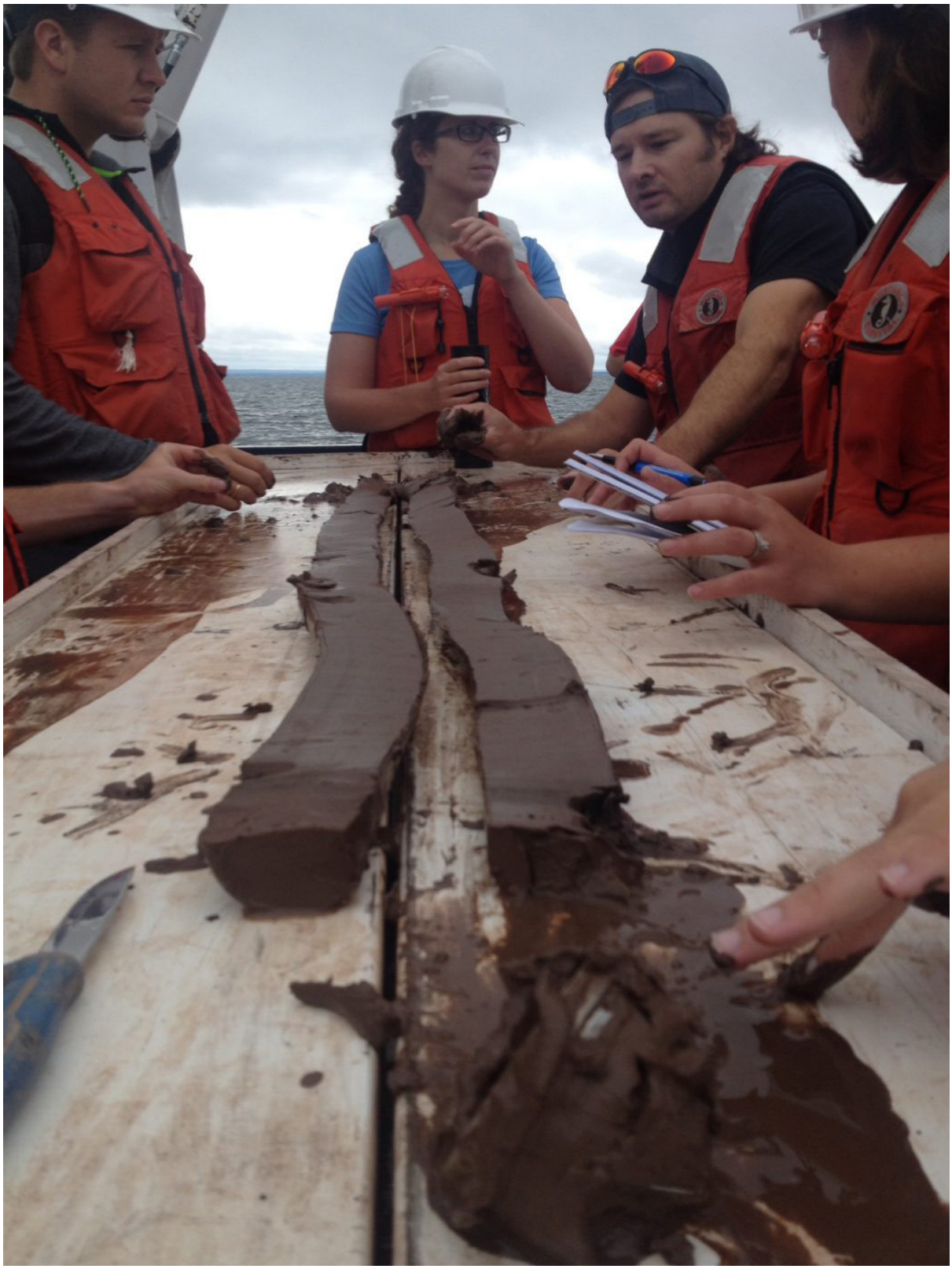

Figure 9. LLO professors and students gather around a sample of Lake Superior mud, which was collected using a coring device and then split into two halves. Lake sediments like this are a time machine, giving us insight into conditions well before scientific records began.
Photo credit: Sergei Katsev.

weeks every year. Our group is always open and looking for new Capstone partners in the Duluth and Twin Cities area for our student projects, and our goal is to keep expanding our list of partner organizations.

Over the last four years, LLO has conducted a "Chief Scientist" training program where graduate students, postdoctoral fellows, and first-year faculty members from outside the University of Minnesota system have participated in a workshop and multi-day research expedition using the *R/V Blue Heron*. Thirty individuals have participated in this program, representing 20 institutions from across the country. The participants not only learned how to plan and execute their own research voyage but also were able to collect samples and data for their own work, learn more about the University of Minnesota and the Large Lakes Observatory, and experience how exciting work on the Great Lakes can be. This program helps bring Great Lakes science to the attention of future scholars from all over the country.

LLO is committed to insuring open channels of communication with the public. The scientists and staff of UMD's Large Lakes Observatory have been diligently and enthusiastically organizing monthly events during the spring, summer, and fall since 2013. During each LLO Science on Deck event, the *R/V Blue Heron* ties up near the Great Lakes Aquarium and extends the gangway so the public can come aboard from noon to 4:00 p.m. Tours are provided by scientists, crew, and students for an overview of the *R/V Blue Heron's* layout and research capabilities. A variety of scientists prepare and present results of large lakes studies under a canopy on deck at each event, as well. Each scientist will answer questions on a related topic and share photos, graphs,

Figure 10. What better place to learn about lakes than aboard a big boat? Here, a party hears about some of the Blue Heron's scientific adventures while the boat is tied up in Duluth harbor at a Science on Deck event. Photo credit: UMD News Service.

equipment, and samples. During the upcoming summer (2018), the *Blue Heron* will stop in Milwaukee and Chicago for Science on Deck events, inviting the public there to visit the vessel and learn about the Great Lakes ecosystem.

Conclusion

LLO works hard to fill a large void in understanding. Though large lakes are important, fascinating, and valuable, our understanding of how they work is very incomplete. Indeed, basic research on the large lakes of the world lags behind its counterpart on the oceans. Our nation's freshwater inland seas, as well as those on others continents, are invaluable resources and are in need of major research initiatives. LLO frequently advocates for increasing attention on these huge "eyes" of Earth.

The research of the Large Lakes Observatory provides more than the wonder of discovery. It serves as the basis for assessing human impact on large-lake ecosystems, and for developing sound policy for protecting these invaluable bodies of freshwater as our global environment evolves.

Figure 11. LLO scientists sometimes find themselves hundreds of miles away from any other persons, with nothing but water as far as the eye can see. This is one of the many rewards of doing scientific research on Earth's largest freshwater bodies. Photo credit: Blue Heron crew.

Judgment can be recognized as a scientific tool. Much of the judgment, knowledge, and skill needed to make good decisions in science is learned through basic research, designed to help us fill in the white space of knowledge, to understand how separate pieces come together to make a functioning whole, and to assess how human actions alter the natural world around us. LLO undertakes with pride and dedication interdisciplinary studies that include biology, chemistry, physics, and geology in order to improve our understanding of these globally significant resources and provide society with knowledge needed to manage them sustainably for future generations.

For More Information:

LLO Social Media feeds:

- Instagram – LLOInstagram
- Twitter – @UMDLLO
- Facebook – UMDLLO, LLOScienceOnDeck

Further reading

Sterner, Robert, Steve Colman, and Thomas Johnson. “Institute profile: The large lakes observatory and the scientific study of the large lakes of earth.” *Limnology and Oceanography Bulletin* 26, no. 1 (2017): 11-13.

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About the Authors

The authors are among the scientists and staff of the Large Lakes Observatory, University of Minnesota Duluth, and they have worked on small and large lakes in Africa, Asia, in the Arctic, as well as in our own backyard in the largest lake on Earth. You may meet some of them at a Science on Deck event, held some summer Fridays on Duluth’s waterfront (see our Facebook page “LLO Science On Deck”).

FEATURE

WATER @ UMN ROUNDUP

By Ben Gosack, Roxanne Biidabinokwe Gould, John S. Gulliver, Tim Gustafson, Beth Knudsen, Leslie Paas, Mark Pedelty, Jim Perry, Robert Poch, Dimple Roy, and Anika Terton

As the editors put this issue on "Water @ UMN" together, we realized that the breadth, complexity, and variety of water-related work at the University of Minnesota could never be encompassed in a few articles. Accordingly, we sent a prompt out as widely as we could, asking water scholars to tell us, in a few paragraphs, what it was about their work that they were most excited about. The short pieces that follow contain some of their responses, in no particular order.

As part of Welcome Week 2010, incoming students to the University had the opportunity to canoe on the Mississippi River. Image courtesy of University of Minnesota.

Roxanne Biidabinokwe Gould

Assistant Professor, Ruth A. Meyer Center for Indigenous Education and Environmental Education, University of Minnesota Duluth

Indigenous Women's Water Practices, Responsibilities and Resistance: Implications for Sustainability

When I was a child, there were pristine and healthy bodies of water where my family camped, fished, and swam. Today most of these bodies of water are polluted and are no longer safe to swim or fish because of industry, development, chemical run offs from farms, salted roads, and climate change. There is a growing concern and movement across the Indigenous world to save and reclaim these bodies of water as the original Indigenous stewards.

The focus of this research is on Indigenous women's traditional practices, responsibilities, and resistance in regard to water since women are often seen as the traditional caretakers of the water in Indigenous communities. Their relationship to water in many communities is connected to creation, sacred sites, pregnancy, and birth. Early observers of Indigenous peoples have often overlooked the importance of Indigenous women's cosmology and contributions to their nations.

Interviews are being conducted with Indigenous women from four regions of the country: (1) where there is a scarcity of water, (2) where Indigenous homelands are/will be impacted by rising sea levels as a result of climate change, and (3) where there is an abundance of water, but the water is polluted as in my Anishinaabe homeland. Indigenous women from the Great Lakes, Dakotas, Southwest, and Hawaiian Islands are being interviewed for this comparative case study which will be examined through a critical Indigenous pedagogy of place.

As the world is forced to address water issues related to drought, pollution, depleted aquifers, rising sea levels, and destruction brought on by development, climate change, and massive storms, I argue that there is a need to look at traditional ecological knowledge (TEK) of Indigenous peoples in collaboration with western science to problem solve the water issues faced by our planet.

John S. Gulliver

Professor, Department of Civil, Environmental, and Geo-Engineering, University of Minnesota Twin Cities

My group's research includes the development of technology to manage and treat stormwater runoff before it enters receiving water bodies. First, we developed the MPD Infiltrometer, which is used to take multiple infiltration rate measurements simultaneously and quantify parameters for infiltration practices. Second, we developed the SAFL Baffle, which is designed to place in a catchment to hold sediment so that it can later be cleaned out by a vactor truck. Third, we developed the iron enhanced sand filter, which will retain both dissolved and particulate phosphorus. These devices are all being built and/or used by cities, counties, state agencies, and other municipal entities to clean up stormwater runoff.

Jim Perry, Beth Knudsen, Ben Gosack, Dimple Roy, Leslie Paas, Anika Terton

Jim Perry, H.T. Morse Distinguished Professor of Water Quality and Environmental Management, Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota Twin Cities,

Beth Knudsen, Minnesota Department of Natural Resources, St. Paul,

Ben Gosack, Minnesota Department of Natural Resources, St. Paul,

Dimple Roy, International Institute for Sustainable Development, Winnipeg, Canada,

Leslie Paas, International Institute for Sustainable Development, Florianopolis, Brazil,

Anika Terton, International Institute for Sustainable Development, Winnipeg, Canada

Seeking and climate sensitive watershed management in 2050

Watersheds are ecosystems and should be managed at the ecosystem scale. However, the future is uncertain due to a range of influences like climate change, demographics, and economics. We cannot predict the future so we must manage adaptively. Globally and locally, we need knowledge, tools, and people to achieve that adaptive approach to management. A current effort ties together a global capacity development approach to watershed-based ecosystem management, and university classes that use an innovative tool developed by Minnesota Department of Natural Resources (DNR) (i.e., the Watershed Health Assessment Framework or WHAF).

The Adaptive Watershed (TAW) is a capacity development program developed by the University of Minnesota and the International Institute for Sustainable Development. It is implemented in a 4-day workshop setting, drawing together stakeholders from a wide range of backgrounds, all with a common interest in a single watershed. The workshop consists of 14 modules. The first seven take participants through a series of steps that help them understand the watershed and its people. The next four advance informed decision making for watershed management. The final three help participants take an inclusive approach to management and commit to future action.

The logic of TAW is brought home in upper level and graduate level water quality classes at the University of Minnesota. The WHAF is a visualization and analysis tool focused on watershed scale management. Students work in groups of four, each using the WHAF to characterize a specific Minnesota watershed. Each group is then given scenarios intended to represent climatic conditions that sub-basins in their watershed are expected to experience in 2050. The overall question posed is: *What should the Board and Manager do in the next 3-5 years to be most ready to adapt to the conditions of 2050?*

Several lessons have emerged from the work to date:

1. Minnesota's WHAF tool is highly innovative and is a rich resource for planning.

2. Traditional approaches to management planning seek to engage stakeholders and represent the breadth of their interests. However, that practice often fails to recognize or protect vulnerable communities; TAW explicitly addresses that.

3. Climate-sensitive planning traditionally predicts future climate conditions (e.g., mean temperature, precipitation) and uncertainty about those predictions. It is relatively rare and somewhat difficult to predict future extreme events, yet those extremes will control much of the perceived impact.

4. It is uncommon to include demographic and economic predictions in such scenarios.

Weaving together the international aspects of TAW, the local aspects of the WHAF, and university classes advances capacity for innovative, forward looking, climate-sensitive ecosystem management of Minnesota watersheds.

Tim Gustafson, Mark Pedelty, Robert Poch

Tim Gustafson, Senior Lecturer, Department of Writing Studies, University of Minnesota Twin Cities,

Mark Pedelty, Professor, Department of Communication Studies, University of Minnesota Twin Cities,

Robert Poch, Senior Fellow, Department of Curriculum and Instruction, University of Minnesota Twin Cities

A River Dance: Ecosong's "Watershed" Spreads the Word About Chloride Pollution and Residential Deicers

Watershed

See the video "Watershed" here.

The Mississippi Watershed Management Organization's Salt Smart program aims to reduce chloride pollution in Minnesota's rivers, lakes, and aquifers through educating residents about the overuse of deicers. When our Ecosong team applied to the MWMO for a mini-grant, they asked if we might be interested in the Salt Smart effort. We certainly were, and within a matter of weeks Tim Gustafson had composed "Watershed," a song about reducing the use of road salts. Here I (Pedelty) intend to explain how we went from a song and concept to the music video embedded above.

At Ecosong we make music videos for environmental partners. Before "Watershed" we produced "We Live in the Lake" to help the Lake Pepin Legacy Alliance (LPLA) recruit members for lake restoration efforts and "You Can Build a Garden" to support Blue Thumb and Minnehaha Creek Watershed District's water and soil stewardship initiatives. "Watershed" was a bit different in that the performers involved came from our campus community and not organizational staff and local musicians, as was the case in our previous videos, all of which and more can be viewed at Ecosong.net.

We Live in the Lake

See the video "We Live in the Lake" here.

After Tim wrote "Watershed," the Hypoxic Punks recorded it at Atomic K Studios, drawing on the talents of engineer Karl Demer. With the recording in hand, I storyboarded and scripted the music video, imagining a bunch of dancers and musicians representing various wintry archetypes (hockey player, figure skater, snowmobiler, grumpy old men, etc.). In my head I imagined them dancing with shovels, but never could I have envisioned anything like what the nine very talented volunteer dancers produced. Given only the most basic blocking and role identities (salters, slippers, "Vanna White" presenters, and shovelers), these skilled artists crafted and performed captivating choreography. Never was so much accomplished for so little. In return for pizza and tacos at rehearsals, we were given dazzling movement and kinesthetic storytelling.

Then, as always, Karl and I edited the video. I come in to our editing sessions with a rough sequence in mind and a Director's sense of entitlement, but Karl has the decades of advanced engineering skills to advance it far beyond anything I could ever do on my own. Lesson one of production and direction is giving the lead editor space to be creative. Those sessions typically go something like this:

> Mark: "Is it possible to have the titling appear to be part of the background?"
> Karl: "Sure." [Karl's fingers then fly over the keyboard and touchpad] "Like that?"
> Mark: "Yes, that looks great."
> Karl: "Have you thought about using a font and graphic like this?"
> Mark: "That looks great."

You Can Build a Garden

See the video of "You Can Build a Garden" here.

"Watershed" was a bit different than the previous music videos and audio and video projects we produced before that. It was a single take sequence rather than a compilation of separate scenes. I knew that with a $3000 budget (the other projects were far costlier) that multiple scenes, shoots, and editing sessions would not be possible, but in this case that limitation felt like a virtue. We had the luxury, therefore, of using the best of about 8 performances and then choosing between various camera angles. The video has the feel of a live performance rather than a media construct because it is a single sequence with constant movement in the frame.

From writing grants to web design for Ecosong.net, making these videos is a lot of "work," but it is every bit as enjoyable as it looks. Ecosong is based on a philosophy of free association—volunteers doing what they love—as well as collaboration and creativity.

With just 5,500 views so far (as of March 23, 2018) spread across the three music videos, we can't claim to have radically expanded the audience for any of our partners' local outreach efforts, at least not yet. Nevertheless, audience feedback, sixteen festival selections, and six festival awards indicate that these videos might have potential to continue serving their purpose and perhaps will reach new viewers beyond the local target audience. To make that happen we need to continue learning more about social media outreach and campaign execution.

One of the most promising developments in that regard is Claire Doty and Ella Cochran's work to develop a curriculum for "We Live in the Lake." LPLA's Rylee Main and MacKenzie Consoer are assisting them in that effort. Students in high schools in the Lake Pepin area, as well as visitors to local parks and nature centers, will watch "We Live in the Lake" and a short instructional video introducing them to the lake's serious sedimentation problem. They will produce videos illustrating their families' connections to the lake (fishing, paddling, etc.) and discuss creative ways to get people involved in restoration.

No matter how many people eventually view these videos, the community music-making and media production involved in each project have helped to organize and mobilize communities of practice. When people are able to combine their individual talents and environmental action, it stokes organizational esprit-de-corps and brings in new blood. That is well illustrated by the talent onscreen in "We Live in the Lake" and "You Can Build a Garden." And for each performer on screen there is an engineer, accountant, cook, editor, education director, and others making it all happen behind the camera. Paolo Friere refers to such community work as "codification," creating something that everyone can point to as representing their collective objective.

