



ESPPulse

A publication of the Michigan State University Environmental Science and Policy Program



What can Michigan policy makers learn from California's experience with groundwater management?



An environmental policy paper by
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Michigan State University

Also inside: Fate of the Earth; ESPP Research Colloquia; Update on WaterCube; ESPP Student Profile; On the Evolution of Organizations; Environmental Science Library Services and much more

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Cover Photograph by Justin Sullivan, Getty

The banks of the Delta-Mendota Canal in Los Banos, California were raised 45 years ago in response to subsidence.



Each year, our program here at ESPP gets a bit bigger and, in my opinion, a bit better. We've continued to tweak different areas to benefit you - our students, faculty and supporters.

We launched the innovative WaterCube program over a year ago to stimulate new interdisciplinary collaborations in water research. Forty five faculty members (including 25 assistant professors) from six colleges formed 13 Cubes to engage in frontier research, addressing a wide array of water challenges throughout the world. After only one year, the teams have produced 10 peer-reviewed publications and generated over \$1.65 million high profile grants. We are looking forward to more achievements from these teams and for expansions of this funding mechanism.

We've been responding to student feedback by reworking two of our core classes in the doctoral specialization to expand the interdisciplinarity of the courses while focusing more on the connections between disciplines. Both courses now involve multiple modules connected by common case studies. And we are continuing to work diligently through the administrative process toward expanding our doctoral specialization to a dual major, which offers our graduates a more visible degree that better matches the credentials they gained through the ESPP experience.

We've expanded our signature events in wider-reaching themes that have created mutually beneficial interdisciplinary partnerships with more departments and colleges across campus. Last fall we worked closely with students and faculty to put on a Fall Research Symposium focusing on Environmental Health. The theme for this year's Research Symposium is Urban Environment, and this new topic is allowing us to form new partnerships and to reach out to more students and researchers. We've also aligned the theme of our Summer Research Fellowship with that of the Research Symposium. Doctoral students receiving the Fellowship will conduct cutting-edge research in Urban Environment during the summer of 2017 and then share their research results with the campus community in the fall semester. Urban Environment is also the theme of our Distinguished Lecture Series for 2017-18.

Our signature event, the Fate of the Earth Symposium, also continues to grow each year. The past two meetings have encompassed a continuing conversation on the Climate-Food-Energy-Water nexus and this year, we have brought in 10 speakers from around the world and across disciplines.

I hope to see you at many of these events and throughout the year as ESPP continues to renew our partnerships around campus and as we expand our connections.

All the best,

Jinhua Zhao, ESPP Director



FATE OF THE EARTH 2017
Climate-Food-Energy-Water Nexus
 APRIL 12-13, 2017 Kellogg Hotel and Conference Center

The fourth annual Fate of the Earth Symposium is a continuation of the important discussions started at FOE 2016 on the Climate-Food-Energy-Water Nexus.

ESPP has partnered with the MSU Fountain Challenge to bring author Charles Fishman to MSU for both the judging of the challenge as well as a keynote speaker for the Fate of the Earth. Fishman is the author of “The Big Thirst: The Secret Life and Turbulent Future of Water.”

Joining Mr. Fishman in speaking on the first day of the symposium are MSU’s own Dr. Joan Rose, the Homer Nowlin Chair in Water Research and recipient of the 2016 Stockholm Water Prize; former Sen. Lana Pollack, currently serving as chair of the U.S. Section of the International Joint Commission; Dr. Michael Mascarenhas of Rensselaer Polytechnic Institute and Lyla Mehta of the Institute of Development Studies in Brighton, United Kingdom.

The first day will also feature a panel discussion on “The Flint Water Crisis: What Have We Learned?” with MSU experts Debra Furr-Holden, Kent Key and Susan Masten. It will be capped off with a student research poster competition.

On Thursday’s Scientific Colloquium, speakers include Shazeen Attari, Indiana University; Jennifer Carrera, MSU Social Science; Rainer Horn, Christian-Albrechts Universitat; Megan Konar, University of Illinois; Vince Tidwell, Sandia National Laboratories; Sergio Villamayor-Tomas, Humboldt Universitat; and David Zilberman, University of California-Berkeley.

This symposium is made possible through the generous endowment of Barbara Sawyer-Koch and Donald Koch.