That's what we do, in a nutshell. If you are interested in learning more about Ecosong's methods and philosophy, please read "We Live in the Lake": Ecomusicology as Community Pedagogy in the *Journal of Music History Pedagogy*. Get involved if it sounds like your thing. Our next projects include a music video about marine sanctuaries in Western Washington, a Minnesota State Park tour, and a global grant project where we will join efforts with partners in India, China, Tanzania, and Haiti. Ecosong is an outgrowth of the Hypoxic Punks band and has been in operation for over a decade, but with projects like "Watershed" we feel like we are just getting started.

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FEATURE

WATER @ UMN ROUNDUP

By Kate Brauman, Sharon Moen, Mary Sabuda, Cara Santelli, Ingrid Schneider, and Shashi Shekhar

As the editors put this issue on "Water @ UMN" together, we realized that the breadth, complexity, and variety of water-related work at the University of Minnesota could never be encompassed in a few articles. Accordingly, we sent a prompt out as widely as we could, asking water scholars to tell us, in a few paragraphs, what it was about their work that they were most excited about. The short pieces that follow contain some of their responses, in no particular order.

The University of Minnesota's Twin Cities campuses are both very close to the Mississippi River and offer unparalleled access for scientific inquiry close to home.
Image courtesy of University of Minnesota.

Kate Brauman

Lead Scientist, Global Water Initiative, Institute on the Environment, University of Minnesota Twin Cities

How do we account for Nature's Contributions to People (NCP), especially when it comes to water? And where in the world are we getting more, or fewer, contributions from nature? I've been working with the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to try to answer those questions, or at least start the process of figuring out how we should answer them. Not surprisingly, figuring out the answers isn't easy. And it's not just that there are lots of totally valid and wildly different ways to approach these issues. There is also a diversity of people, from countries and cultures all over the world and spanning disciplines from anthropology to hydrology, with voices that need to be heard. One of the main goals of IPBES is to be more actively inclusive than environmental assessments in the past have often been, with a particular emphasis on including Indigenous and Local Knowledge in our assessment and on including the perspectives of Indigenous and Local Communities.

This has been a huge challenge for me, and a good one. Much of my work is focused on the big scale and the generalizable. To assess NCP related to water, I've reviewed literature on how deforestation in different parts of the world affects runoff and sliced and diced global data sets of evapotranspiration from different biomes. But we know the way that people manage the landscape, and how they've been managing it for generations, affects how the water flows across it. And we need to find ways to integrate that specific, local knowledge into our global assessment. We know that when things are hard to count, we often don't account for them at all. We don't want to leave anything out, but we also don't want to change its value or importance by counting it the wrong way. It's a challenge. And our first attempts will probably be wrong. But we're going to try anyway.

Sharon Moen

Senior Science Communicator, Minnesota Sea Grant, University of Minnesota Duluth

Solving the St. Louis River Estuary's Mercury Problem

Call it what you will—mercury, Hg, hydrargyrum, quick silver—this element isn't supposed to be fish food. Yet unnatural levels of mercury accumulate in aquatic food webs after coal-fired power plants and other industrial activities send it swirling into the atmosphere. This heavy metal eventually falls back to Earth where sulfate-reducing bacteria can change it into nerve-damaging methylmercury (MeHg). MeHg accumulates up the food chain after sticking to algae, which are eaten by tiny aquatic grazers (zooplankton). The grazers are eaten by small fish, which in turn are eaten by larger fish, and so it goes … sometimes in a direction that damages human health.

See video "Solving the St. Louis River Estuary's Mercury Problem" here.

In this video, graduate student Amber White explains how Sea Grant-funding is allowing University researchers to understand variable methylmercury levels in the St. Louis River and its estuary.

University of Minnesota Sea Grant scientists and their collaborators at the U.S. Environmental Protection Agency and Wisconsin Sea Grant are examining the processes leading to elevated MeHg levels in walleye and other sportfish in parts of the United States' largest tributary to Lake Superior, the St. Louis River. Their work is poised to inform decisions concerning dredging materials, habitat restoration, and fish consumption advisories. The results of the study are helping to define why some waters are plagued with MeHg more than others. MeHg abundance reflects:

- wetland abundance
- water chemistry (temperature, dissolved organic matter, pH)
- landscape qualities (soil type, ground cover)
- microbe activity
- mercury abundance and form (it exists in three species that behave differently in the environment)

No method of cooking or cleaning can reduce the amount of MeHg in a meal of fish since it binds to proteins in animal tissues, including muscle. Enjoy fish without worrying about an unhealthy dose of mercury by following the Minnesota Department of Health fish consumption advisories, and by eating smaller fish and species lower on the food chain.

Mary Sabuda, Cara Santelli

Mary Sabuda, Graduate Student, Newton Horace Winchell School of Earth Sciences, University of Minnesota Twin Cities,

Cara Santelli, Assistant Professor, Newton Horace Winchell School of Earth Sciences, University of Minnesota Twin Cities

Clean water is essential for every organism on Earth, yet many freshwater sources are polluted with high concentrations of metals and metalloids from mining, agriculture, and other industries, which can cause adverse health effects in animals and plants. Selenium (Se), specifically, is a problem because it is essential in small doses to most organisms for survival, yet high concentrations

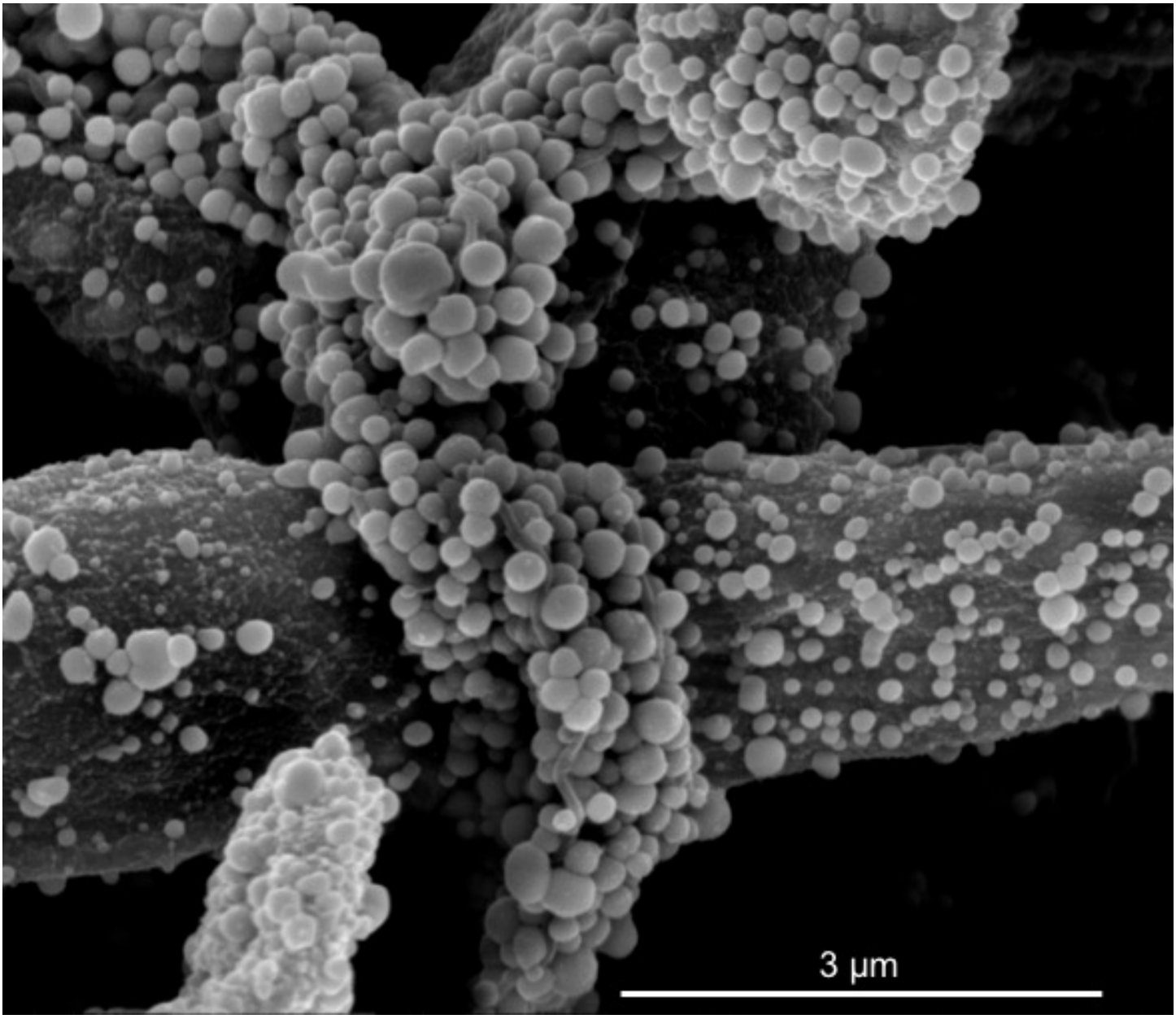
Mining of the Phosphoria Formation's phosphorus- and selenium-rich rocks in southeastern Idaho raises concerns about Se toxicity. Image courtesy of Carla Rosenfeld

can be detrimental to life. Similar to how mercury can be stored for long time periods within organisms in an environment, selenium can also bioaccumulate, which renders upper trophic level species extremely vulnerable to the effects of selenium. Mining of shale beds for phosphate ores, coal, and oil can release selenium into the environment, which can then become available to organisms. This can also occur during refining of these extracted resources and via natural weathering and runoff from Se-rich rocks. Unfortunately, current clean-up strategies are expensive, time-consuming, and resource-heavy. To efficiently clean up elevated concentrations of metals within freshwater sources, the Santelli Lab at the University of Minnesota has identified six common species of fungi that are capable of chemically transforming metals and metalloids, such as selenium. Some of these fungi can convert water-soluble selenium to an immobile solid

The fungal species, Alternaria alternata, transforms Se from a water-soluble state to solid red Se nanoparticles. Image courtesy of Jennifer Kenyon.

phase or a volatile phase, while others perform similar transformations with other heavy metals such as manganese, copper, nickel, and cobalt. To better understand this process, the lab combines information about geology and water chemistries in the environment with genomic techniques to understand how these fungi perform this essential "detoxification" on a genetic level.

Laboratory benchtop culturing experiments allow for a controlled environment in which to assess fungal gene functions and track the chemical transformation of selenium. Combined, these techniques provide the framework for designing and implementing an efficient engineering strategy for remediating metal(loid)-polluted areas.



Fungal selenium bionanoparticles (produced here by Paraconiothyrium sporulosum) imaged using a Scanning Electron Microscope. Image courtesy of Carla Rosenfeld.

Ingrid Schneider

Professor, Department of Forest Resources, University of Minnesota Twin Cities

Eight years strong, the University of Minnesota's Department of Forest Resources continues its experiential learning opportunities in select Minnesota National Parks: the Mississippi National River and Recreation Area and the St Croix National Scenic Riverway. Each spring students in the course Managing Recreational Lands (FNRM 4232/5232) work with park personnel to understand park visitor issues and apply their new-found knowledge and creative problem solving to inform park management. Park staff provide background information on select sites, host students on field trips, and constructively comment on final project presentations at the end of the semester. Students apply management frameworks and fresh ideas to perplexing real-world management problems while networking with agency personnel. The team-based approach contributes to the real-world application as does the final presentation to park staff and former students. Ideas from student projects are shared with park and regional staff and have informed project planning and ideation. Based on their success, the partnerships has been invited to share their work on a National Park Service panel on STEM learning at the 2018 National Center for Science and Civic Engagement Conference.

Shashi Shekhar

McKnight Distinguished University Professor of Computer Science & Engineering, University of Minnesota Twin Cities

Spatio-temporal Big Data Tools for Water Quality Monitoring

Water quality monitoring is usually based on infrequent (e.g., weekly) sampling and time-consuming (e.g., hours to days) testing methods, making it difficult to make timely decisions to protect water and environment in the face of pollution events. Recent advances include monitoring sensor networks to provide increased sampling frequency and associated big water-quality data. However, it is computationally expensive to analyze these big datasets due to their spatio-temporal nature, large volume, and high update rates. Our goal is to advance new scalable spatio-temporal big data mining tools[1], such as the flow anomaly miner, for water quality monitoring and early warning systems. Next, we describe the flow anomaly (FA) miner tool.

A flow anomaly miner identifies time-intervals with significant mismatch between the measurements of a pair of consecutive upstream and downstream sensors monitoring a flow. Mining FAs is computationally expensive because of the large number of time points of measurement and potentially long delays between consecutive sensors due to slow moving (e.g., wetland) water bodies. Traditional outlier detection methods (e.g., t-test) are suited for detecting transient FAs (i.e., time instants of significant mismatches across consecutive sensors) and cannot detect persistent FAs (i.e., long variable time-windows with a high fraction of time instant transient FAs) due to a lack of a pre-defined window size. In contrast, our Smart Window Enumeration and Evaluation of persistence-Thresholds (SWEET) [2] algorithm reduced computation cost by orders of magnitude using a smart counter and efficient pruning techniques. Experimental evaluation using a real dataset from Hydro-Lab sensors monitoring Shingle Creek (MN) showed our proposed approach outperforms baseline alternatives.

ACKNOWLEDGMENTS: This work was supported in part by the National Science Foundation, the U.S. Department of Defense, and the University of Minnesota.

Footnotes

[1] J. M. Kang, S. Shekhar, M. Henjum, P. J. Novak and W. A. Arnold, Discovering Teleconnected Flow Anomalies: A Relationship Analysis of Dynamic Neighborhoods (RAD) Approach, Proceedings of the International Symposium on Advances in Spatial and Temporal Databases, Springer LNCS 5644, 2009.

[2] J. M. Kang, S. Shekhar, C. Wennen, P. Novak, Discovering Flow Anomalies: A SWEET Approach, pp.851-856, Proceedings of the Eighth IEEE International Conference on Data Mining, 2008.

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FEATURE

WATER @ UMN ROUNDUP

By Thomas Fisher, John A. Hatcher, Todd Klein, Laurie Moberg, Jennifer E. Moore, John L. Nieber, Jian-Ping Wang, Wei Wang, and Kai Wu

As the editors put this issue on "Water @ UMN" together, we realized that the breadth, complexity, and variety of water-related work at the University of Minnesota could never be encompassed in a few articles. Accordingly, we sent a prompt out as widely as we could, asking water scholars to tell us, in a few paragraphs, what it was about their work that they were most excited about. The short pieces that follow contain some of their responses, in no particular order.

Jay Cooke State Park illustrates the natural beauty of northern Minnesota. The St. Louis river flows to Duluth and Lake Superior. Image courtesy of University of Minnesota.

Thomas Fisher

Professor and Director, Minnesota Design Center, University of Minnesota Twin Cities

Water and Innovation

Several years ago, civic leaders in Minneapolis and St. Paul began to develop, between the two Twin Cities campuses of the University of Minnesota, a former industrial area now called the Towerside Innovation District. The Minnesota Design Center, which I direct, has long been involved in helping the neighbors and landowners in the district, including the University, envision what an innovation district means in the 21st century, not just in terms of technological and economic development, but also in terms of renewable – and threatened – resources like water.

The district stands on top of a former river and wetland and so water has played an important role in its past – and will play an equally important role in its future. Some of the planning my center has done at Towerside, with landscape architect Bruce Jacobson and architect John Carmody in the lead, has involved daylighting the water that still runs below the surface in the district as part of a set of linked green spaces that complete a missing segment of the Twin Cities' bike and pedestrian network. In partnership with the Mississippi Watershed Management Organization, we have also helped with the placement of a district storm water, bio-retention basin to clean surface water for irrigation and industrial uses. These examples show how innovation in water use remains one of our greatest opportunities as we think about economic and community development in the years to come.

John A. Hatcher, Jennifer E. Moore

John A. Hatcher, Associate Professor, Department of Communication, University of Minnesota Duluth,

Jennifer E. Moore, Assistant Professor of Journalism, Department of Communication, University of Minnesota Duluth

One River, Many Stories: A Community Storytelling Project

In April 2016, faculty in the Journalism Program at the University of Minnesota Duluth asked a question: What would happen if all of the storytellers in a region turned their attention to one topic?

The answer was One River, Many Stories—a media collaboration between professional and amateur storytellers in northern Minnesota and northwest Wisconsin. Participants were asked to tell one story about the St. Louis River watershed. As the largest estuary feeding Lake Superior, the river was an easy choice for a topic. The St. Louis River's rich history as a water resource parallels the narrative of this region: stories of triumph, struggle, and renewal. Duluth's past, present, and future can be found in the river's diverse and ever-changing landscape.

Funded in part by the Knight Foundation Fund of the Duluth Superior Area Community Foundation, One River, Many Stories tested ways media collaboration could inspire innovation and nurture engagement among professional journalists, educators, and citizen storytellers. Participants were asked to share their published work on social media and use one of the project's hashtags: #OneRiverMN, or #ChiGamiiziibi (the Ojibwe name for the St. Louis River). Nearly 50 original stories were aggregated on our website, onerivermn.com, and over a thousand social media posts were documented.

Our study of One River, Many Stories' impact ("Disrupting traditional news routines through community engagement," *Journal Studies*) found encouraging results for projects that attempt to rally participation from commercial news organizations, citizen journalists, public broadcasters, and digital-first news organizations. Participants told us the project encouraged them to learn new things. Many said they developed a new passion for telling their own stories about the river and its communities. One River, Many Stories also fostered new relationships—especially among our local scientific and artistic communities.

The St. Louis River proved to be a powerful catalyst for inspiring community storytelling. As we look ahead, we are asking how we can continue to engage citizens and journalists alike to tell community stories often overlooked by traditional media. We also want to explore how our project can serve as a model for university-community partnerships who share our desire to facilitate innovation and collaboration in the twenty-first century media ecosystem.

To view our final report or to order a hard copy, visit our website: http://onerivermn.com/final-report/.

Read a review of One River, *a play that grew out of the One River, Many Stories project, here.*

Laurie Moberg

River Life, Institute for Advanced Study, University of Minnesota Twin Cities

River Life, a program in the Institute for Advanced Study at the University of Minnesota (UMN), creates opportunities for campus-community engagement, public scholarship, teaching, and research focused on water, place, and community. One of our current initiatives, We Are Water MN, is a traveling exhibit and six-week event series focused on telling Minnesota's water stories through diverse ways of knowing. We Are Water MN is a partnership among the Minnesota Humanities Center, the Minnesota Pollution Control Agency, the Minnesota Historical Society, the Minnesota Department of Health, the Minnesota Department of Agriculture, the Minnesota Department of Natural Resources and eight different host communities across the state that will display the exhibit and gather water stories. The exhibit opens at the University of Minnesota in October 2018.