Day 1: Public Symposium Wednesday April 12

All activities will take place in Big Ten B&C, Kellogg Hotel and Convention Center

Time	Speaker
8 a.m. - 8:45 a.m.	Registration and breakfast
9 a.m. - 9:15 a.m.	Welcome by College of Social Science Dean Rachel Croson
9:15 a.m. - 10 a.m.	The Water Quality Crisis: Are We Risking Our Health? by Joan Rose , MSU
10 a.m. - 10:45 a.m.	Water and Human Development by Lyla Mehta , Institute of Development Research
10:45 a.m. - 11 a.m.	Coffee/tea break
11 a.m. - 11:45 a.m.	What Water Needs Now: Smart Water in the Era of Climate Change & Donald Trump by Charles Fishman , author
12 p.m. lunch speaker	No Clean Slate - Opportunities to Clean Up the Mess You are Inheriting by Lana Pollack , International Joint Commission
2 p.m. - 2:45 p.m.	Troubled Waters: Access and Safety Under Emergency Conditions by Michael Mascarenhas , Rensselaer Polytechnic Institute
2:45 p.m. - 3 p.m.	Coffee/tea break
3 p.m. - 3:45 p.m.	The Flint Water Crisis: What Have We Learned? Panel Discussion with Susan Masten , Debra Furr-Holden and Kent Key , MSU

Day 2: Scientific Colloquium Thursday April 13

8 a.m. - 8:30 a.m.	Registration and breakfast
8:30 a.m.- 9:15 a.m.	Misperceptions of water use and water systems by Shahzeen Z. Attari , Indiana University
9:15 a.m.- 10 a.m.	Water Poverty in a Land of Wealth: Considering the Implications of Water and Coupled Resources in Low-income Communities in the United States by Jennifer Carrera
10 a.m. - 10:15 a.m.	Coffee/tea break
10:15 a.m. -11 a.m.	Effect of land-use Management Systems on Coupled Hydraulic Mechanical Soil Processes by Rainer Horn , Christian-Albrechts University
11:00 a.m. - 11:45 a.m.	Food is Groundwater in Disguise: Aquifer Depletion, Food Security and Drought by Megan Konar , University of Illinois
12 p.m. - 2 p.m.	Lunch
2 p.m. - 2:45 p.m.	Challenges and Opportunities at the Evolving Nexus of Climate, Energy, Water and Waste by Vincent Tidwell , Sandia National Laboratories
2:45 p.m. - 3:30 p.m.	Bottom-up Nexus Adaptations Through the Lenses of Polycentric Governance by Sergio Villamayor-Tomas , Humboldt University
3:30 p.m. - 3:45 p.m.	Coffee/tea break
3:45 p.m.- 4:30 p.m.	Climate Change Water and Energy by David Zilberman , University of California Berkeley

ESPP Research Colloquia 2017: Big Data to Biomass

Attending and participating in research seminars and colloquia is an essential part of a strong intellectual culture at the Environmental Science and Policy Program. In 2017, a committee formed of ESPP students – Judith Namanya (Geography), Zachary Curtis (Civil and Environmental Engineering), Nick Skaff (Fisheries and Wildlife), Ran Duan (Journalism) and Christina Azodi (Plant Biology) – have organized a number of interdisciplinary roundtable discussions and research presentations.

In January, Curtis organized an intriguing roundtable discussion exploring the use of big data in research titled “Understanding Complex Human-Environment Systems: New Opportunities and Innovative Approaches.” The panelists for discussion included, Dr. Syed Hasham (Civil and Environmental Engineering);

Dr. Shu-Guang Li (Civil and Environmental Engineering); Dr. Jianguo Qi (Geography, Environment and Spatial Sciences); Dr. Pat Soranno (Fisheries and Wildlife).

In a roundtable discussion held in February, panelists aimed to explore the balance between science and traditional knowledge in watershed management initiatives.

Organized by Namanya, the panelists of “Watershed Management: Balancing Science and Traditional Knowledge” included Dr. Erin Dreelin (Fisheries and Wildlife); Dr. Shawn Wilson, Director of Research, Gribi College of Indigenous Australian People, Southern Cross University; Donald Shook, Grand Traverse Band of Ottawa and Chippewa Indians; and Dr. Jay Zarnetske (Earth and Environmental Sciences).



Christina Azodi (Plant Biology) discusses her research in the Science Communication Workshop. Photo by Mitch Lindstrom

Duan organized a roundtable discussion and workshop that explored science communication. Placing importance on research dissemination, panelists discussed how to effectively communicate their research to others within academia and the general public. The panelists included John Besley (Advertising and Public Relations); David Poulson, (Knight Center for Environmental Journalism); Tom Dietz, (Sociology); and Sheril Kirshenbaum, director of The Energy Poll at The University of Texas at Austin's McCombs School of Business.

Mahlet Garede (Biosystems & Agricultural Engineering) conducted the first student presentation of the year. In her lecture, she discussed a thermochemical conversion and electrochemical upgrading of biomass to displace fossil fuels and provide carbon sequestration strategies. Hongbo Yang (Fisheries & Wildlife) conducted his presentation on the complex effects of payment or ecosystem services in rural areas.

By Mitchell Lindstrom

NEXT COLLOQUIA: Social, Political and Scientific Challenges of Zika Outbreak
with Drs. Steven Bursian (Animal Science), Michael Kaufman (Entomology)
and Joseph Messina (Geography). Organized by Nick Skaff
3 p.m. Wednesday April 26 2017 * 273 Giltner Hall

Urban Environment to be the subject of 2017 Fall Research Symposium and Distinguished Lectures

The many aspects of environmental research, policy and academics which take place in urban settings are the subject of ESPP's Fall 2017 Research Symposium and so much more.

Leading up to the November symposium, ESPP has offered numerous doctoral students with Summer Research Fellowships in the areas of Urban Environment. These students will be working on projects including studying organic vegetable farming in urban areas in Nigeria; comparing infrastructure between Detroit and Windsor; researching the effects of conservation policies on urban security in China; modeling the ability of Traverse City to become 100 percent energy renewable by 2020; addressing urban food insecurity in Peru and Ecuador; and evaluating domestic water contamination and public health in the informal settlements of Dar es Salaam City, Tanzania.

In return for their fellowship, the students will present their research at the Fall 2017 Research Symposium, an event planned by and for doctoral students to showcase their research both in oral presentations and through a research poster competition. Over the past four years, the symposium has been a major success drawing 298 attendees from at least six different colleges within MSU along with a significant number of participants from other universities, government, private sector, and general public. Our vision for the event is to bring together multiple communities on campus that are working on different aspects of environmental health to share their experiences and identify collaborative opportunities.

Finally, the topic of Urban Environment will carry through the 2017-18 Distinguished Lecture Series. Instituted in 2009, ESPP's Distinguished Lecture Series seeks to engage world class researchers, policy makers and practitioners with the MSU environmental research and education community. Distinguished Lecture speakers give a public lecture on an interdisciplinary topic and interact with MSU faculty and students. The Series is designed to provide an important interface between MSU and global leaders working on cutting-edge environmental issues. An important function of the Series is to facilitate interactions among MSU researchers from diverse fields to address issues that cross disciplinary boundaries.

In 2014, ESPP expanded its Distinguished Lecture Series to include events organized jointly with other units at MSU. ESPP is offering to partner with individual departments and units at MSU wherein ESPP co-sponsors a limited number of visits by distinguished scholars to deliver lectures on pressing environmental issues.

The selection of the speakers will be made by an esteemed and interdisciplinary committee of MSU researchers including:

- **Janice Beecher**, Director of Institute of Public Utilities, professor of Public Policy
- **Guo Chen**, Associate Professor of Geography and Global Urban Studies
- **Tim Gates**, Associate Professor of Civil and Environmental Engineering
- **Jack Harkema**, Institute for Integrative Toxicology, professor of Pathobiology
- **Matt Syal**, Research Director, Sustainable Construction Management; professor of Construction Management

The committee is chaired by ESPP Associate Director **Vlad Tarabara** (Civil and Environmental Engineering). To nominate a speaker for the Distinguished Lecture Series, email the speaker's curriculum vitae to essp@msu.edu.

CORE CLASSES EMBRACE INTERDISCIPLINARITY ESP 801 and 802 changed to modular format

The new curriculum design reflects ESPP's objective of providing an interdisciplinary preparation to a cohort of students from diverse background pursuing an interest in environmental science and policy. An environmental case study will be adapted as a crosscutting theme for the course and a common point of reference for learning in ESP801 and ESP802. These two core courses build a foundation for an integrative experience in the capstone ESP804 course where students, having taken ESP801 and/or ESP 802, work on team-based projects that span the social/natural science spectrum.

ESP801 "Physical, Chemical, and Biological Processes of the Environment" provides students with a broad overview of environmental science from the perspective of natural sciences and engineering. ESP801 will be co-taught by four MSU instructors and will include four modules: Environmental Geosciences, Biology/Ecology, Environmental Chemistry, and Environmental Engineering. Coordinating Instructor: Dr. Vlad Tarabara (Civil and Environmental Engineering, ESPP).

Module 1: Environmental Geosciences Instructor: Dr. Anthony Kendall (Geological Sciences). Dr. Kendall develops and applies models and field methods to understand the landscape hydrologic cycle, and how humans impact water quantity and quality through land use and climate change.

Module 2: Biology/Ecology Instructor: Dr. Daniel Kramer (James Madison, Fisheries and Wildlife). Dr. Kramer's research adopts a coupled human and natural systems approach to the conservation of biodiversity.

Module 3: Environmental Chemistry Instructor: Dr. Hui Li (Plant, Soil and Microbial Sciences). Dr. Li's research focuses on fate, transport and impact of organic contaminants, pesticides and pharmaceuticals in natural and engineered environments.

Module 4: Environmental Engineering Instructor: Dr. Wei Liao (Biosystems and Agricultural Engineering). Dr. Liao works on developing sustainable solutions to utilize organic wastes for value-added chemical and fuel production.

ESP 802 "Human Systems and the Environment" focuses on the anthropological, economic, geographical, legal, political, and sociological concepts of human systems and environmental change. It is co-taught by instructors in Sociology, Economics, Anthropology and Geography. Coordinating Instructor is Dr. Emilio F. Moran (John A. Hannah Professor of Global Change Science, ESPP).