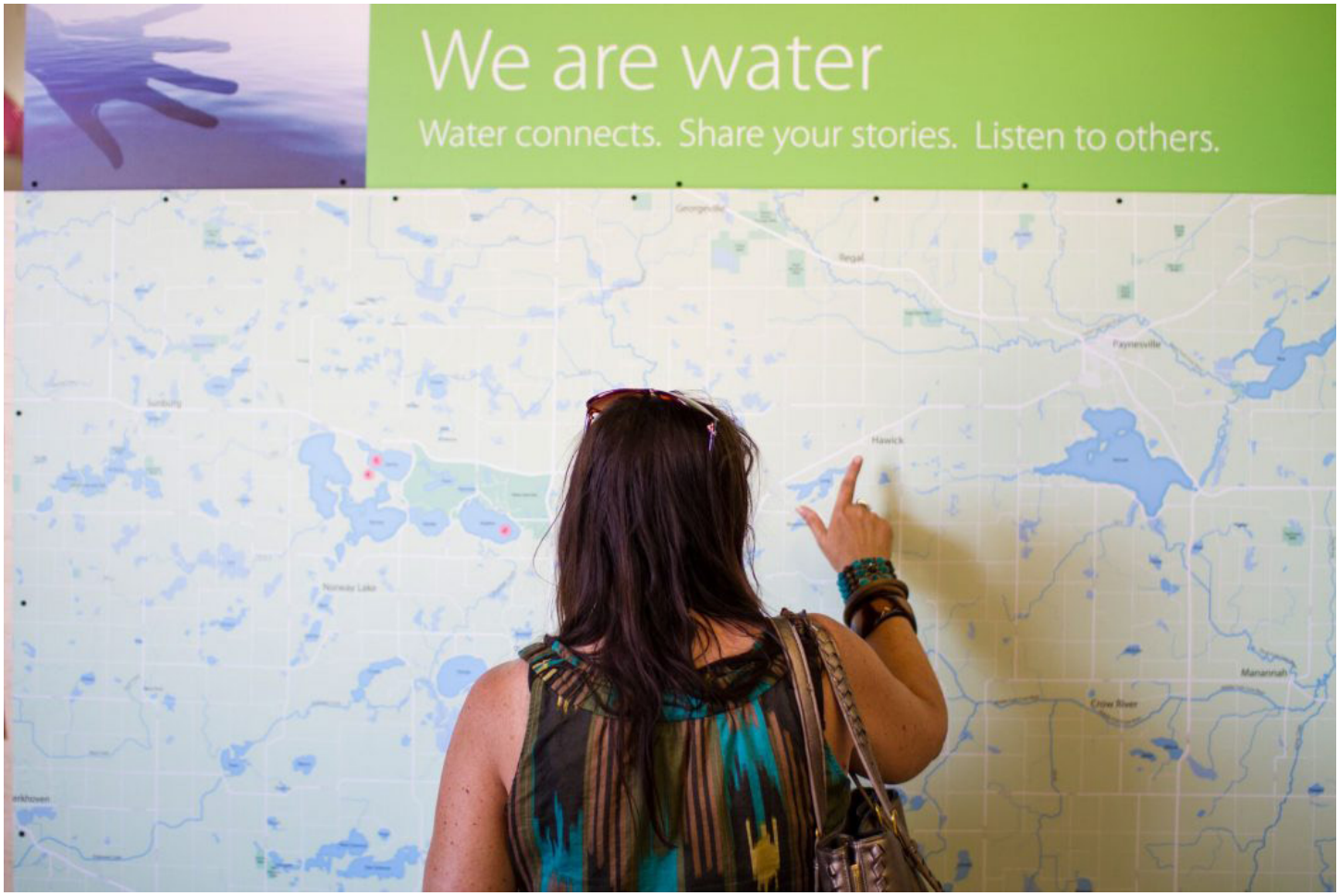
We Are Water MN exhibit preview.

We Are Water MN focuses on two main objectives:

First, the project aims to engage with nondominant perspectives and learn from them by asking people to share their water stories. The stories we tell about water are informed by our histories, culture, and experience and speak to inequalities in social power dynamics. While hosted here at UMN, we are focusing on integrating stories from across community and campus ways of knowing. By engaging diverse ways of knowing water through story, we begin to appreciate the social dynamics of our relationships with water and with each other.

Second, the project aims to foster responsible actions toward our waterways. Studies of water quality across Minnesota tell us that 40 percent of Minnesota waterways are impaired, but this does not tell us how to tie human care, behavior, and action to our waters. Through story, people begin to see their own connections to water; by hearing other people's stories, we see that our experiences and relations differ, often based on the uneven distribution of effects from impaired water systems. Appreciating our own water stories and the water stories of others helps mobilize action toward conservation and care.

While the exhibit will only be on campus for six weeks, we expect We Are Water MN to spur ongoing efforts for community-campus engagement, water conservation, and River Life's objectives to facilitate public scholarship focused on the meanings and permutations of water.



We Are Water MN Story Map preview.

John L. Nieber

Professor, Department of Bioproducts and Biosystems Engineering, University of Minnesota Twin Cities

Minnesota: How much water is there; how is it changing?

How much water do we have in Minnesota, and why would we want to know? In all the years of water research within the state, there has never been a direct accounting for the volume of water present in wetlands, lakes, streams/rivers, soil, and groundwater. However, it is something that researchers and water management agencies would like to know to make it more feasible to manage and utilize our available water resources more efficiently. It is recognized in the field of hydrology that the volume of water stored in soils and groundwater is related to the flow in streams and rivers, and also impacts the healthy exchange of this water with lakes and wetlands. In the field of limnology, it is recognized that the volume of water in lakes directly affects the time required for chemical constituents like nitrogen, phosphorus, and organic carbon to travel through aquatic ecosystems; this has a direct influence on the health of those ecosystems.

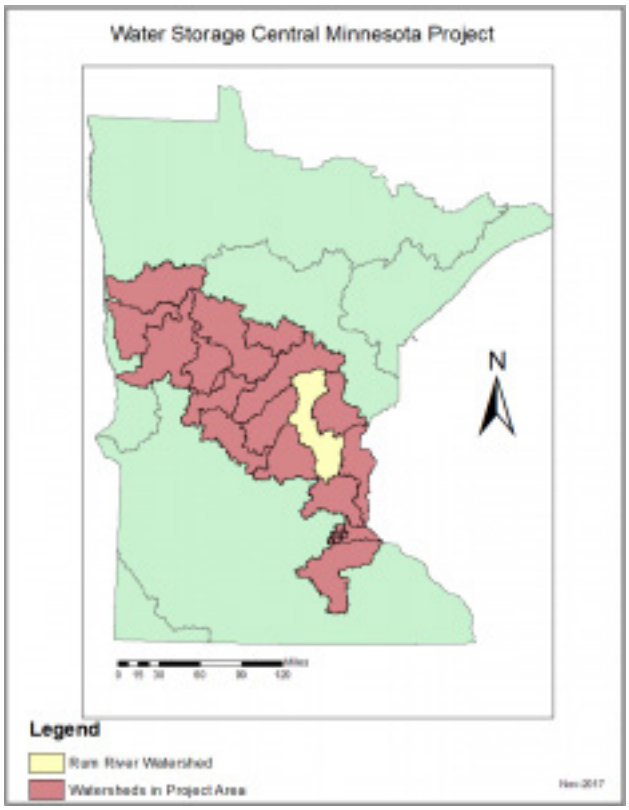


Figure 1. Map of study area. The HUC-8 watersheds are outlined. The highlighted watershed is the Rum River watershed. Image courtesy of John L. Nieber.

In a current project funded by the Legislative-Citizens Commission on Minnesota Resources (LCCMR), a team of researchers from the University of Minnesota departments of Bioproducts and Biosystems Engineering (John Nieber, Bruce Wilson, Joe Magner, Roman Kanivetsky) and Soil, Water, and Climate (Tim Griffis, John Baker), and Jared Trost from the US Geological Survey is using various methods to quantify the storage of water within a region comprising 17 HUC-8 (approximately 1,200 sq. miles in area) watersheds extending from the Twin Cities Metro Area to Moorhead (Figure 1). The methods include direct point measurements of water quantity (e.g., water levels in monitoring wells and in lakes), water balance calculations (precipitation, evapotranspiration, surface runoff), streamflow measurements, and satellite measurements including the GRACE (gravity) satellite, the SMOS (Soil Moisture & Ocean Salinity) and SMAP (Soil Moisture Active Passive) soil moisture satellites, and the WorldView satellite. Through a combination of these methods, the researchers intend to derive estimates of water storage and water storage

change within these watersheds. An illustration of the streamflow data used in the study is shown in Figure 2 for the Rum River watershed; illustration of water storage in the Rum River watershed as measured by the signal from the GRACE satellite is shown in Figure 3. Ultimately the project team would like to extend the analysis to all of Minnesota, and to assist state agencies to take more advantage of satellite and other aerial remote sensing methods to quantify the status of water storage within the Minnesota landscape.

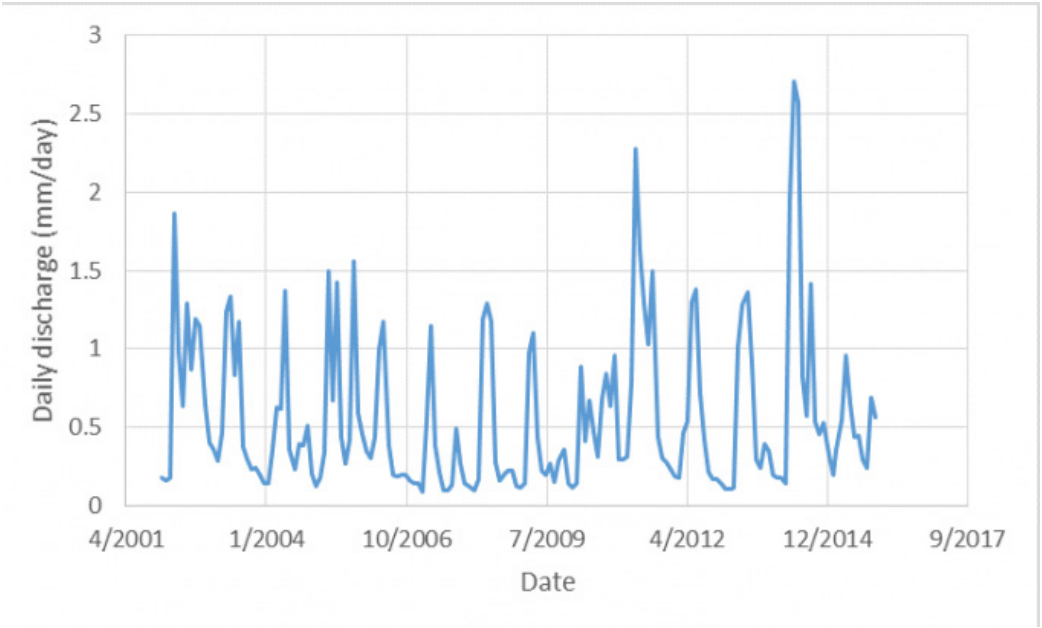


Figure 2. Illustration of the mean daily flows by month at the gaging station for the Rum River. Image courtesy of John L. Nieber.

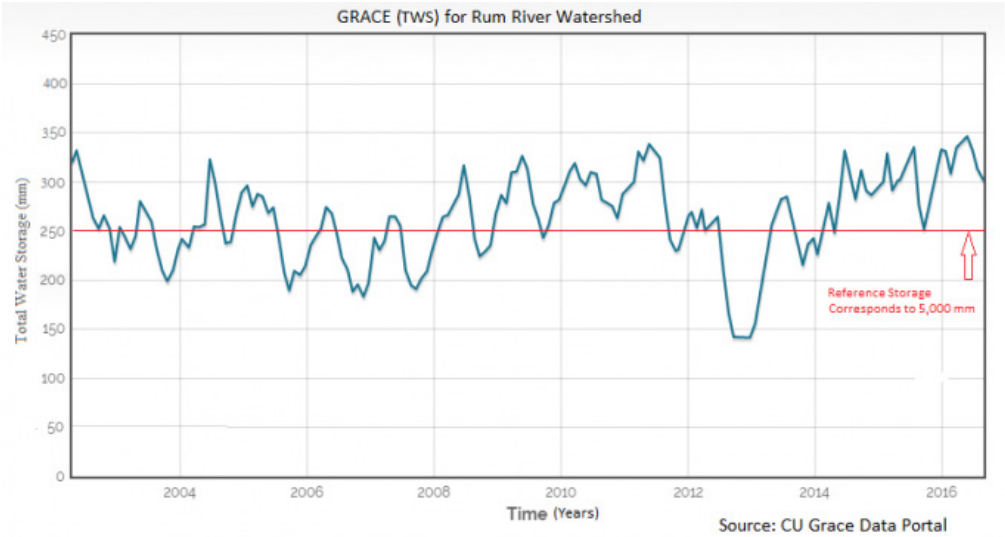


Figure 3. Variation in total water stored in the Rum River watershed for the period 2002 to 2017, as measured by the signal from the GRACE satellite. The total stored water includes all water stored in groundwater, soil moisture, lakes/wetlands, and streams/rivers. Gains in water storage originate from precipitation, while losses include evapotranspiration, river discharge, and consumptive use by human activities. The variation is presented as relative to the reference level of 5 m of stored water. Image courtesy of John L. Nieber.

Jian-Ping Wang, Wei Wang, Todd Klein, Kai Wu

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Applying Nanomagnetic Technology for the Detection of Heavy Metals from Drinking Water

Mercury contamination has been an important environmental and health concern throughout the world for decades. High exposures to mercuric ion (Hg2+) may result in acrodynia (pink disease) and damage to the nervous system and kidneys. Furthermore, mercuric ion is stable and soluble in aquatic systems, and methyl mercury can accumulate in bodies through the food chain, which is known to cause brain damage and other chronic diseases, even paralysis and death. Nowadays, the detection of trace-level toxic heavy metal ions mostly relies on bulky and costly analytical instruments in central labs. Driven by this need, Prof. Jian-Ping Wang and his group at the University of Minnesota developed and tested a diagnostic platform designed to detect mercuric ion (Hg2+) using nanotechnology.

They applied the knowledge that mercuric ion can specifically bind in between two DNA thymine bases and lead to the formation of a thymine-Hg2+-thymine (T-Hg2+-T) pair. Their developed testing process, which parallels the commonly used DNA hybridization process, involves DNA strands acting as sensors capturing a target analyte, to which a detectable object will bind to the sensor-analyte complex. In that case, a GMR (Giant Magnetoresistance) chip is used as the surface, and a magnetic tag (magnetic nanoparticle) is the detectable object. If the analytes are present in the sample, magnetic tags will bind to the GMR sensor resulting in a change in the electrical signal.

This diagnostic platform reaches a detection limit of 10 nanomoles per liter (nM, nmol/L) in both buffer and natural water, which is the maximum mercury level allowed in drinking water regulated by U.S. Environmental Protection Agency (EPA). Because of the features of GMR biosensing

technology, this GMR Hg2+ bioassay is pointing toward a convenient and rapid field test. Furthermore, as a versatile and strong contender in molecular diagnostics, GMR bioassay has great potential for the application of other pollutants monitoring in environment and food samples.

Recently, Prof. Wang's group has successfully developed and tested a prototype of Z-Lab, a portable diagnostic platform designed to perform on site testing of biological samples for various ailments. This is the first version of the prototype developed for point-of-care diagnostics.

Prof. Jian-Ping Wang and the Z-Lab diagnostic platform developed in his group. From left to right: Dr. Roy Huchzermeier, Prof. Jian-Ping Wang, Dr. Todd Klein. Image courtesy of Nokia Sensing Xchallenge and Jian-Ping Wang.

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FEATURE

FIELDS: THE TRANSFORMATION AND HEALING OF THE WHITEWATER VALLEY

By Maria DeLaundreau

They say hindsight is 20/20. Farmers of the past didn't have information about environmentally friendly agricultural techniques. The farming techniques used today to reduce erosion and other negative environmental effects were developed as we learned from agriculturally derived disasters. Situated in the Whitewater River Valley less than 10 miles from the confluence with the Mississippi River, Beaver, Minnesota was one such town that suffered. Farming the steep valley slopes and floodplains contributed to a degraded landscape and exacerbated the effects of

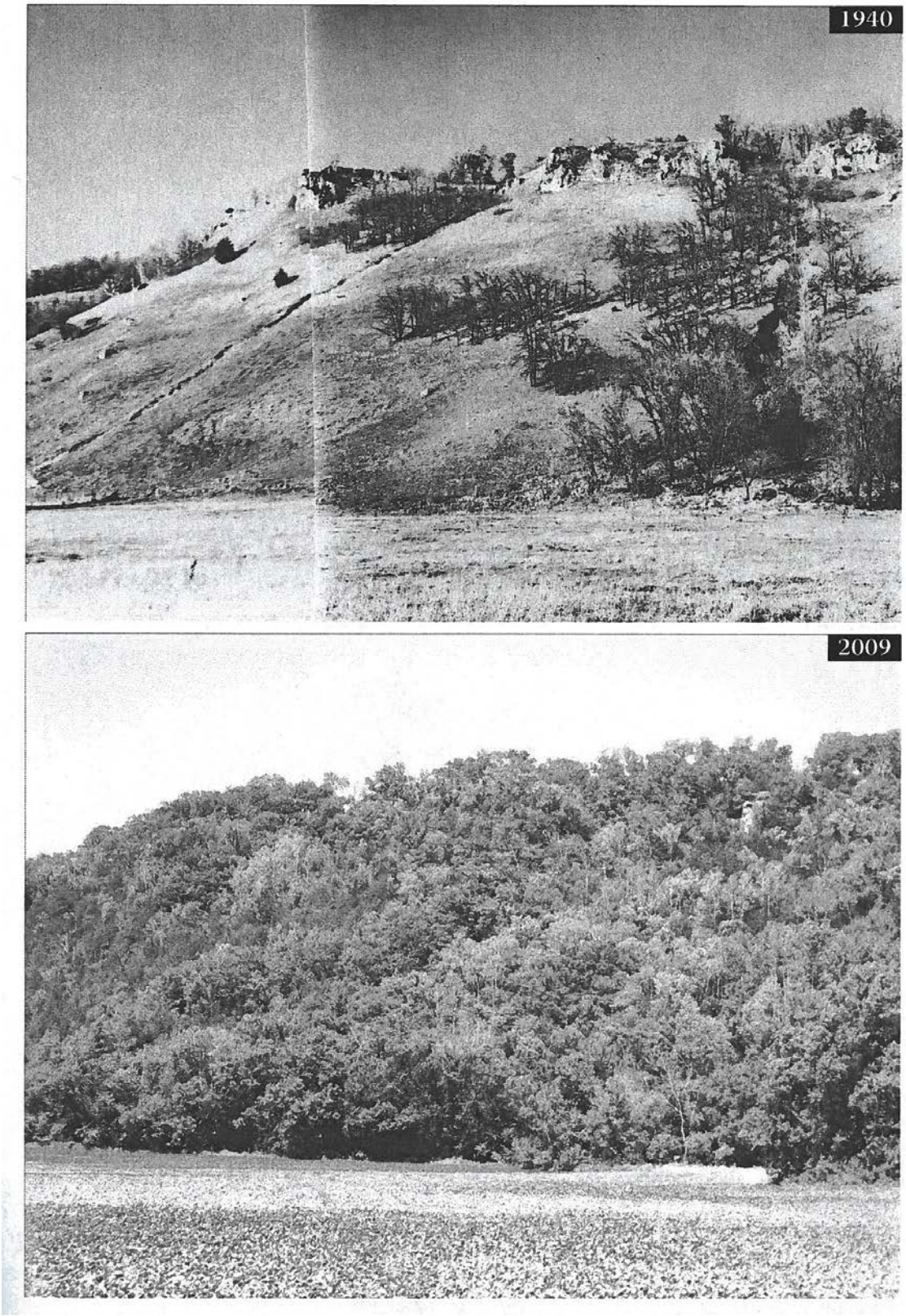
Landscape view at Whitewater Park. Notice the fields on the hillside. Image courtesy of the Minnesota Historical Society.

landscape-altering floods. In the 1920s, the town was flooded up to 20 times per year, and in 1938 Beaver was flooded 28 times. Crops and homes alike were not only flooded, but buried as the hills eroded; eventually, the floods deposited 15 feet of sediment, reaching almost to the town's second story floors. By 1940, residents were forced to abandon their community. Today the bluff country is scarred in ways that may seem subtle, but are apparent to natural resources professionals from "reading" the vegetation and soils. We are still learning how to heal this damaged natural system.