Module 1: Sociology: Dr. Jennifer Carrera (Sociology, ESPP). Her research focuses on the causes and consequences of impaired access to water and sanitation among low-income populations; sociological perspectives.

Module 2: Economics: Dr. Joseph Herriges (Economics, ESPP). His research in environmental economics provides a perspective on the economics of water management and water infrastructure, and ways in which economics provides insights on human decisions towards environment.

Module 3: Anthropology: Dr. Lucero Radonic (Anthropology, ESPP). Provides insights from an anthropological perspective on how cultural dimensions impact use of the environment, how communities self-organize, and engage in social mobilization.

Module 4: Geography: Dr. Amber Pearson (Geography, ESPP). Provides geographical perspectives that highlight the spatial aspects of human-environment interactions especially with regards to health, water, and food systems.

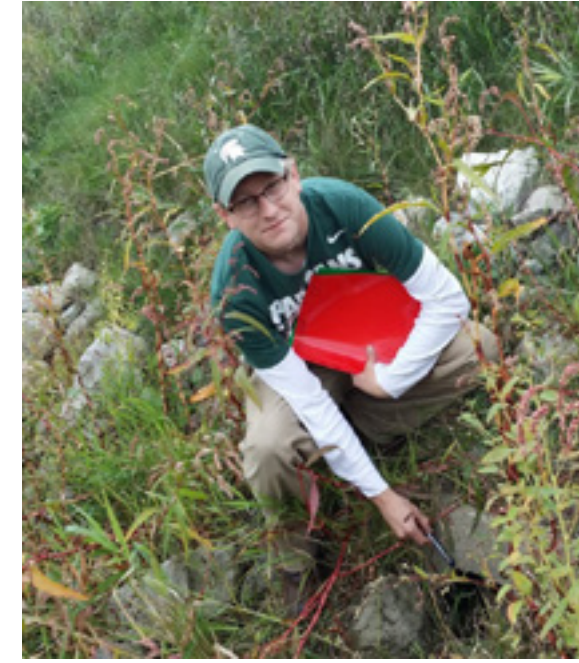
ZACH CURTIS: Exploring the links between research, resource management and decision-making

Major/Research Area: PhD, Environmental Engineering

Focus: Quantitative/computational hydrology, groundwater modeling

Year of study: 3rd year PhD student

Biosketch: There's a quote by Albert Einstein that reads, "Logic will get you from A to B. Imagination will take you everywhere." Zach brings this worldview to his current pursuit of a PhD in Environmental Engineering from Michigan State University. His goal: Help communities develop and better understand water resource sustainability — at a time when water resources are threatened and under growing duress locally, nationally and abroad. Zach, a native of mid-Michigan, will utilize groundwater and watershed modeling for his PhD research of a water resource hazard in "his own back yard"—brine upwelling into lowland and coastal areas of Michigan. Zach's love for science has taken him from point A to pursuing a PhD. Everything in between (i.e., a BS degree in Astrophysics; summer research in Boulder, Colorado; brief graduate studies at Boston University and a MS degree from MSU in Environmental Engineering) has prepared him for the next step in his academic career. In addition to his research, Zach has served as a Teaching Assistant for the CoRe Engineering program in the College of Engineering and enjoys serving as a boys' and girls' soccer coach at a local high school. Hiking/camping, live music and live sports, and photography are just a few of his personal interests.



Zach talked with ESPP student aide Kera Howell.

What motivates me: While I was working on my undergraduate studies in physics and astronomy, I remember feeling concerned and helpless about many contemporary environmental issues. Over time, I realized that with further studies I could apply my background in fundamental science to help solve complex environmental problems. Making the choice to help shape a positive future through informative environmental research - rather than sitting by as a pessimistic bystander - was a liberating feeling, and it has been a source of motivation ever since.

How ESPP has helped me in my degree: The exposure to different perspectives and research methodologies in ESPP has been pivotal to the improvement of my science communication. I have gained a sense of what other scientists and the general public know about hydrology and water resources, and I have an easier time understanding the research of scientists in other environmental fields. Perhaps most importantly, I have developed an appreciation for the links between my research, resource management, and decision-making.

by Kera Howell

Finding a Professional Society That's 'Just Right'



By Bonnie McGill
ESPP, Integrative Biology

Probably many ESPP students can relate: your research doesn't really fit into any one discipline, therefore finding a natural fit at a professional society doesn't come easy, yes? In my case, my work is at the boundary between aquatic and terrestrial, applied and basic ecology, social and ecological, local and global.

Sound familiar? While it's been a struggle to find my home professional society, it's also a challenge to find a society big enough such that there are likely to be people with a common interest in my lesser known research area—carbon emissions from carbonates added to agricultural soils. I tried on the Ecological Society of America. When that didn't quite fit I tried on the Society for Freshwater Science. It didn't quite fit either. Don't get me wrong; both of these are excellent societies and conferences for thousands of ecologists. Feeling a little like a brown haired Goldilocks, I've been hoping that the American Geophysical Union conference would feel 'just right.'