Before the catastrophe in the Whitewater Valley, there were no formal programs to prevent erosion. Preventing erosion was a critical first step toward the recovery of this region. Local farmers were eager to adopt new tillage and land management practices to prevent future disasters from erosion and flooding. National attention was likewise turning to soil and erosion issues, and in 1935 the federal government passed a law creating the Soil Conservation Service, the predecessor of the Natural Resources Conservation Service (NRCS), to implement soil-conservation practices throughout the country. Shortly after, in 1941, the Whitewater Soil and Water Conservation District (SWCD) became the ninth SWCD in the state. Together, these agencies and local farmers worked to reduce erosion.

The valley proved unsuitable for towns and agriculture, but the Izaak Walton League of Minnesota saw its potential and petitioned for the establishment of a game preserve in 1931.

Erosion was so severe this stone wall was partially buried. Image courtesy of Stanley W. Trimble.

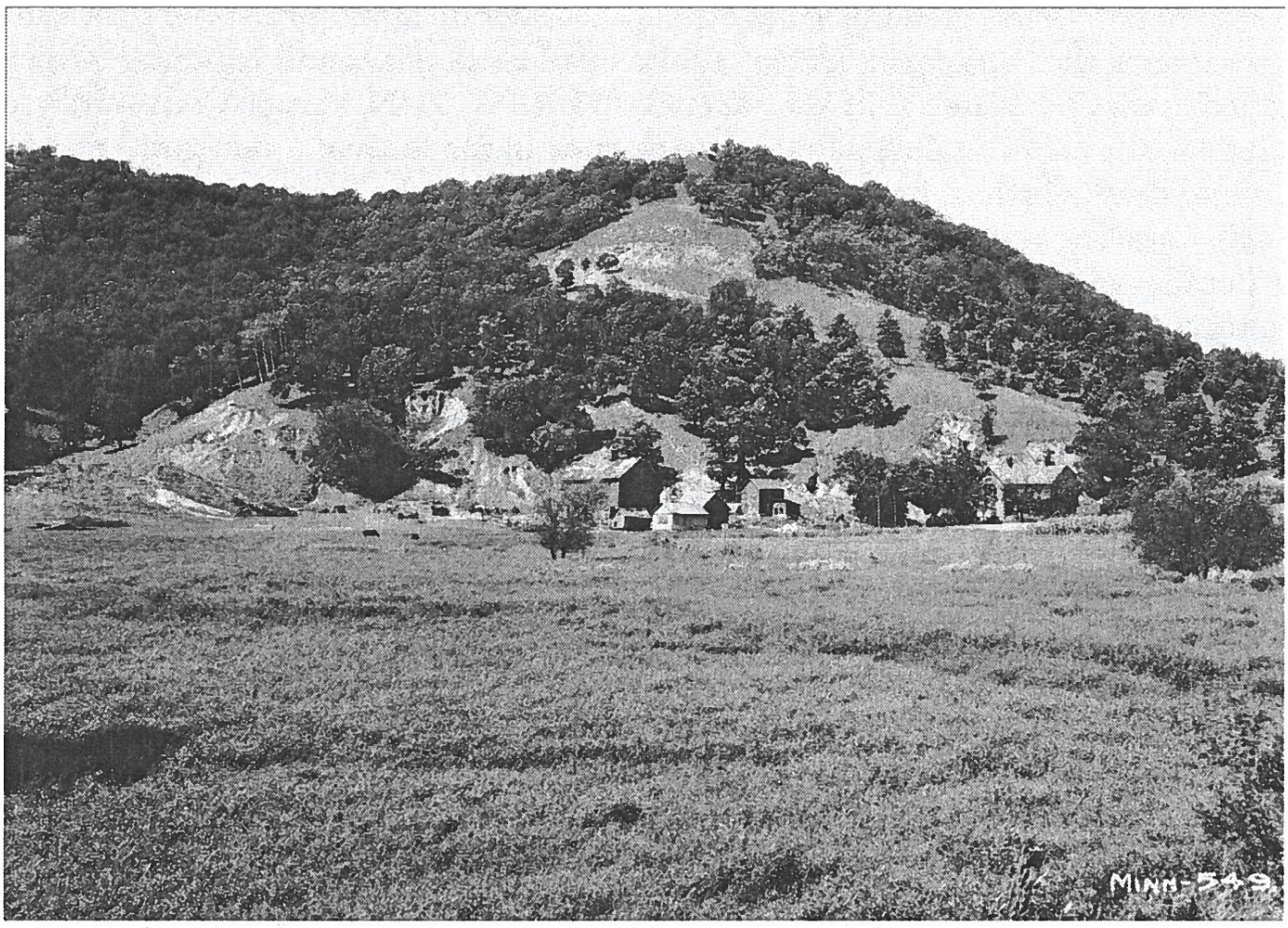


In 1940 (top) much of the native vegetation was cleared, destabilizing the soil and leading to the formation of large gullies. By 2009 (bottom) bluffs were allowed to convert back to native vegetation, stabilizing the gullies and soils. Image courtesy of Stanley W. Trimble.

Residents were relieved to sell properties whose values had plummeted, and today locals have a place to hunt and recreate. Once the geology was stabilized and the land protected, the biology was given a chance to recover.

However, native biotic communities did not reestablish everywhere in the valley on their own. Some plant communities, like sand prairies, proved resilient, and seeded in naturally, but other areas converted to low quality monocultures of an invasive species. Here invasive reed canarygrass is a symptom of historic degradation that is limiting recreation and wildlife habitat. Ten feet of silt accumulated following the floods and created an opportunity for reed canarygrass to colonize the bottomlands. This wetland grass is notorious for spreading and establishing faster than other species in bottomlands, especially when the native soils were broken apart and native seed banks buried.

Don Nelson, former manager of the Whitewater Wildlife Management Area (WMA), knew the reed canarygrass was not helping him meet the WMA's land management goals. The WMA strives to perpetuate and enhance populations of rare species and uncommon plant communities, produce wildlife for the public to hunt and fish, and support other forms of outdoor recreation, like bird watching, canoeing, hiking, photography, and foraging. The reed canarygrass fields have no rare plants or animals, provide habitat for only a handful of animals, and lack the beauty



A farm in the Whitewater Valley with a field of what is likely invasive reed canarygrass in the foreground. Image courtesy of Stanley W. Trimble.

of more diverse systems that attract recreation. The Whitewater WMA needed ecological restoration—the recovery of an ecosystem that has been degraded, damaged, or destroyed—to improve its ecological and recreational value. Unfortunately, there are no well-established practices to convert reed canarygrass in the floodplains to a forest. When my research team applied for a permit to study integrated reed canarygrass control and floodplain tree planting, Nelson saw a win-win situation.

I am a graduate student at the University of Minnesota researching how to transform degraded fields of invasive reed canarygrass to healthy native floodplain forests. The research site at Whitewater WMA stood out to me right away as I first approached it, and captured my interest. Hugging the bluffside on a minimum-maintenance, one-lane dirt road, I drove though beautiful forests before reaching a toe slope (the lower part of a slope where the incline lessens and gradually grades into the valley floor) sand prairie dense with grasses and horsetails. Birds and bugs chirped and buzzed. I cut perpendicular to the slope following the prairie perimeter down a path dividing the lively toe slope prairie from another grassland. Even to the untrained eye, these ecosystems are different. On my left, patches of different greens and tans, heights, and textures differentiated between clumps of different plant species. Butterflies, bees, and other bugs flitted and zipped, swerving around the grasses and horsetails from one colorful flower to the next. On my right, the vegetation was all one color, one height, and one texture for acres and acres. This low-diversity field was dominated by invasive reed canarygrass, and I was going to turn it into a native forest.

Reed canarygrass is poor wildlife habitat. Image courtesy of the author.

The sand prairie in the foreground supports a vibrant ecosystem, including big bluestem, Indian grass, horsetails, and beautiful flowers such as hoary puccoon, and spotted horsemint. Many beneficial pollinators and other wildlife rely on this prairie. In the distance, reed canarygrass has taken over. Image courtesy of the author.

Conservation Corps members helped researchers plant over 12,000 trees in an exact scientific layout, guided by the rope to make sure planting lines were straight. Image courtesy of the author.

The boundary between these two fields represents the boundary between a healthy and resilient prairie, and an invasive grass stifling biodiversity. Few birds nest in reed canarygrass. Forests, on the other hand, provide habitat for many birds, especially here along the Mississippi Flyway, a migration route along the Mississippi River that birds from Central America follow like a highway to the heart of North America. Bottomland forests are home to birds large and small, including red-shouldered hawks, bald eagles, cerulean warblers, and golden prothonotary warblers.

In this restoration experiment, my research team and I planted a variety of flood-tolerant trees and are controlling the reed canarygrass with herbicide for two years. This invasive species has proven stubbornly persistent over time, but it is not invincible. Spraying the herbicide on the grass weakens it, and allows trees to compete against it. As the trees grow canopies and shade the sun-hungry grass, they lessen its ability to exclude native species from growing; over time, the reed canarygrass may be replaced by a community of native species.

I am still waiting to see the long-term results of the study. Forests establish on the order of decades to centuries, not the two-year time span of masters research, but already I am delighted with some of the changes I've seen. My young trees are growing roots strong enough to withstand next year's floods. I found a tiny bird's nest in a tree that had been in the ground for only a few months, and a tree frog greeted me from another tree we planted. I'm still waiting for the trees to produce shade for me to enjoy during lunch, but when I take a break from data collection and look out across the valley, I see progress.

The valley's bluffs are covered in a mosaic of forests, prairies, and rare cliff habitats, not precarious farm fields. The native vegetation holds water longer after rain events, and releases it slowly into the river, reducing its erosive potential. The WMA boasts species so rare, they are protected under the Endangered Species Act, including the Karner Blue butterfly, rusty patched bumblebee, and threatened Leedy roseroot, a beautiful cliff-dwelling flower. River levels still naturally rise and fall, but the floods are not as devastating as before.

Seeing the landscape transform after catastrophic floods and erosion to this little Eden reminds me of nature's resiliency. Studying restoration strategies reminds me we have more to learn about areas we have damaged beyond the point of self-recovery. Collectively, we are learning from past mistakes and now take greater care to reduce erosion, safeguard our soils, and protect our waterways. I am optimistic that restoration research and implementation of the results will help our degraded floodplains at the boundary of the aquatic and the terrestrial heal, and lead to the restoration of the biodiversity and beauty. Someday these young trees will break the spell of reed canarygrass, and become a forest crowned by the flaps and chirps of colorful birds and the buzzing of contented insects. Its foundation will be touch-me-nots with exploding seed pods, cheerful cut-leaf coneflowers, and small violets. This field-turned-forest at the intersection of water and land will boast a healthy and diverse native community, with humans as an integral member of its transformation. It all began with fields.

This young cottonwood tree is thriving, and grew several feet just a few months after planting. Image courtesy of the author.

This tree frog moved in quickly after diversity was added to the floodplain in our study plots. The tree tag tells researchers this tree is located at the Whitewater site (WW), in plot 31, and is a cottonwood tree. At the end of the tag the tree gets a unique identification number, so its growth can be tracked over time. Image courtesy of the author.

References/Further Reading:

Environmental history of the bluff-country: Trimble, Stanley W. 2013. *Historical Agriculture and Soil Erosion in the Upper Mississippi River Valley*. Boca Raton, FL: CRC Press.

Whitewater Wildlife Management Area: http://maps1.dnr.state.mn.us/faw/wma/descriptions/wma0900900.pdf.

History of Beaver, MN: Winona County Historical Society. 1962. *We Remember: the Beaver Story; 100 Years in the Whitewater Valley, Beaver, Minnesota*. Winona, MN: Winona County Historical Society.

Environmental history of the Whitewater Valley: http://www.whitewaterwatershed.org/wp-content/uploads/2017/01/Whitewater-Watershed-Conservation-History_Minnesota.pdf.

Whitewater Watershed: http://www.whitewaterwatershed.org/.

History of Natural Resource Conservation Service (NRCS): https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/about/history/?cid=nrcs143_021392.

Major Historical Floods: https://www.weather.gov/arx/historicalfloods.

2008 Whitewater Flood: https://www.mprnews.org/story/2008/03/06/whitewaterrecovers.

2008 Whitewater Flood: http://www.winonadailynews.com/news/local/whitewater-state-park-still-seeing-changes-from-flooding-a-decade/article_d67f6553-63d0-5f1d-87a6-6af0ca76b740.html.

Gray tree frogs: http://www.dnr.state.mn.us/reptiles_amphibians/frogs_toads/treefrogs/gray.html.

Whitewater Wildlife Management Area: Interview: Don Nelson, Whitewater WMA Manager.

Whitewater Wildlife Management Area: Interview: Christine Johnson, Acting Whitewater WMA Manager.

Recommended Citation

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About the Author

Maria DeLaundreau coordinates and conducts land stewardship ranging from site to landscape scales, and is completing a masters degree at the University of Minnesota in natural resources science and management. She enjoys recreating in nature and delights in good tea.

GEOGRAPHIES

LAB ON THE RIVER – SNAPSHOTS OF THE ST. ANTHONY FALLS LABORATORY

By Barbara Heitkamp

The St. Anthony Falls Laboratory (SAFL), which falls under the College of Science and Engineering at the University of Minnesota (UMN), is one of several historic buildings along the Minneapolis riverfront. Constructed in 1938 using funds from the Works Progress Administration (WPA), SAFL utilizes the 50-foot elevation drop over the St. Anthony Falls to bring water into the building for use in experiments and research of fluid dynamics.

St. Anthony Falls Laboratory on the Minneapolis riverfront in 1942. The landmarks of Minneapolis are evident, as well as SAFL's intimate relationship with the river. Courtesy of University of Minnesota Archives.

Lorenz Straub, UMN professor and engineer, was the mastermind behind constructing a hydraulic research facility on the Mississippi River. He served as the building designer and architect and after construction, served as SAFL's director until his death in 1963. You can read more about SAFL's history and research here.

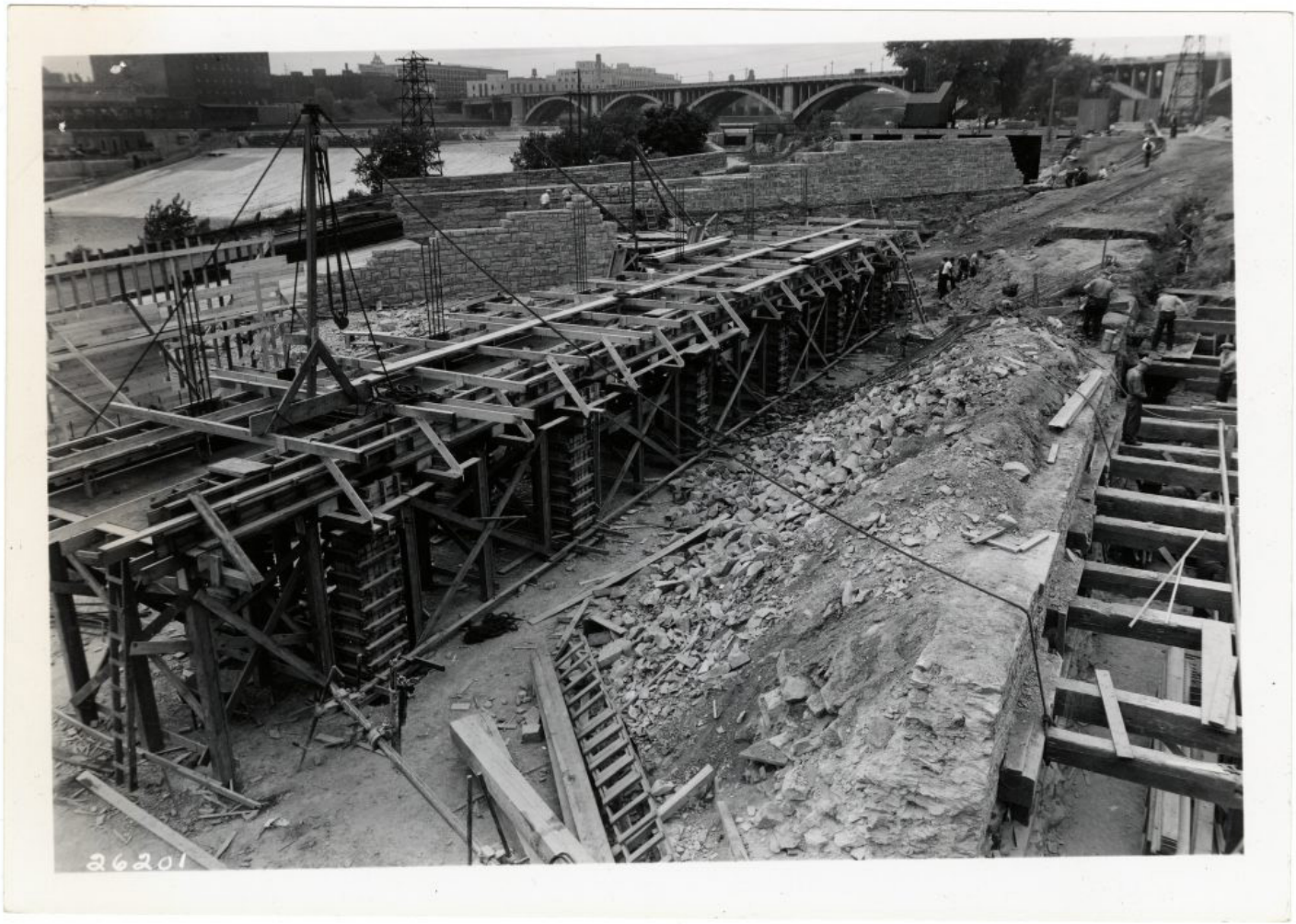
The following gallery showcases several photos from the early years of the laboratory, including construction. While most Minneapolis riverfront architecture has evolved beyond its original intended use, 80 years later SAFL continues its original function of educating the next generation of researchers who seek to answer some of society's most complex environmental concerns through basic and applied research.