It is a very expensive meeting and I wanted to get as much bang for my buck, so I waited until now that I'm in my fourth year with plenty of data to present. It was a great time in my career to go because I have enough results to get useful feedback while still having time to make improvements or try a different approach to my research before writing and defending my dissertation. Usually when I go to meetings people have never heard of agricultural liming. But at AGU, I met with several fellow scientists knowledgeable and interested in carbonates! Like I said, it's not the sexiest part of the carbon cycle*, but in a meeting of 23,000 people I was able to find a handful of like-minded scientists who had insightful questions and feedback for my research. They had interesting tales of carbonate research to share as well. My poster, titled "Agricultural liming, irrigation and carbon sequestration," won an Outstanding Student Paper Award in the Hydrology section.

Even though the conference is huge, AGU felt 'just right' for me and my research. There was a good showing of MSU research there as well (e.g. see Erin Haacker's previous post). I plan to attend many more AGU conferences in my career. Many thanks to ESPP for supporting me to attend!

**Of course, to me, mineral carbonate weathering is the sexiest part of the carbon cycle!*



Need Research Help? Check out the Library Services for Environmental Sciences at MSU

By Eric Tans,
Environmental Sciences Librarian

For both faculty and students, conducting research is one of the most important activities at MSU. The MSU Library's primary mission is to support our students and faculty's research across all stages of the research life cycle. Reviewing the literature forms the foundation of any research project, and libraries are traditionally associated with this research stage. The MSU Libraries' collection is a great place to start any research project.

The MSU Library, however, provides research services beyond accessing the collection. The library has a research data management team that can assist with managing data, from writing a data management plan to providing best practices for standardized file naming conventions, developing descriptive metadata for your project, short or long term storage, and data publication. To learn more about Research Data Management at the MSU Libraries or to inquire about working with the library to manage your data, please send an email to researchdata@mail.lib.msu.edu. The MSU Libraries has also recently hired several librarians with specialized skills that can offer additional services to faculty and students. Amanda Tickner is our GIS Librarian and can offer a whole suite of services, including workshops, assistance with finding geospatial data, creating custom maps, and more. We also recently hired a Data Services Librarian, who will start work in September and will provide expert support for data management, analysis, and storage.



I also have been involved in supporting faculty research projects. I assisted with a bibliometric article on lion and human interaction, developing the search strategy, conducting the search, formatting the results, and writing my methods. I was also involved, along with another colleague at the MSU Libraries, with a text mining project harvesting the full text of several ecology journals to analyze how research methods and data set size has changed over time. I negotiated the terms of use with the publishers to allow for legal access to the full text while my colleague developed the code used to parse the text and generate the data.

Outside of research, the MSU Libraries also support teaching and student learning. I have given instructional sessions on searching, thinking critically about resources, and using the library to classes on environmental topics across campus, including for Fisheries and Wildlife, Geography, History, Lyman Briggs, and James Madison. For each session I have worked with the instructor to tailor my instruction to the class and produced an online course research guide custom designed for the class. My goal for these sessions is for students to not only learn about finding appropriate sources for their assignment, but also to begin to think critically about information outside the classroom.

My job is to support teaching and research on campus. I enjoy collaborating with and helping both students and faculty here at MSU, and please contact me at tans@msu.edu with any questions about our collection, research, data management, or any other service the library provides.

What motivates conservation in areas of abundance? A WaterCube success story

In the summer of 2015 the drought in California entered its fourth year. It's not the state's first drought—water has been scarce in California for decades—and, as a result, the average Californian is motivated to conserve water. But what motivates people to conserve in parts of the country where there is an abundance of water? Why do people in Michigan, let's say, work toward lowering their water usage? This is the question being asked by the Abundant Resources Research Group (ARRG) at Michigan State University. Coming from a range of disciplines, the ARRG's four faculty researchers—Adam Zwickle, Joe Hamm, Sara Fingal, and Bruno Takahashi—are contributing their expertise to researching these motivations.

The ARRG team came together under the MSU WaterCube initiative, a unique funding model that promotes interdisciplinary research around water. Unlike grant-funded research, which requires a fully fleshed out proposal, the WaterCube gives its teams more autonomy, allowing them to take an idea and determine how they will approach it as they go.

The program works like this: Faculty members apply to their dean for a token, which represents \$20,000 in research spending over two years. Half of each token is funded by the Environmental Science and Policy Program. The other half is funded through the colleges using a flexible funding mechanism. Three or more collaborators with tokens then come together to create a WaterCube team—they call this cubation. Each team must include members of at least two colleges, and one member of the team should be a new partner.

Each member of ARRG brings something unique to the work. Joe Hamm explained, "The reason we identified the team we have is that each of our areas is one we expect to be important for abundant resource management." In Hamm's case, he has spent time researching trust. "Trust tends to be predictive of voluntary behavior," he said. "Historically, this has been done in the scarce resource context where institutions ask people to voluntarily act to prevent scarcity issues but there is good reason to believe that trust would be important in an abundant context."