All images courtesy of University of Minnesota Archives.

The St. Anthony Falls Laboratory was built on the site of a former Minneapolis pumping station (building in foreground at right) that was shut down in the early 1900s after a typhoid epidemic.

Lorenz Straub with a scale model of the proposed St. Anthony Falls Laboratory. 1937.

1936 pre-construction photo of the lab site. The pumping station has been deconstructed.



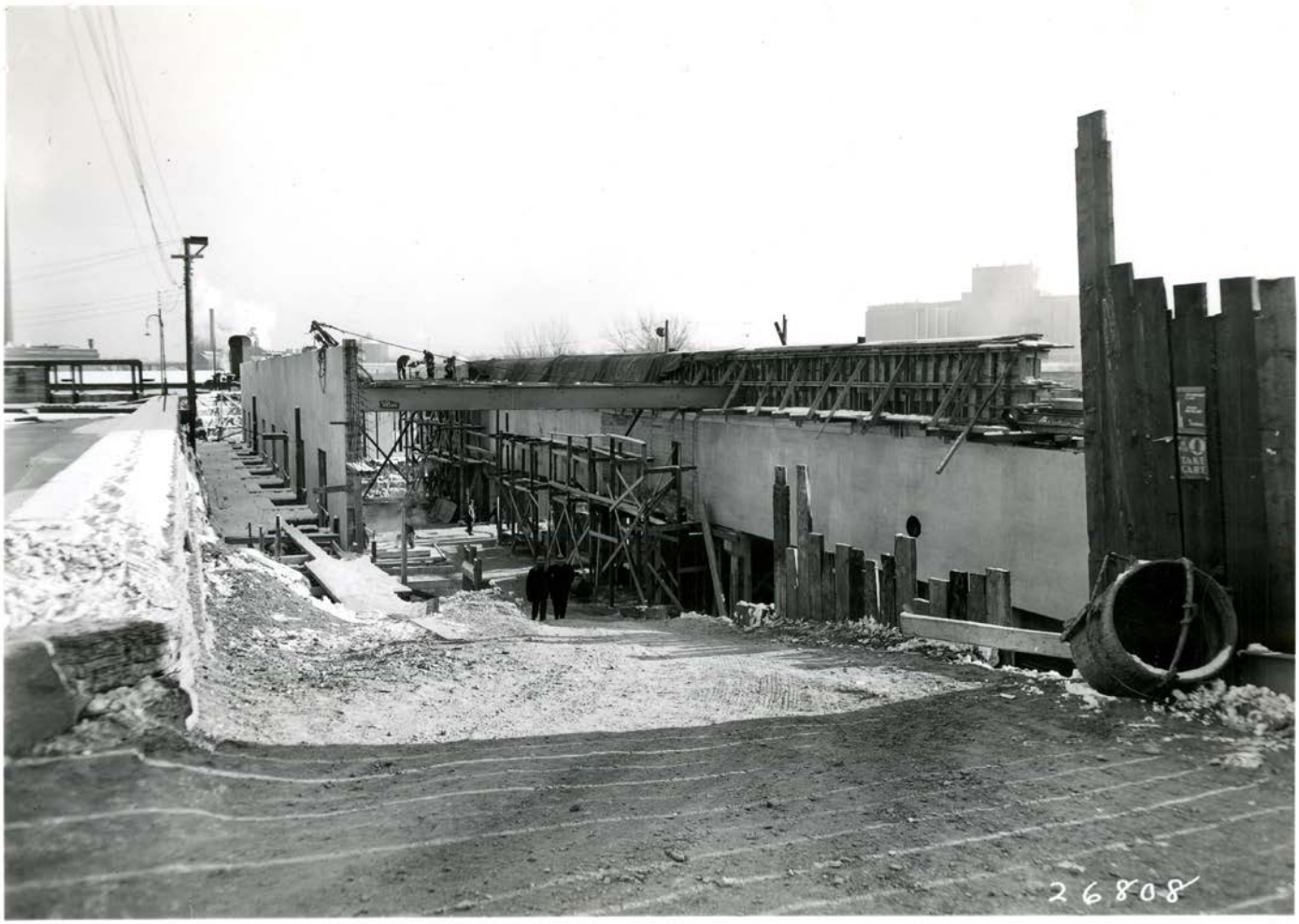
1936 construction of SAFL's supply channel that would divert up to 300 cfs (cubic feet per second) of river water from above St. Anthony Falls through SAFL's experimental facilities.

Laboratory construction in 1936 included excavation of approximately 30,000 lbs of limestone to expand the bottom floor where SAFL's outflow channel takes diverted water back to the river below St. Anthony Falls.

A 1936 view to the bottom of the laboratory where the turbine of the former pumping station still resided at time of construction. To this day, the basement floor of the lab is referred to as "the turbine level."

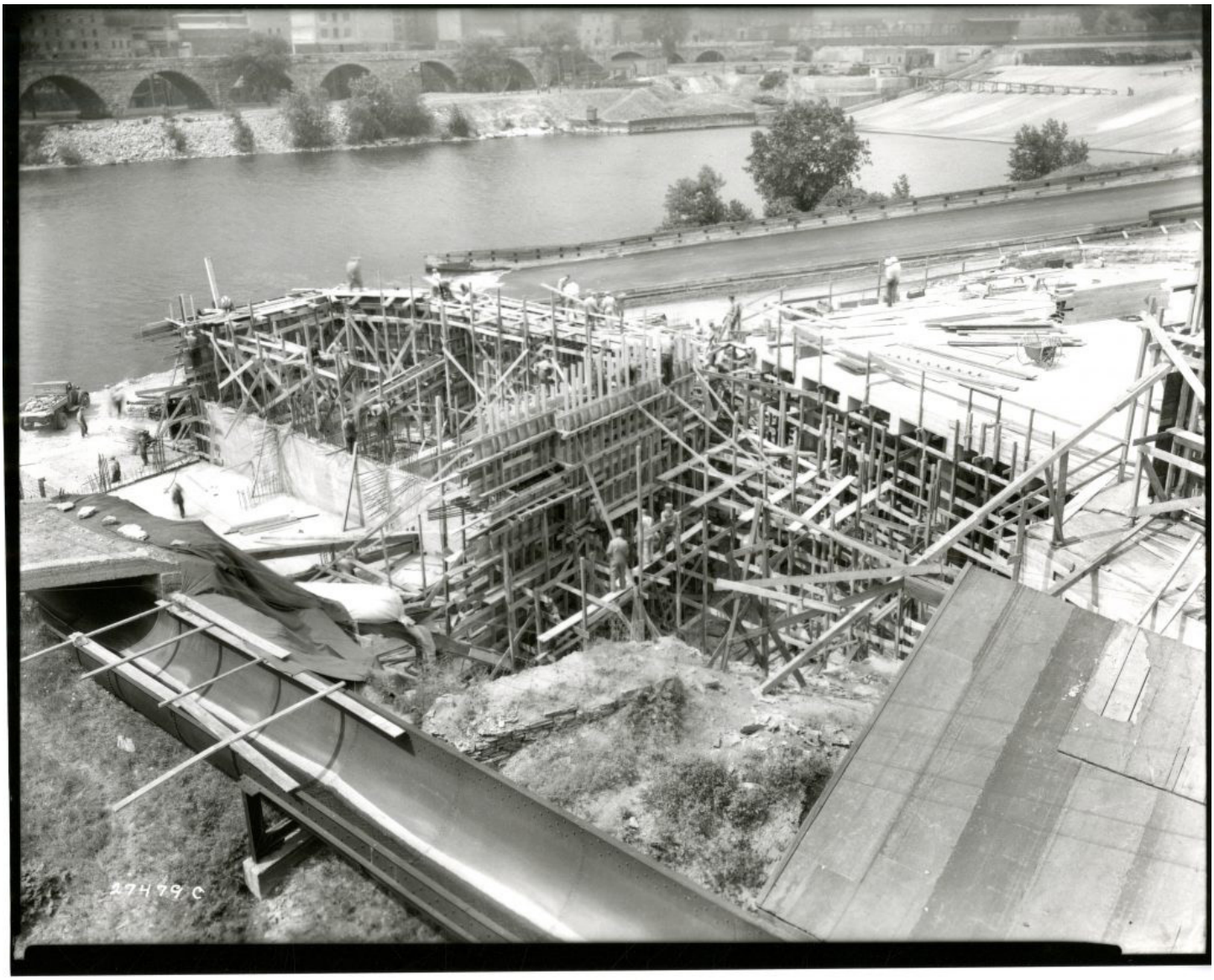
SAFL's exterior walls were constructed using limestone quarried on site, 1936-37.

Workers building the exterior walls of the laboratory in 1937.

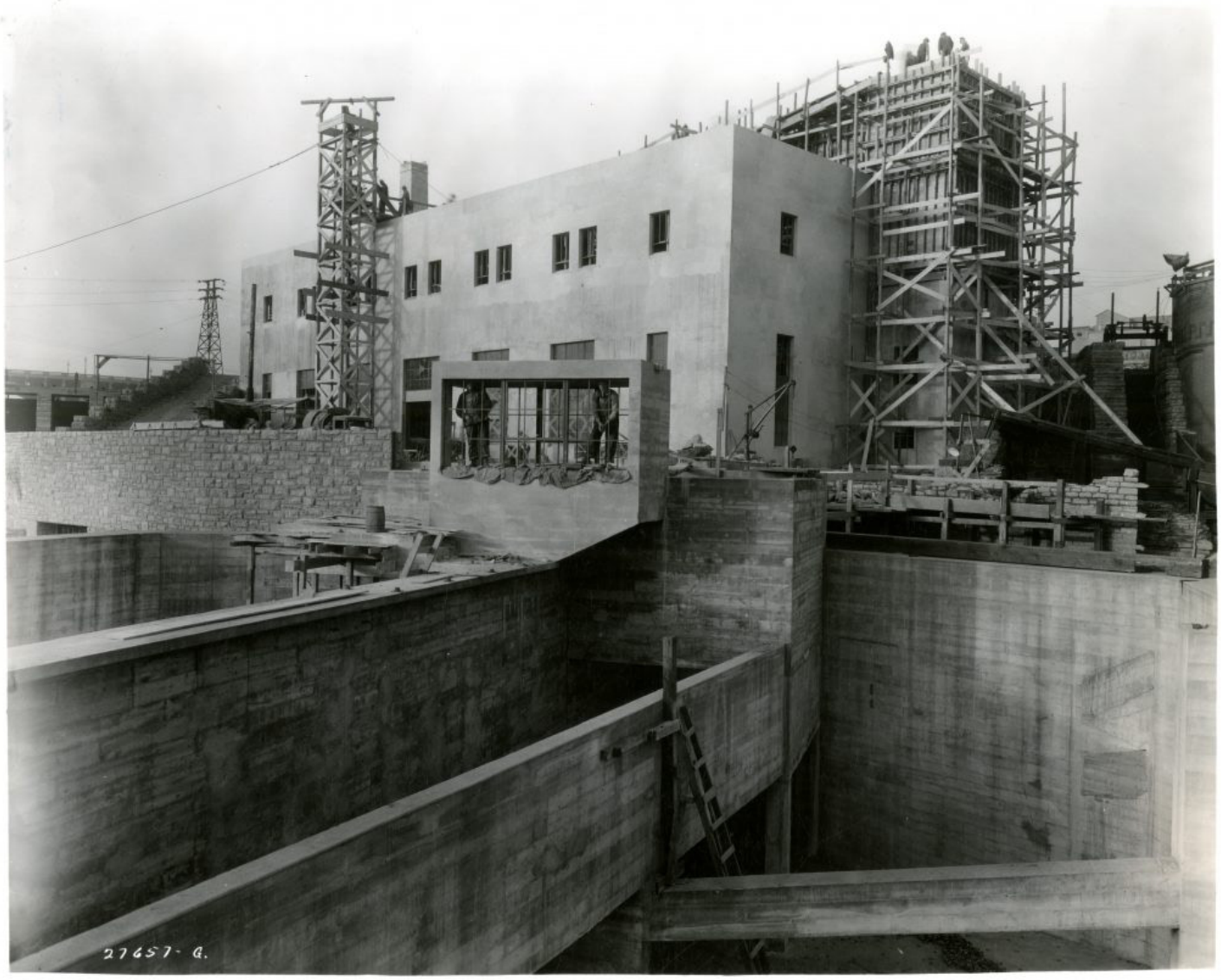


1937 construction of the model floor, SAFL's largest modeling/experimental space with access to the adjacent supply channel (middle of photo). Note the NSP (Northern States Power) diversion canal to the north (left of picture).

Construction photo of SAFL in 1937, showing extensive timber framing and the outflow channel, used to send water back to the river after its use in the laboratory. Viewed from near the river's edge.



Construction of SAFL's volumetric tanks used for deep water research, the basement level used for experiments, and lower deck. The basement level was designed to flood when the river levels rose above a certain level. Notice the Stone Arch Bridge and St. Anthony Falls in the background.



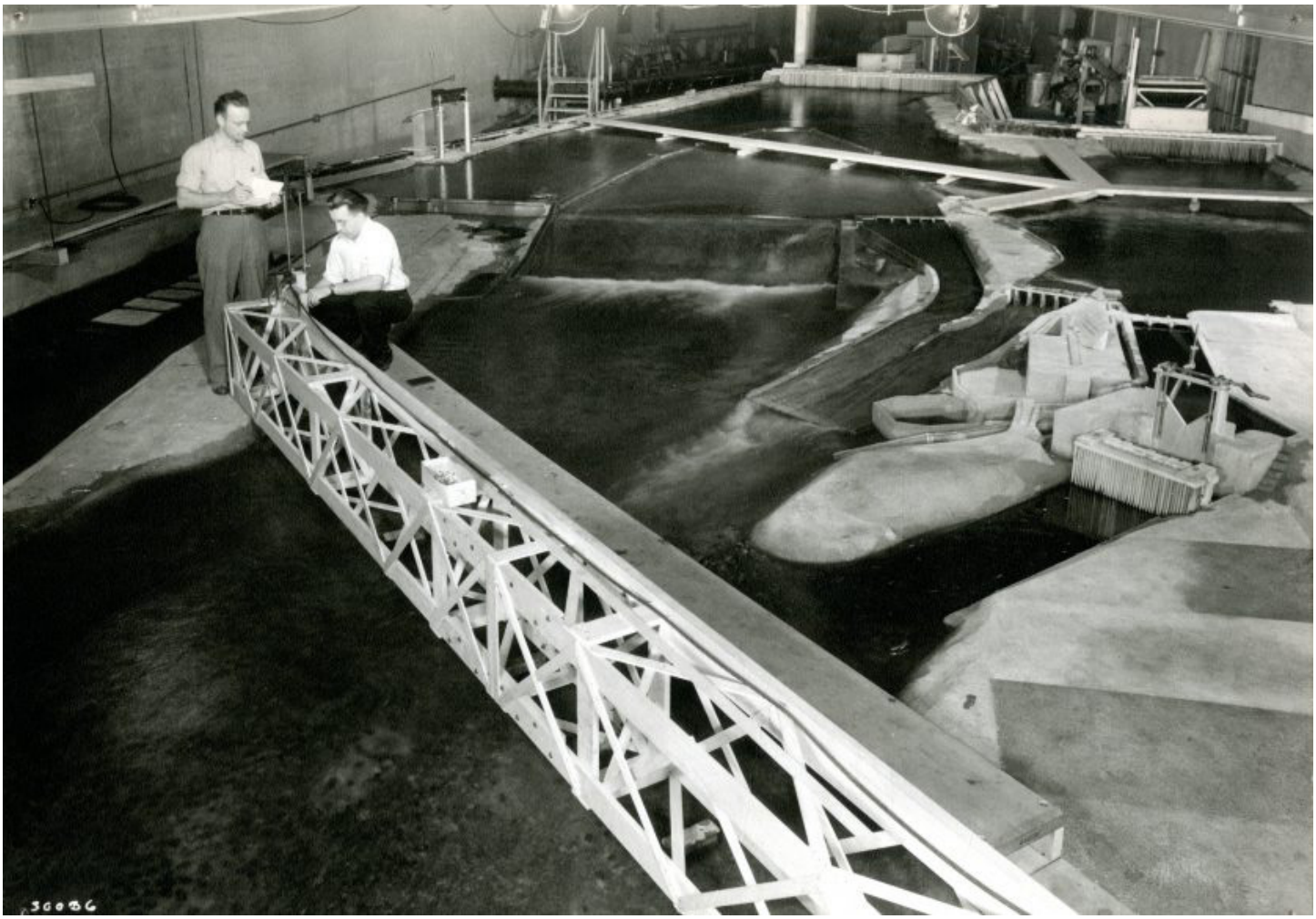
Continued construction of the laboratory in 1937. The building is starting to take shape. The volumetric tanks in the foreground are partially complete, later to be used for research requiring greater water depths.

The original outflow channel that moves water from the laboratory back to the Mississippi River was constructed for the former Minneapolis pumping station in the 1880s. The pumping station was demolished to make way for the lab. Note that the pumping station turbine (center of photo) still remains.