One of the four cube members, Bruno Takahashi, summed up the value that comes from the WaterCube approach: "I am a researcher of environmental communication, including the role of journalists. I was trained as an environmental social scientist, so I feel comfortable working with the other members of the cube. I am definitely learning more about the integration of multiple perspectives, especially from a humanities perspective, something that I haven't been really exposed to in the past."

According to Adam Zwickle, "When



Adam Zwickle, Criminal Justice and ESPP



Bruno Takahashi, Journalism

it comes to resource management, all the focus has understandably been on areas of scarce resources." With its focus on areas of abundance, the team's research is exploring new territory. "When you think about sustainability from a big picture—planetary or continental—perspective, this is a closed system. So conserving water in the Great Lakes is not directly impacting, let's say, the Central Valley in California, but it's still good."

The first step for the team was to develop a proof-of-concept study. For this, they interviewed facility managers on the campus of Michigan State University. Since water is a relatively cheap resource on campus and there is no shortage of supply, the team wanted to know what motivated these individuals to make decisions to conserve water. The interviews were conducted and analyzed by Media and Information doctoral student Kristen Lynch, who presented a poster on the research in 2015 at the annual Environmental Science and Policy Program Research Symposium.

The research identified four main areas of motivation. The first two areas were expected. Managers felt they had an economic responsibility to conserve as well as a mandate from the University. "The other two had nothing to do with Michigan State University, nothing to do with dollars and cents, nothing to do with job description," Zwickle said. "It had to do with experiences they had on rivers and lakes as children in Michigan and thinking ahead and wanting their own children to have similar experiences with water in the future."

The Office of the Great Lakes and the Water Heritage Project Jon Allan is the director of the Michigan Department of Environmental Quality's (MDEQ) Office of the Great Lakes. The office is releasing the final version of its comprehensive water strategy, which lays out a 30-year plan for managing this critical resource in Michigan. In creating the report, Sustaining Michigan's Water Heritage: A Strategy for the Next Generation, the project team at the Office of the Great Lakes talked with residents around the state and asked them what they valued about the Great Lakes. These interviews were documented in the report, but the transcripts have not undergone close analysis.

"The MDEQ has a lot of data, all these transcripts," said Zwickle, who got in touch with Allan after hearing the director speak on Michigan Radio. "We thought this would be a great way to expand the research. It is secondary data, so there are some issues—we didn't write the questions—but we analyzed all that data and are already finding similarities with the pilot study conclusions."

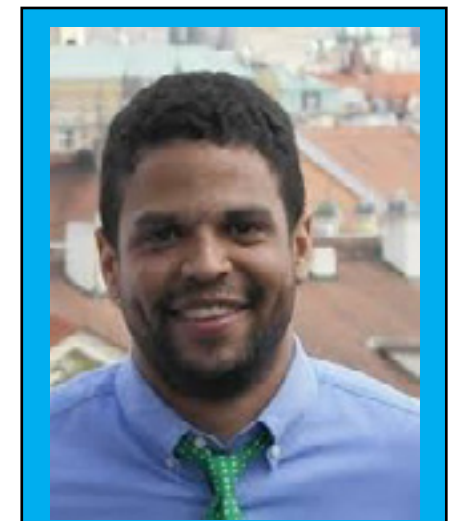
The interdisciplinary make-up of ARRG means that each member of the team not only brings specific expertise, but uniquely benefits from participation. Sara Fingal approaches this research as an environmental historian. She has been working with a graduate student on the Water Heritage project and had several meetings



Sara Fingal, Lyman Briggs

with members of the MDEQ. "These interviews revealed concerns about water diversion from the Great Lakes and the conservation of local and state resources for recreation and drinking water," she said. "I'm getting critical insight into how ideas about water in the Great Lakes region have changed over time and the concerns that have persisted over multiple generations."

Director Allan, for his part, is happy to have the team working with his office. "Their work is very complementary to our



Joe Hamm, Criminal Justice and ESPP

A WaterCube Success Story, continued

own,” Allan said. “By applying content analysis, they are identifying the language people use to talk about these issues, which tells us how they think about these issues as well.”

“We like the way they come at this, under the lens of abundance,” he said. “The solution sets you have in areas of scarcity—the politics of scarcity—don’t apply when you live in areas of abundance. The team is helping us develop different solution sets.”

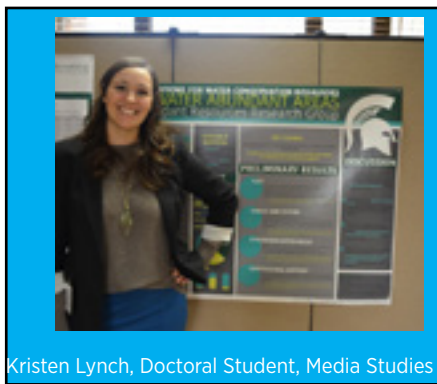
As the team looks at how people make decisions about resource allocation from a perspective of abundance or scarcity, how people perceive abundance and scarcity becomes important, explained Joe Hamm. “Some of that will be driven by whether the resource itself is abundant or scarce, but we also know that people can look at the same body of water and see it as relatively abundant or scarce as a function of, for example, the use they have in mind for the water or the metric by which they determine scarcity.”

With that in mind, ARRG is also working with water user groups. This work is being led by Brockton Feltman, a graduate student in MSU’s Community Sustainability program.

“The water user groups that I am studying are a product of Michigan’s adoption of the Great Lakes – St. Lawrence Compact,” Feltman said. “The Compact places minimum flow standards on Michigan waterbodies and recognizes the right for water permit holders and local government officials to collectively design allocation behaviors for satisfying demands while meeting environmental standards. This is basically collaborative governance within watersheds, introducing a degree of authority decentralization that helps ensure rules can be made more congruent with local realities while still meeting other Michigan water laws.”

Feltman is interviewing farmers. “My research centers on the question: What social-ecological variables do Michigan farmers believe to be indicators of water availability?” he said.

It’s an important question. As Feltman explained, “Literature on collaborative governance finds that the likelihood of participants cooperating is the degree to which members share similar beliefs about how water availability should be measured.”



Kristen Lynch, Doctoral Student, Media Studies



Brockton Feltman Graduate Student, Community Sustainability

Reprinted from: Forster, M. (2016). What motivates conservation behavior in areas of abundance? *The Engaged Scholar Magazine*, 11, pp. 18-19.

MSU team lands NSF grant to study hydropower

ESPP Appointed Faculty Dr. Emilio Moran (Geography), has been awarded a \$2.6 million National Science Foundation grant to help communities affected by hydroelectric projects achieve sustainable food and energy production.

Moran is the Principal Investigator of “Rethinking Dams: Innovative Hydropower Solutions” together with Co-PI Dr. Nathan Moore (Geography). Dr. Moore is also an affiliated faculty member with ESPP.

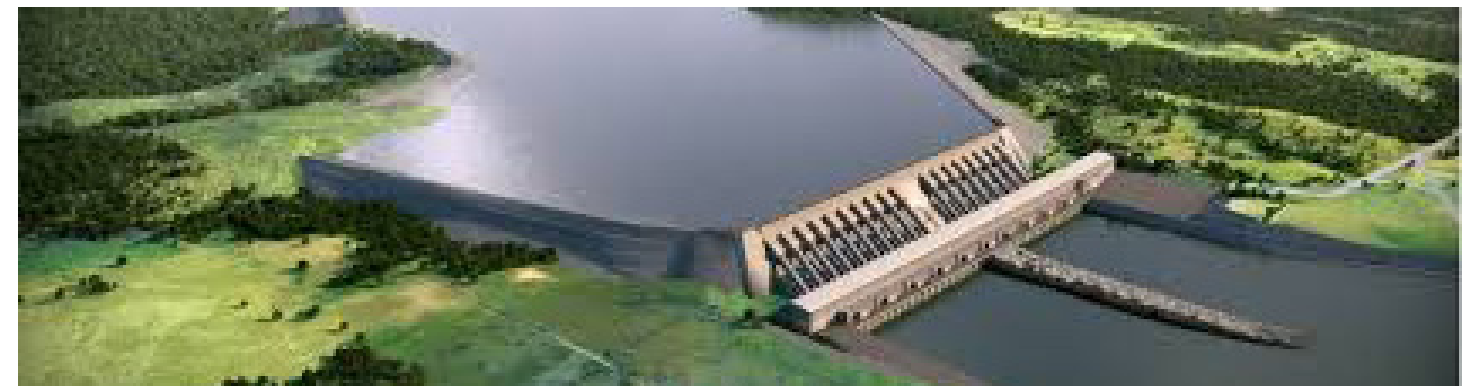
Hydropower dams have been an important part of worldwide energy production, but they also have resulted in substantial negative environmental and social outcomes. This study proposes a new way to think about hydropower, one that looks not just at energy production as the goal, but as an integrated system that can generate ecological, economic, and societal benefits beyond electricity. The study will model scenarios to assess how hydropower technologies can be deployed in new ways, such as through enhancing production of food by applying river sediments on cropland as fertilizer, or by changing hydropower technology toward smaller dams and in-stream turbines to reduce negative outcomes on river ecology and fish productivity.

Along with the training of students and postdocs, a web-based decision support system will be developed to inform stakeholders about alternative hydropower designs and locations, offer options to increase benefits to stakeholders, and serve as a lasting legacy for policy makers, scientists, and local institutions in managing their food, water and energy resources. The scenarios for redesigned hydropower will constitute a transformation in how hydropower is viewed, replacing a top-down approach that mandates a single-minded focus on maximizing energy production with a bottom-up approach informed by the complexity interlinking the food, energy, and water systems.