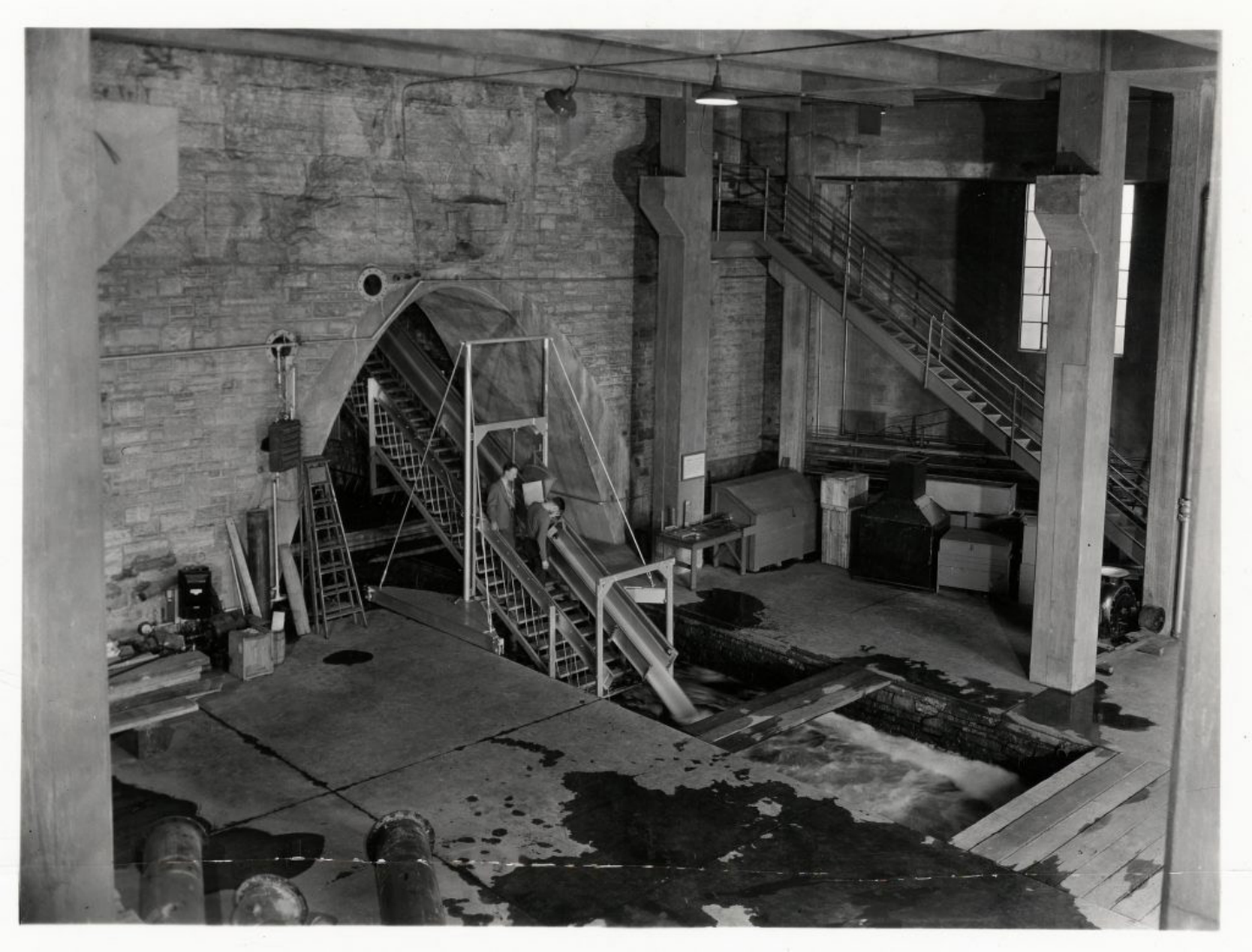
The basement level of the laboratory is constructed over the top of the outflow channel where water exits the building and rejoins the Mississippi River below the falls.

The completed St. Anthony Falls Laboratory in 1938. Notice the volumetric tanks in the foreground, and the city behind the lab.

View of the St. Anthony Falls and flood bypass channel alongside the newly completed St. Anthony Falls Laboratory with the volumetric basins visible in the foreground.

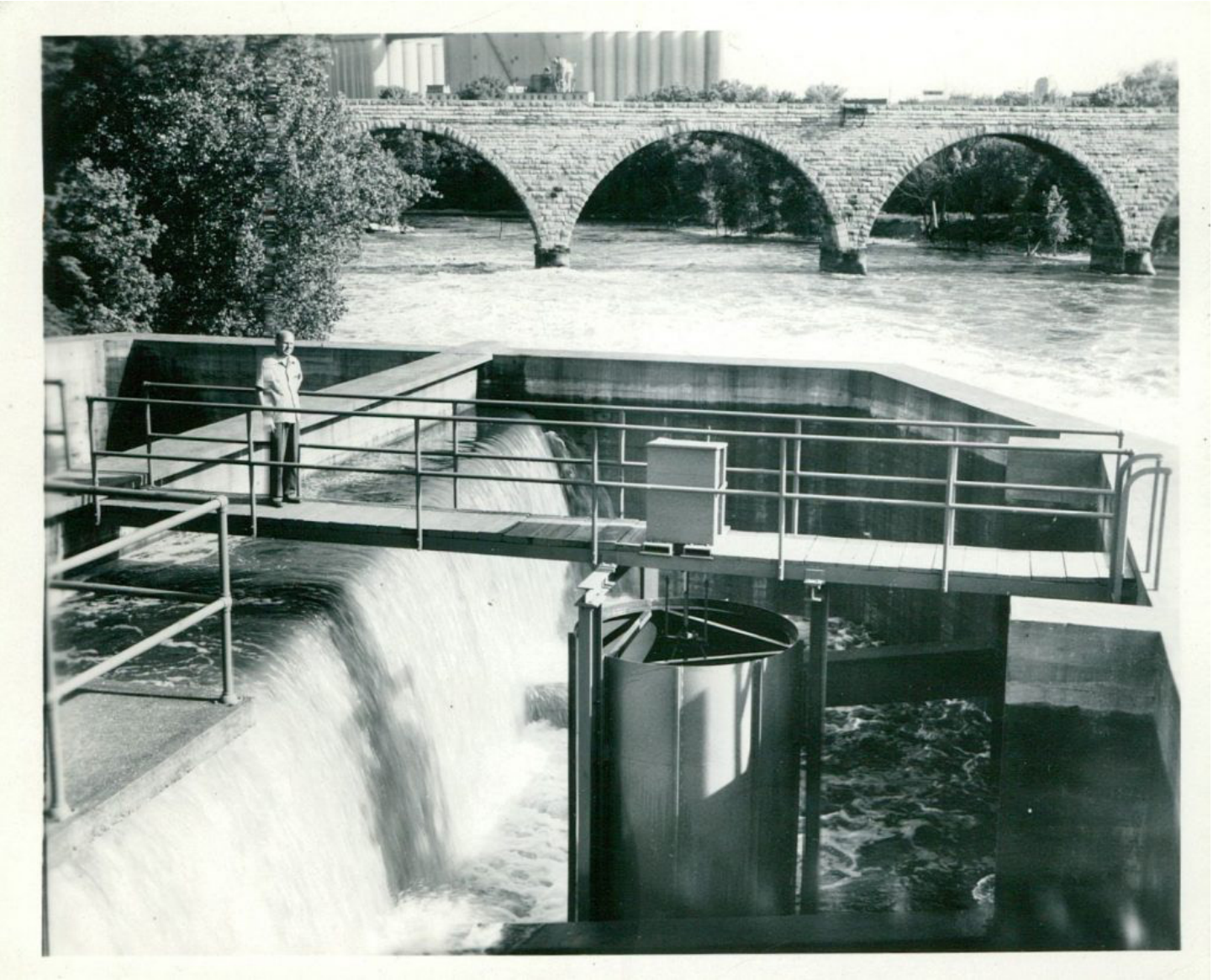


For several years, SAFL hosted a 1:50 scale model of the Mississippi River on its model floor. The model included the stretch of river from the Hennepin Avenue Bridge just upstream of St. Anthony Falls to the Washington Ave Bridge about one mile downstream. The model was built to better understand the potential effects upper and lower dams and locks on the Upper Mississippi would have on navigational conditions.



Water sent down an experimental channel (called a flume) enters SAFL's outflow channel, sending the water back to the river. This particular experiment explored the aeration behavior of water in an open channel.

See video of aerated flow in open channels from the SAFL film archives.



Lorenz Straub standing on the volumetric tank facility.
Notice the Stone Arch Bridge in the background.

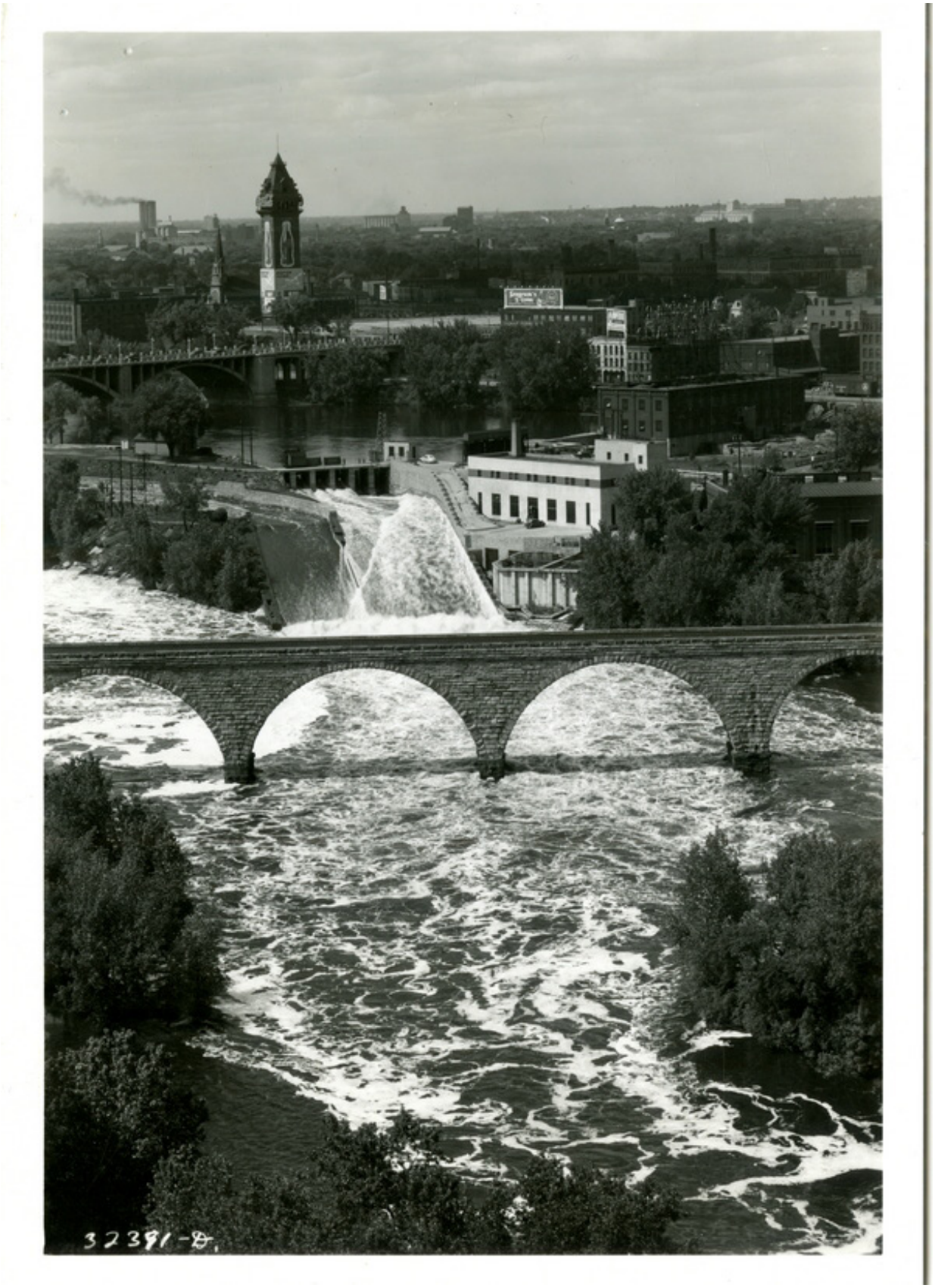
St. Anthony Falls Laboratory on the Minneapolis riverfront in 1942. The landmarks of Minneapolis are evident, as well as SAFL's intimate relationship with the river.

A view across the upper deck at SAFL showing the river itself from the perspective of the laboratory in 1942. Modern visitors to the lab will notice that the building has been expanded considerably since then.

The Minneapolis Chamber of Commerce held a meeting on SAFL's shop floor in the early 1940s. This is the first floor above the basement level, and not designed to be flooded when the river rises.

Lorenz Straub works at his desk at SAFL. He served as the director until his death in 1963.

Aerial view of the Minneapolis waterfront in 1942. Notice SAFL at the upper center of the river-front, downstream of the horseshoe dam and upstream of the Stone Arch Bridge. You can also see the Pillsbury A Mill on the upper bank.



Aerial shot of the laboratory showing its relationship to the Stone Arch Bridge and with water coming down the flood bypass channel just to the left of the laboratory building.

SAFL under the Stone Arch Bridge from the river itself in the 1940s. This iconic picture is beloved and has been used extensively by SAFL in publications and materials since.

All images courtesy of University of Minnesota Archives.

Recommended Citation

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About the Author

Barbara Heitkamp is the communications specialist for the St. Anthony Falls Laboratory (SAFL). She joined the SAFL technical staff in August 2011 and moved into the communications position in June 2014. Her technical background is in geology and hydrology, with a B.S. degree in geology from Texas Christian University and an M.S. degree in water resources science from Oregon State University.

IN REVIEW

REVIEW OF *ARTS OF LIVING ON A DAMAGED PLANET: GHOSTS AND MONSTERS OF THE ANTHROPOCENE*

By Karen Bauer

We are in the Anthropocene

There is something quite embarrassing about reading a book in public that appears to be upside down. The collaborative piece of work known as *Arts of Living on a Damaged Planet* is separated into two parts: "Monsters and the Art of Living" and "Ghosts on a Damaged Planet." The reader must physically turn the book upside down to get from one part to the other. On each cover's bottom right corner, a hint of the other side's cover is present, helping the reader realize that the two parts are closely connected.
After completing this book, however, the feeling of embarrassment seems to make sense. Each part is composed of essays from scholars in an array of different fields, such as anthropology, ecology, art, and literature. While each scholar comes from a different discipline, they are all dealing with the same issue in these books: human damage. Humans are what have made and what continue to make the planet damaged. Living in the Anthropocene epoch, the editors begin both parts of the book illustrating some of the reverberating consequences that our actions have on the world and those who inhabit it. Industrial pollution, for example, has had negative impacts on the Earth's geology and ecosystems, pushing

Detail from Scyphozoan or Lion's mane jellyfish, Cyanea capillata. Image courtesy of Alexander Semenov.

us further and further into the belly of the beast: climate change.

Humans should feel embarrassed when reading this book and must confront the damages that we have made to the planet before it is too late. Both the "Monsters" and "Ghosts" sections of this book confront the issue of human-induced damage. In "Monsters," the authors show just how interconnected our lives are with nonhuman species and the problematic ways that our actions disrupt their lives. With "Ghosts," the authors illustrate the effects that the humans of today have on the humans and species of the past, the ghosts being forever present in our landscapes as a form of remembrance. Although separated into two parts, every author is ultimately wrestling with similar issues pertaining to the question of life.

How are human and nonhuman species to live on, protect, *and* create life on a damaged planet?

Arts of Living on a Damaged Planet: Ghosts and Monsters of the Anthropocene.
Anna Tsing, Heather Swanson, Elaine Gan, and Nils Bubandt, Editors.
2017 University of Minnesota Press.

Monsters: We have never been individuals

The greatest lesson that "Monsters" teaches us is about our entanglements with other species.

With modernity, humans are taught the importance of individualism. Instead of working as a collective to move forward, the individual works alone for progress. With this mindset, the connections that humans have with nonhuman species are often ignored and forgotten.

"Our society's ecological amnesia is profound, and it limits us from understanding our current and past impacts on the species and ecosystems around us." (Ingrid Parker, "Monsters," p. 161)

The authors in this book all work to debunk the myth of individualism. Instead, they illustrate both the nonhuman multispecies assemblages that have been around since the beginning of time, and the problems that can arise from not recognizing or ignoring the importance of these entanglements.

Take jellyfish, for example. They may seem innocent, but many have the ability to be monstrous. Not only can their stings send beachgoers to the hospital, but the comb jellyfish of the Black Sea consume large amounts of small fish, emptying the sea of other species. Jellyfish were not born monstrous, though. Due to human overfishing, shipping, pollution, and global warming, jellyfish

Scyphozoan or Lion's mane jellyfish, Cyanea capillata. Image courtesy of Alexander Semenov.

have been forced to defend their life against humans and other species any way possible.

Humans have created a monster out of jellyfish, entangled in their lives whether they like it or not.

Ghosts: Enmeshment in Landscape

The authors of "Ghosts" illustrate the multiple spatial and temporal layers that both the living and dead possess, and the influence that these layers have in shaping our landscapes.

Ghosts, like monsters, create entanglements. They inhabit the same spaces as the living. Their presence can be felt and seen indirectly, haunting humans and nonhumans in order for them to begin to understand the effects they cause on the present and the future.

"...'we' is not homogenous: some have been considered more disposable than others." (Anna Tsing et al. "Ghosts," p. 4)

One of the most important features of ghosts is their ability to demonstrate the unequal relations among species that continue to occur and cause negative effects.

Ingrid M. Parker's piece entitled "Remembering in our Amnesia, Seeing in our Blindness," discusses the Great Meadow on the campus of the University of California, Santa Cruz (UCSC). While this natural landscape is well-protected from campus development and is praised for its biodiversity, it has a surprising history that many people do not know about. The Great Meadow as it stands today is a landscape haunted by the ghosts of human and nonhuman species of the past. Only 16 percent of the species found in the meadow are "native plants." The rest of the plants were brought by Spanish colonists in the eighteenth century. Ecologists and historians say that the original California "grasslands" were actually fields of wildflowers. The history of these wildflowers in the Great Meadow, along with that of the Amah Mutsun tribe who were the first human inhabitants of the meadow, are often not mentioned.

"The idea that disaster will come is not new to indigenous peoples; genocidal disaster has already come, decades and centuries ago, and has not stopped, and the people have not ceased ongoing worlding either." (Ursula K. Le Guin, "Monsters," p. 44)

While there is such a long and active history of erasure on the part of humans, especially when it comes to humans inflicting violence on others, ghosts do not let this happen. They serve as reminders of what lives were destroyed in the path towards so-called "progress."

They also remind us that it is still possible to live through the damage. Despite the removal of many of their native plants and people, the Amah Mutsun in Santa Cruz, for example, continue to prosper in this world. Having nearly 600 enrolled members, this tribal band works hard to make room for themselves in the present and future, while simultaneously remembering the past. Their Relearning Program for example, aims for members to relearn traditional ecological knowledge (TEK) as a way to more effectively help with contemporary environmental issues. Thus, the ghosts of the Great Meadow remain crucial in the fight to restore the damaged planet.

An explosion of rare California poppies in the Great Meadow on the UC Santa Cruz campus. Photographer Gregory Gilbert.

"We should worry but not despair." (Dorion Sagan, "Monsters," p. 174)

There is no denying that nonhuman and human species are bound up with one another. This entanglement is what allows life to continue. Not recognizing or ignoring this entanglement, however, is what destroys life and what damages the planet.

As an anthropologist trained in considering different ontologies, reading this book made me realize that I had no idea about the full extent that I had with other species and their worlds. While it is very easy and okay to feel overwhelmed after reading this book, it only begins to become a problem if the reader does not do something to change this feeling.

Each author of A*rts of Living on a Damaged Planet* shows the fragile state that our planet is currently in due to human-induced environmental changes. While this book serves as a warning, it also inspires a call to action with some authors offering solutions to begin fixing the problem.

Perhaps the most common strategy provided is the expansion of knowledge practices and conversations. I strongly believe getting others to recognize these extensive entanglements is the first step in producing change, especially those whose ancestors have a very explicit history of destruction. Reading this book has inspired me to engage in more critical conversations regarding climate change with other academics and non-academics. These conversations will begin by foregrounding humans' past actions as a result of current problems, inevitably bringing about the ghosts of the past while doing this. They will also pull from different branches of knowledge, not relying on a specific one to discuss such an expansive issue. Moreover, it is imperative that more interdisciplinary dialogue, work, and action take place for creative solutions to arise.

We cannot fix the planet by ourselves, though. We must rely on the help of the living, the dead, human, and nonhuman entities to bring about change.

Recommended Citation

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About the Author

Karen Bauer is a second year Ph.D. student in the Department of Anthropology at the University of Minnesota, Twin Cities. Generally, Karen is interested in the effects of copper-deposit mining in the communities that make up the Intag Region of northern Ecuador. Her current research specifically seeks to understand how local conflicts over land, water, and identity articulate with global and planetary agencies, through examining the effects of transnational mining companies, international environmental organizations, and the indigenous Earth Mother, *Pachamama*, in the village of Junín, Ecuador.

PERSPECTIVES

ONE WATER: A NEW ERA IN WATER MANAGEMENT

By Jeremy Lenz

Under the leadership of the US Water Alliance, a multi-sector coalition of leaders from more than 940 industry, government, and community organizations has joined forces to develop and advance practical solutions to the toughest water challenges facing our nation. As part of the "One Water for America" initiative, this diverse group collaborated to create the recently published One Water for America Policy Framework. Leaders and stakeholders from the One Water initiative gather annually, and will hold their annual One Water Summit in the Twin Cities, Minnesota on July 10th-12th.

The complex urban waterfront in New York city is emblematic of the balance between the challenges and solutions regarding our water infrastructures.

Context on the complexities of water issues

Water is a familiar, essential, and ubiquitous part of our daily lives. As a result, it is easy to engage people in conversations about the importance of "water" and build consensus on the need to "solve water issues"—but that is where the simplicity ends.

As a society, we have high expectations. We expect on-demand access to abundant clean water for industrial, commercial, agricultural, and residential uses. We expect pristine lakes and rivers. We expect ample low-cost food from domestic agriculture. We expect all wastewater to disappear, without a thought. And we expect to receive this societal infrastructure while paying little to nothing for it.

Faced with the ever-growing demands of water consumers and static or shrinking budgets to meet those demands, our physical and regulatory water infrastructure is breaking under its own weight. Consider this: there are more than 51,000

This wicket gate removal at the Grand Coulee Dam on the Columbia River illustrates the massive scale of our water infrastructure. Image courtesy of Bonneville Power Administration.

community water systems in the U.S., more than 80 percent of which serve fewer than 3,300 people and 55 percent of which serve fewer than 500 people. And there are nearly 15,000 wastewater treatment plants in the U.S. By contrast, there are approximately 3,000 electricity providers.

As our nation's water infrastructure fractures, communities around the country face environmental and public health crises, such as widespread flooding, drinking water contamination, and drought. Moreover, our nation's water management challenges take place in the context of global environmental trends stressing global water resources.

Although water management problems are often understood and addressed as local, community issues, they are actually interconnected national problems that require multi-sector, system-wide solutions at every level of government.

One Water introduces its big ideas

Acknowledging the interconnected nature of water management throughout the United States and the need for multi-sector coordination and collaboration, in 2017, the US Water Alliance along with partners developed a One Water Roadmap to help shape this concept into seven arenas for action that can help transform how our nation views, values, and manages water.

"Through its One Water framework, the US Water Alliance is playing a unique role in our nation. They are the only organization bringing together the most diverse set of voices on water, and this will lead to more holistic solutions," explained Snehal Desai, Executive Vice President and Chief Growth Officer for Evoqua, former Global Business Director for Dow Water and Process Solutions, and current US Water Alliance board member. "The solutions must be at all levels because, although water is local, the context of funding and regulations are often at a state and national level."

Over the past year, the US Water Alliance held listening sessions with 500 leaders from government and industry to hear their best ideas for sustainable management of water. From those conversations, US Water Alliance identified seven big ideas that it believes can best accelerate solutions to water management problems. In its One Water for America Policy Framework, the US Water Alliance introduced its big ideas and offered concrete actions that can be taken at the local, regional/state, and national levels.

The Policy Framework document provides an in-depth explanation of each big idea, and corresponding policy recommendations. At the highest level, the big ideas are:

1. **Advance regional collaboration on water management.** Pointing to the myriad of siloed water managers, this big idea stresses the importance of regional collaboration, and advocates for watershed-scale planning, coordinating services to better operate and maintain infrastructure assets, and consolidating utility service.

2. **Accelerate agriculture-utility partnerships to improve water quality.** Noting that agriculture is a major water consumer and a primary source of non-point source pollution, this big idea highlights the importance of identifying new ways to fund land management best practices that balance conservation with productivity.

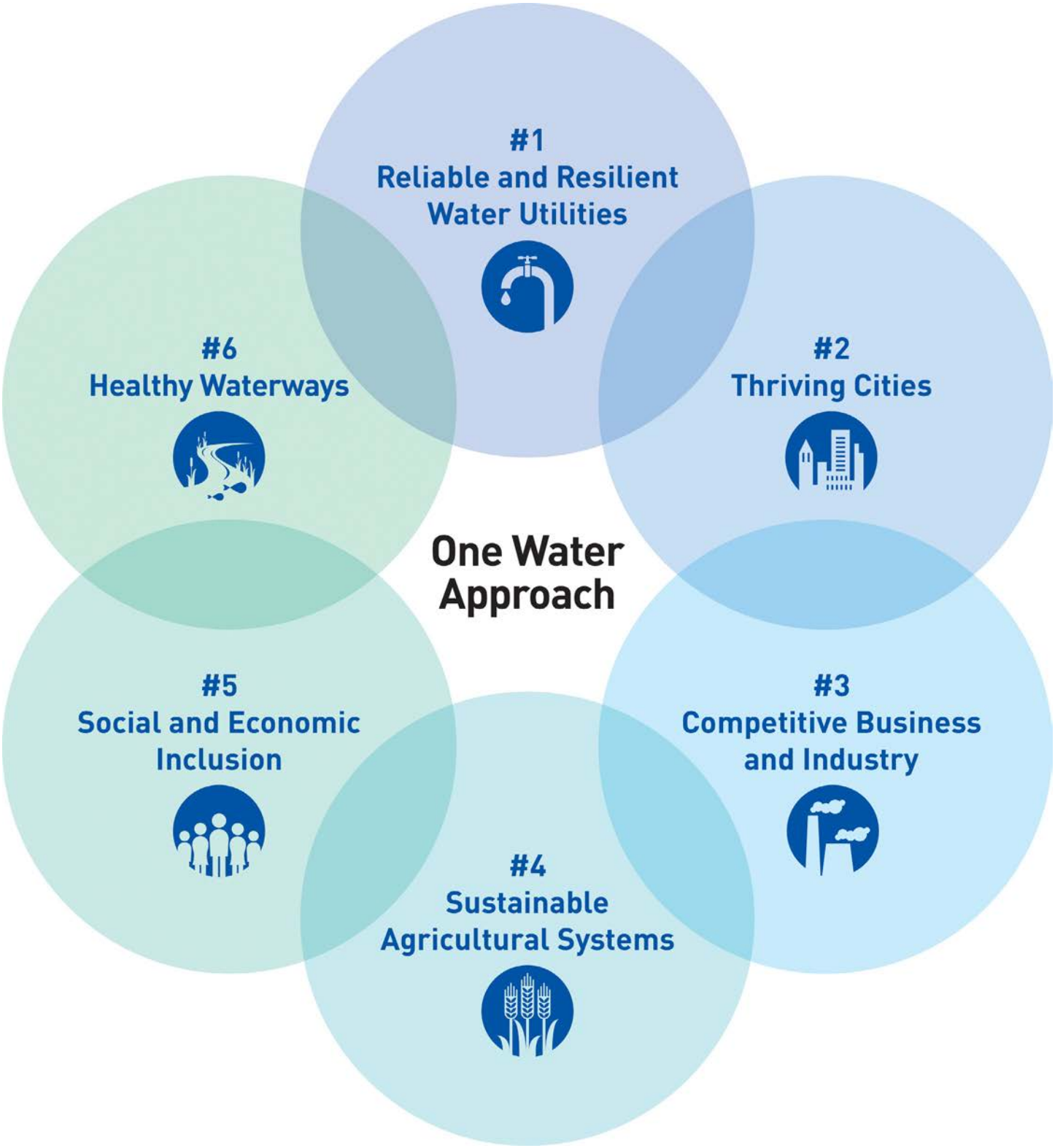

Illustration of the One Water approach that involves complex and interwoven solutions with many partners across jurisdictions. Image courtesy of the US Water Alliance.

3. **Sustain adequate funding for water infrastructure.** Acknowledging that water infrastructure is, and will continue to be, primarily funded by water, sewer, and storm-water rates and charges, this big idea stresses the importance of measuring the actual cost of water management and reducing that cost by optimizing current practices and adopting technology innovation.

4. **Blend public and private expertise and investment to address water infra-structure needs.** Defining the water utility sector as both public and private, this big idea identifies the importance of public-private partnerships as a promising source for new investment and innovation in water manage-ment, and suggests ways to remove current barriers to mutually beneficial public-private partnerships.

5. **Redefine affordability for the 21st Century.** Affirming the challenge of guaran-teeing universal access to affordable water and sewer service, while also ensuring financial viability of water utilities, this big idea identi-fies policy solutions aimed to make and keep water affordable for all.

6. **Reduce lead contamination risks, and embrace the mission of protecting health.** Citing the present-day challenge of lead in drinking water, this big idea encour-ages multi-sector community-wide solutions to make safe drinking water a public health priority.

7. **Accelerate technology adoption to build efficiency and improve water service.** Recognizing the unique potential for new technologies to solve water problems, this big idea identifies important policy and regulatory hurdles to technology adoption and recom-mends specific changes to those hurdles.

"During the listening sessions, one of the issues we heard about was the challenges around the state of our water infrastructure," said Radhika Fox, CEO of the US Water Alliance. "The water infrastructure needs are like what we haven't seen in 50, 100, 150 years, when previous leaders made a generational investment. Today, we are at this dawn of a replacement need. We want to make 2018 the year of water investment."

One Water Summit

The One Water movement is gaining national momentum. 250 people attended the Water Summit in 2015, and the 2018 Water Summit is expected to draw almost three times that number—a demonstration of the One Water initiative's importance and potential impact. Last year, 650 people attended the One Water Summit near the Mississippi River delta in New Orleans. On July 10–12 2018, the One Water Summit will occur near the Mississippi headwaters in the Twin Cities, Minnesota. Hosting grand scale solution-based summits at the Mississippi River headwaters and delta symbolize the whole-system thinking and partnerships needed to enter a new era of water management.

The University of Minnesota is an active sponsor of the summit, providing expertise, speakers, and tour venues. On the University of Minnesota's role, Paige Novak, Joseph T. and Rose S. Ling Chair in Environmental Engineering, Department of Civil, Environmental, and Geo- Engineering,

says, “As educators and researchers we can play a strong role in advancing the ‘one water’ concept: helping to ingrain this approach to water management in our students and helping managers determine, through research, how changing up-stream or down-stream processes could alter, positively and negatively, the water system as a whole.” One Water is a call to action that invites all of us to participate in solving our nation’s water challenges through the concrete solutions proposed in the One Water for America Policy Framework.

Recommended Citation

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About the Author

Jeremy Lenz is a strategy and industry relations consultant who helps public and private clients tackle water technology challenges. (The US Water Alliance [USWA] is a client for Lenz.)

PRIMARY SOURCES

WATER AS A SPACE FOR INCLUSION

By Brianna Menning

What do you think about when you think about inclusion? Is it a matter of diversity? Come one, come all? Is it someone else's problem to worry about?

Inclusion is something I spend a lot of time thinking about and have over the course of my career. Being aware of inclusion also means being aware of limitations—your own, others, gaps of knowledge, and how to create an environment of being welcome. I consider this at the heart of the various careers I have had—directing a national AmeriCorps program in community organizing; working in sustainability in the U.S., India, and

The Mill Ruins in the St. Anthony Falls Heritage Zone, Minneapolis. Image courtesy of River Life, University of Minnesota.

China; and in my current role at the Institute for Advanced Study (IAS) at the University of Minnesota. The scale and scope of what inclusive means has been different in each role but has been the driving force in why I have felt connected to each role I have taken.

You may be wondering what this has to do with primary sources. For me, creating primary sources is part of our overarching intent to be inclusive. The IAS is known for its work to encourage and create interdisciplinary work at the University of Minnesota—all system campuses, across all colleges, without any particular theme. It can make the work more complicated, but it also means that the door is open to any possibilities. As part of the IAS's history, we organize and host a variety of programming and events—frequently things you wouldn't find elsewhere on campus because they might not fit. This has included a number of programs concerning water over the years on topics such as environmental justice, access to water and hydrotechnologies, and Native rights to water. For example, in June 2016 the IAS hosted an international institute, "Grasping Water." This discussion explored rivers in Africa, Asia, and North America, with a specific discussion on "The Evolution of River Transport."

Grasping Water: The Evolution of River Transport

See the video "Grasping Water: The Evolution of River Transport."

Territoriality, Sovereignty, and Water: Indian Rights and Law

In April 2017, the IAS and the Minnesota Historical Society presented a panel of Native people discussing "Indian Rights and Law" related to water issues.

See the video "Territoriality, Sovereignty, and Water: Indian Rights and Law "

We record almost every program that we have (with the speaker's permission) and make them available via our YouTube channel (and the University Libraries Media Archive). Many of these videos follow the format of our events: they are about 90 minutes long (around an hour of presentation, followed by around 30 minutes of Q&A). As we are aware, a 90-minute video is really long. That is too long for most people to watch unless it's a topic or speaker that they are particularly interested in. So how do you make that content available to someone who won't spend 90 minutes watching the video, but is still interested in the content? This is where we get into issues of primary source. We have an extensive video library and have worked with faculty members who have classes of students taking these lengthy presentations, as well as video interviews, and making them into short (2-3 minutes) video segments—a snippet of the topic that can lead to potentially more interest in the longer primary source.

We have also started investing in captioning IAS videos in an effort to be inclusive. When we pay to have our videos captioned, we spend a few more dollars to have a transcript made of the presentation and make that available. This is another primary source document that is freely available; it may be a resource to a student writing a paper on resilience, or to the local newspaper reporter who wants to cite a speaker who presented with us. This kind of interest was apparent after we hosted a panel discussion with three local experts on "Resilience," with two faculty members and a local government official this past winter. The discussion explored the various ways we think about resilience, as more than just a question on sustainability. With a transcript available, you don't have to search through to a particular minute on the video. Instead, you can scan the PDF document to see what was said.

Resilience (with Captions)

See the video "Resilience (with Captions)."

Note: To display the captions, click the small "CC" button that appears in the lower right-hand corner if you click on the video.

For me, these decisions come down to questions of who your intended audience is and what your goals are. If our goal is to be inclusive so everyone has access, then captioning is necessary. If you want these events to have a life beyond the audience in the room when they happen, recording them is required. And then you need to take the next steps—to think through what your audience's needs are, and how you meet them where they are. How can these be a teaching opportunity for students (e.g., to learn video editing technology, or to learn how to cull an argument down to its most salient points via quotes from a PDF document or segments of video clips)? How does this work give these documents new life and new audiences? How does it broaden the audience for the IAS? How does it help the University of Minnesota meet its educational goals, and its obligations as a land-grant institution called to serve the public of the state?

The questions I am left with are questions of what our responsibilities and obligations are, as well as what our opportunities are. I think creating videos, and then using our resources carefully to caption and create transcripts allow us to better serve the university community and the greater public. It makes the university's investment in our programming go further, and creates learning opportunities for students, as well as makes our programming accessible to those who are deaf, hard of hearing, or simply prefer not to watch lengthy videos (I will admit to being in that last category).

We haven't totally met our own standards yet. We are slowly building our collection (we have almost all of our events recorded, but we have only just started creating transcripts and captioning for our videos). We are making progress and are excited about the opportunities that this is creating—opportunities that we hadn't thought about before we started this. Building a library of resources and finding themes across years of work allows us to serve even more people. This can be done through creating more "discoverable" resources related to issues of water, as well as examining issues of equity and justice. These are all important themes to the work of the IAS, and how we can bring people together now and in the future.

Other examples of water-related programs presented at the IAS:

- We are Water: The University and Minnesota's Water Future
- Is Water a Human Right? From Flint to Minnesota
- More than the Mississippi: The River as "Here"
- Environmental Humanities on the Schuylkill River

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About the Author

Brianna Menning is the Programs and Communications Manager at the Institute for Advanced Study, where she has fun plotting interdisciplinary programs and projects. Born and raised in Minnesota, she loves spending time in the outdoors near water with her husband and daughter. She is very interested in issues of equity and access, broadly speaking.

TEACHING AND PRACTICE

THE RIVER IS THE CLASSROOM

By Linda Buturian

This is a story about water.

The Mississippi River flows just beyond the buildings on the University of Minnesota's East Bank where my office is. Most days, as I have done throughout my 16 years here, I walk along the river to the classrooms where I teach. It would be hard to find a person on campus who

Illustration from "Every Day Epiphany" in "The Changing Story: digital stories that participate in transforming teaching & learning" by Linda Buturian, 2016. Image courtesy of Yong Ye.

doesn't share a nostalgic fondness for the river as we glance at it, drive over it, and jog and bike across it. We are happy to claim the river under the bridges, across the swathes of pavement, and framing the city skyline.

But this is a story about water, and water flows:

Into us.

The water we drink and use on the Twin Cities campuses comes from and returns to the Mississippi River. Colleague Jonee Brigham, creator of art-led environmental education, Mississippi River Water Journey camps, helped me understand that our drinking water is processed from two water treatment plants, and our sewage from the campuses goes into the Mississippi at the same wastewater plant.

Students in seminar "Water, Water, Everywhere? Investigating & Protecting Our Life Source" on the Mississippi River, 2008. Image courtesy of Linda Buturian.

Into our learning.

In 2007 I designed a writing-intensive seminar that introduced students to water resource topics including those relevant to the Mississippi, from disciplines in the sciences and the humanities. I sought out colleagues who specialize in water—ecologists, environmental chemists, engineers, planners, artists, and community activists and organizers. To communicate the multifaceted nature of water as well as access students' visual ways of knowing, I designed a capstone digital story assignment asking each student to select a water resource topic and create a 5-10 minute media project, which featured an interview with a relevant specialist. These stories were shared on a public site. Spring 2008 was the first iteration of Water, Water Everywhere? Investigating & Protecting our Life's Source.

As a creative writer and teacher of literature, I found it natural to begin the course by having students read poems, short stories, and essays about water, and getting them writing narratives about their own experiences. Many students' potent memories involve water, whether it's enjoying a family vacation to the ocean or summers at their cabin on the lake, or nearly drowning in a strong

Students in seminar "Water, Water, Everywhere? Investigating & Protecting Our Life Source" on a walking bridge over the Mississippi River, 2009. Image courtesy of Linda Buturian.

river current, or getting stung by a jellyfish, or never learning to swim due to the inherited trauma from their parents' frantic crossing of the Mekong or China Sea in order to save their own lives.

I didn't have to teach students to care about water, but instead created a space that allowed them to recognize that water has been a part of their living from as early as they can remember (and earlier). Calling on what was already existent in them, I selected readings, films, guest speakers, and field trips that helped students connect their lived experiences to larger issues: ecosystem health and runoff from large-scale industrial agriculture; infrastructures that perpetuate unequal access to clean water; the impacts of privatization of water; unplanned development that leads to depleting our water sources; and geopolitical decisions to use water as a power-play, leaving vulnerable citizens in the crosshairs. Students were also introduced to the many possible solutions to these complex challenges.

At some point in the semester we went out to practice taking pictures along the Mississippi. The liberation students and I felt venturing down by the river returned with us into our classroom. Playfulness and creativity informed

Students in seminar "Water, Water, Everywhere? Investigating & Protecting Our Life Source" on a walking bridge over the Mississippi River, 2010. Image courtesy of Linda Buturian.

our discoveries as we interacted with images, research, writing, and discussion, in part because we were figuring it out as we went, but also due to the elemental roles of creativity and playfulness in engaged and experiential learning. Einstein referred to the process of discovering insights through interacting with different modes of inquiry as "combinatory play."

Each student selected a topic, conducted research, and sought out a University of Minnesota (UMN) or community expert, interviewed them on camera, and bravely persevered through the hydra-headed technical problems, especially that first year, (before the University had Smart Learning Commons which supports students' media projects). Topics in that first seminar included bottled water marketing, rainwater harvesting in India, and mercury contaminating urban lakes. We hosted a premiere with members of the public, ate popcorn, and students introduced their digital stories and shared what they learned.

In my years of teaching I had not before experienced such a consistent level of engagement with subject matter and investment in creating final projects. These were freshmen. What was going on? Several things, one of which involved the narrative visual nature of the digital story.

I continued to feel along the rope of these questions as I taught the seminar several more semesters. Over the years we visited the St. Anthony Falls Lab at Hennepin Island on the river to learn more about interdisciplinary ecosystem research, the Weisman Art Museum

Illustration from "In the Beginning" in The Changing Story: digital stories that participate in transforming teaching & learning by Linda Buturian, 2016. Image courtesy of Lauren Cooper.

to engage with art inspired by water, and always spent time along the Mississippi. Students often chose story topics that connected to their lives and academic interests. An agriculture student who grew up on a dairy farm researched manure management and interviewed farmers she knew. A Carlson School of Management student tackled the question of fiscal responsibility with regard to 3M and groundwater pollution, and traveled to 3M to interview one of its lawyers (an issue that has resurfaced in the news and courts as of late). Students created stories that questioned why the university has a ten-year contract with Coca Cola given its global impact on water and lives; that revealed effective ways to teach the water cycle to third graders; that educated about wild vs. factory-farmed salmon; and that tackled climate change and bleaching of coral reefs. You can find their stories here.

After teaching the seminar, I understood more about applied experiential learning, participatory use of multimedia (Jenkins et al. 2006), and transformative learning (Cranton 2016). Currently many educators and organizations are using digital stories as a teaching and communication medium and it's exciting to learn from these stories.

Phoebe Ward, Megan Mastel, and Linda Buturian in the course "Solving Complex Problems: Mississippi Global, Local: Community-based Approaches to Living with Rivers, Sustainably" on a walking bridge over the Mississippi River, 2015. Photo courtesy of Patrick O'Leary, University of Minnesota.

This is a story about water, and water connects us.

I could not have taught that course without the support of my department chair, colleagues, academic technology fellows, the College of Education and Human Development (CEHD), community members, and especially the many unfettered students. Nor could I have taught the first-year inquiry course I soon created with two colleagues around sustainability and social action, and then with a social scientist, where hundreds of CEHD freshmen created relevant stories. Later, when I designed an upper division course connecting learning about the Mississippi River to other global rivers, and only two students enrolled, I thought it was doomed, but my chair approved it. That was in 2014. While writing this column, I contacted the two students and asked them what, if any, enduring learning occurred as a result of our course, "Solving

Students in "Thailand: Global Change, Communities, and Families" with Catherine Solheim on the Mekong River, 2015. Image courtesy of Linda Buturian.

Complex Problems: Mississippi Global, Local: Community-based Approaches to Living with Rivers, Sustainably." Megan and Phoebe's digital stories and their brief reflections, used with their permission, follow my column.

More recently, I collaborated with Professor Catherine Solheim in Family Social Sciences to design a study abroad course in Thailand, along the Mekong River: Thailand, Global Change, Communities, and Families. Once students returned to campus they created digital stories reflecting on what they learned. Narratives that are alive in water and in the villagers who live with the river, as well as in our students, are reflected in their stories.

This story reads like a straight line ascending trajectory, but it was not. Technology is a modern-day trickster and more than one student lost a digital story and had to start over. I spent hours flailing with technology. Course proposals were rejected, multi-year projects around water culminated in little more than lessons learned, a college closed, and a department dissolved. From water I learned to change course and keep flowing.

This story of water needs:

The scent of sage that I breathed in as we are smudged, those of us gathered for a Nobel Peace Dialogue Session, hosted by Augsburg University. Members of tribes including Dakota, Ojibwe, and Standing Rock Sioux, and others from the U.S. and Canada, were in the Dakota Memorial in Fort Snelling State Park. We listened as a tribal member shared stories of how this land is sacred to the Dakotas. And how, depending on which account is listened to, more than 1,600 Dakota noncombatants, men, women, and children were forced to live in an encampment here, in truth a concentration camp, over the winter of 1862-63. Estimates vary, but many froze or starved to death there, and the survivors were put on a steamboat down the Mississippi to the Missouri river. Those who did not die on that journey were sent to Crow Creek Reservation in South Dakota. Dakota people were forcibly removed from Minnesota, and there has never been an official acknowledgment that they belong and are welcome here. The airy feeling of tobacco in my hand as we walked silently down to the *B'dote*, offered our petitions and prayers, then scattered the tobacco in the waters near the confluence of the Mississippi and Minnesota Rivers.

The beauty of the wild Rum River (Dakota name, *Watpa wakan*). I've walked along the stretch on our land for twenty years. My family and I have also swum and fished in, paddled, floated, and snowshoed on this river, which eventually flows into the Mississippi. (It took me several years to put together that rivers connect my work and my home.)

The dignity of the Iraqi delegates who visited the university in 2009 to learn more about water remediation, as they shared through a translator the challenges they face due to lack of access to clean water. The challenges are due to a grim combination of our country's targeting of their drinking water and sanitation systems during the invasion in 2003, combined with several consecutive years of low rainfall, and Hussein's atrocities, as well as northern countries controlling the water flow of the Tigris & Euphrates.

The dank smell of the Big Muddy, the warmth of the water, and the pull of the current as we waded into it up to our waists. The jolt of delight I felt dunking a broken, beyond-repairing iPad, then handing it to two students so they could also baptize it in this ancient, polluted, wondrous river.

The spray of warm water from the Mekong River (translated *mother river*) on my face as my colleague Catherine Solheim and I, along with 20 students, listened to teacher Kru-ti, who was speaking in Thai through a crackly microphone above the roar of the motor, about local knowledge, then waiting for his friend to translate. The rocking of the boat made our students sleepy in their life jackets, but they persevered as long-haired Kru-ti gesticulated out at a scattering of rocks and boulders rising above the water line. They looked like any rocks in a river to us, but Kru-ti shared the sacred stories specific to those rocks, and that the eggs of fish species are hidden

Himalayan Juntavero, Chak Kineesee, Oot, Miwatr Roikaew "Kru-ti" with Catherine Solheim on the Mekong River, Thailand 2015. For more information, visit Mekong Mosaic: Life Along the River. Image courtesy of Linda Buturian.

under them. These are fish that locals depend on for food and livelihood, yet Thailand and China plan to blast those rocks to widen the river so they can send barges down to the West to transport goods.

See the video "Mekong Mosaic" here.

The aroma of Thai white rice, vegetables from the market and just-caught fish cooking on open stoves, as later that evening on the banks of the Mekong, our Thai friends make us a feast. They create songs and music, playing traditional instruments, while we sweat and eat and dance and laugh together.

Rocks and boulders on the Mekong River, Thailand 2015. Image courtesy of Linda Buturian.

Water connects us. *Wakan*, Euphrates, Mekong, Mississippi. The vulnerability of living downstream connects us.

When students spend time with stories of water, in this case the Mississippi River, they become initiated not only into the qualities of water but also the darkness. They feel the tug of a line that connects them to what is alive in water, and the narratives of the past, present, and future that are revealed there. These narratives tell of the bones of runaway and enslaved people, and displaced murdered Native Americans, and the earliest immigrants too poor to live far enough away from the flooding. The stories speak of contaminants that undermine fish and other aquatic species' ability to thrive, and survive. Students come to understand that they play a part in this epic story cycle. And while much is given to them, something is also required of them.

Their spirits rise in hope at the beauty and wonder of this river, and the undaunted people who spend their life's portion enjoying and fighting for it. One of them is Sharon Day, member of the Bois Forte Band of Ojibwe, who leads Water Walks along rivers throughout the U.S., including here in her native state of Minnesota. A few years ago she walked the length of the Mississippi River, which took her 64 days. Sharon walks with other Native Americans and anyone else interested, and meets up with local people in their communities along the way. Women take turns carrying a copper vessel of water that they gathered from the headwaters and use in healing ceremonies along the length of the river.

Why is this a story about water?

I remember the moment, several years ago, on a warm spring day, when I was walking on the river side of River Road where there is no sidewalk and you have to keep an eye out for cars while focusing on your footing lest you slip under the large gap in the fencing and topple down the steep rocky incline. I was looking for bald eagles hidden in the trees along the bank, when I turned around and spotted one with its head swiveled in my direction. It was unnerving, stalking an eagle only to discover the bird clocking me. I glanced down at the Mississippi, and caught my breath, as it suddenly occurred to me that all these years I thought I was working on water, but what if it was the other way around—that water is working on me.

Why is that improbable to most of us? When Sharon Day was asked by the Minnesota Public Radio host why she takes part in the water walks—is it to raise awareness about the pollution? She paused and said, "We support all of the efforts to improve the quality of the water...but what we are bringing to this work is that water is a living entity...the real purpose is to speak to the spirit of the water, to address that spirit, to say to that spirit the same way that we do when we go to church and offer prayers, to say that we love you and we thank you for this gift of life."

Water is alive; it comprises 70-85 percent of our physical selves and animates all living beings. Everything we eat and drink contains water. As ecology professor Jay Hatch said to my students when he was a guest lecturer, given how much of our planet is covered in water, and that we need it to exist, rather than calling it Planet Earth we should have dubbed it Planet Water.

This is a story about water, about the Mississippi River, and about how the river is in us, and water is living, and has agency distinct from what we use it for. If these are true, could the river then be regarded as a kind of culture? If we applied intercultural elements of understanding, for example the Cultural Iceberg Model, to our engagement with the Mississippi River, how are we doing, respecting and embracing this culture as part of the rich diversity we experience on our campus (Hall 1977)?

What would happen if every student who attends the UMN-Twin Cities would be required to take a one-credit course on the Mississippi River, taught by faculty, staff, students, and community members? Students could choose from Recreation (zip lining across, canoeing in), Indigenous Storytelling, Plein Air Painting, Coding and Designing for the River, the Business of Commerce on the River, Winter Camping near the Headwaters, Aquatic Wonders, Youth, Environmental Racism, Justice and the River, Global Connections to the River, Twain Move Over: Women Write the Miss., and more. Maybe Wang Ping would be willing to come over from Macalester College and lead students in rowing, then create river flags for Kinship of Rivers. The School of Music and Ananya Dance Theater could work with students to create an original composition and choreograph a dance inspired by the river. At the semester's end, students would organize a colloquium and share their findings. As part of the colloquium, musicians would play their composition while the dancers would perform on a flatboat just as the sun is setting golden across the water.

All students who graduate from UMN-Twin Cities would share an understanding that their lives are intertwined with this remarkable river. And when they settle into their communities in White Bear Lake or Dubai, in the Nordeast or Springfield, along with locating the nearest coffee shop, they would orient themselves in some way by the rivers or lakes they are fortunate to live near. And when they turn on their tap, they would be grateful, and curious to seek out its source, and they would understand that their lives are connected to that water. Because students are inheriting this story. They don't own the story but they belong to its inheritance.

We need each other and the river and other living beings to remember what is perhaps the most vital secret of our existence.

This is a story about water, and water is a living narrative, and we have our being in this story.

Phoebe Ward

Phoebe Ward was a student in "Solving Complex Problems: Mississippi Global, Local: Community-based Approaches to Living with Rivers, Sustainably" (Spring 2014).

Digital Story: Climate Change

I spent a lot of my class with Linda Buturian thinking about the invisible dimensions of water. Later, in other classes, I would learn about nutrient loads and hydroperiods, the origins of oxbow lakes and the catalogue of fishes. And all of this would be precious. But that's not what I think of when I think of rivers, not at first: I think of the boat I went out on with my family one summer, and the soft evening air on my face; I think of walking out on a bridge in winter, and gazing out at a river frozen stone-hard and flat as a blank page of paper; I think of the Jura River where my grandmother's family farmed pigs.

Rivers are, I suspect, an indispensable feature of many of our personal histories. We travel down rivers in borrowed boats and our great-great-uncles drown in rivers and rivers bring us white crests of shell and rivers cast up stinking fish for our child-selves to shriek at and rivers baptize us and rivers give us a place to sit with friends and talk about nothing. To forget that is to forget a part of ourselves. That intersection of science and soul is difficult to put into words, but it is there, I believe, that the secret to protecting our rivers is kept. Linda made sure that we understood that the story does matter, because stories are how we as human beings decide who we are. So what we need to do, if we want to protect rivers, is tell the story of the rivers that brought us here.

Phoebe Ward graduated from the University of Minnesota in 2016 with a BA in Global Studies. She is starting a graduate program in Environmental Conservation at the University of Wisconsin-Madison in summer 2018, and hopes to eventually enter the field of water resource management.

Megan (Trehey) Mastel

Megan (Trehey) Mastel was a student in "Solving Complex Problems: Mississippi Global, Local: Community-based Approaches to Living with Rivers, Sustainably" (Spring 2014).

Digital Story: River Journey

Linda's class about the rivers was a beautiful, meandering journey through, for me, previously uncharted territory in my undergraduate education, and emphasized a practice that I continue to follow: telling the stories. A large component of our work included a self-guided video project which was a window into the power of communicating ideas through visual storytelling. It was inspiring to connect with members of the community and learn about their use of art and creative expression to illuminate the issues surrounding our water here in the Upper Midwest.

The experiential nature of the class, in the way that we went outside to be with the river, sit with

the river, engage and laugh and cry and share stories about what the river meant to us, is what has left me realizing to this day that the deepest and most memorable learning happens outside of the classroom.

Megan Mastel graduated from the University of Minnesota in the spring of 2014 with a B.S. in Family Social Science. She is the owner of Natura North Holistic Health, a healing arts practice based in the Twin Cities and surrounding areas. Megan is also a teacher, designer, and mentor with Land by Hand and the co-creator of Open Hearth Permaculture Education.

References Cited

Cranton, Patricia. 2016. *Understanding and Promoting Transformative Learning: A Guide to Theory and Practice, Edition 3*. Stylus Publishing, LLC. https://play.google.com/store/books/details/Patricia_Cranton_Understanding_and_Promoting_Trans?id=ydKHDgAAQBAJ.

Hall, Edward T. 1977. *Beyond Culture*. New York: Anchor Books.

Jenkins, Henry, Ravi Purushotma, Margaret Weigel, Katie Clinton and Alice J. Robison. 2006. *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*. MacArthur Foundation Reports on Digital Media and Learning. Cambridge: The MIT Press.

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About the Author

Linda Buturian teaches in the department of Curriculum & Instruction in the College of Education and Human Development, UMN. She is the author of The Changing Story: digital stories that participate in transforming teaching and learning (2016) and World Gone Beautiful: Life Along the Rum River (2008). Linda is currently an Educator Fellow with the UMN's Institute on the Environment. She looks forward to spending a week with students during fall 2018 on the Mississippi River discussing storytelling, community, and the natural world.