The project will generate innovative solutions that will improve the acceptability of hydropower development in the U.S., Europe, and across the world. This project focuses on the epicenter of contemporary hydropower development, the Amazon Basin, which is arguably the region where innovations will be most transformative because of its biological and cultural importance, especially because 85% of power in Brazil is produced this way.

Dr. Moran and Dr. Moore also have joint appointments in the Center for Global Change and Earth Observation (CGCEO). This important project also involves collaboration between geography, natural sciences, engineering and college of agriculture and natural resource

By Becky Young,
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On the Evolution of Organizations

By Molly J. Good and William W. Taylor

Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife

John Beck

School of Human Resources and Labor Relations

Robert Lambe

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John Robertson

Michigan Department of Natural Resources Fisheries Division - retired

Like people, organizations—groups of people working together toward a common purpose—come in all varieties. Whether you joined the Boy Scouts or Brownies, pledged a sorority or fraternity in college, obtained a job, or acquired membership to a professional society such as the American Fisheries Society (AFS), you have probably been a part of an organization at one point or another in your life. Similarly, we (the authors) have been associated with many organizations, and each of us feels as though we have been shaped both personally and professionally by our involvement in these organizations over time.

Serving in a leadership role in an organization, however, like many of us have done, comes with its challenges. Not only should you be knowledgeable, work well with others, and have vision and good communication skills, but you should also be flexible and adaptable—all hard traits to master! For, as time goes by, people and, thus, organizations go through periods of change. Sometimes, change occurs because an organization wants to change to either augment its mission or remain competitive with similar organizations in changing biological, physical, and social environments. Other times, change occurs because an organization has to change if it wants to excel or simply survive. At the bottom line, change occurs, so organizations need to prepare for it rather than fight it.

Organizations that can be flexible in, and appropriately choose to adapt to, times of change will flourish while those that cannot will likely become obsolete and, ultimately, perish.

In our history of working with an array of organizations ranging from universities and state and federal management agencies to binational commissions and for-profit and nonprofit groups, we have all experienced change and evolution in our organizations over time. It is often easy for us to become content and comfortable in our respective roles within our organizations and difficult for us to get in the habit of anticipating or sensing whether change, or a response to change in the environment, is necessary. In our experiences, however, we have found that the need for organizational change has the potential to creep up on us. We can liken these observations to those of a couple of frogs in a pot of slowly warming water, as described by systems scientist and Massachusetts Institute of Technology lecturer, Peter Senge, in his 1990 book, *The Fifth Discipline: The*



Art and Practice of the Learning Organization. At first, like us at times, the frogs appear to be comfortable in the warm water; so comfortable, in fact, that they fail to sense that the water is warming. When the water comes to a boil it is already too late for the frogs to sense the threat that they were gradually experiencing and, thus, the frogs perish. Similarly, an organization that does not acknowledge the need for change or anticipate it can also perish once it becomes too late for change to occur.

Even though it may be challenging and uncomfortable to prepare ourselves for change, we must acknowledge that change in the environment and the need for organizational evolution are inevitable. In last month's issue of *Fisheries*, authors M. Good and W. Taylor discussed the impact of change on an individual working in his or her profession, using fisheries and aquatic ecosystems as the context for their discussion. In this article, we present some of our strategies for organizations to avoid the same unfortunate fate as the frogs found themselves in when the water came to a boil, failing to sense their ultimate demise. We hope the following “lessons learned” from our past experiences help others anticipate, and make a choice about, facilitating change as needed in their own organizations. For, in the end, organizational change is important. It can drive large-scale future progress and overall growth that is required to maintain and enhance an organization's relevance and responsiveness as the environment changes.

DETERMINE THE NEED FOR CHANGE

Organizations are structured and function to fulfill their goals and objectives, which generally are ever-changing. As such, organizations need to have systems in place that allow them to change in relationship to the changing environment.

This is always balanced with the need for certainty of processes within an organization so that chaos does not reign. Bureaucratic procedures, while not always appreciated, allow for stability in an organization, just as routines do in individual lives. However, these procedures cannot be so confining as to not allow change. It is not enough to say, “Well, this is how it has always been done,” as you can get better at doing the wrong thing! An organization must therefore have the capacity for change if it wants to stay important and relevant to society.

The sigmoid curve (Figure 2) described by Charles Handy, an Irish philosopher, depicts the dynamics of the evolution of an organization. The sigmoid curve illustrates the success and performance of an organization based on its choice of how and whether it responds to change through time. Successful organizations already possess the procedures and processes that allow them to innovate, grow, and improve their success. But, many of these organizations do not make a change or respond to change until it is too late (Figure 2, B), or when organizational innovation, growth, and improvement become more difficult to achieve due to hesitation or lack of time and resources to pursue and potentially strike out in new directions. If an organization waits to respond to change until point B, then the organization can become inefficient or, worse, ineffective, leading ultimately to failure. Fear not, however, for organizational failure can be avoided by responding to change earlier (Figure 2, A). Whether an organization eventually chooses to accept change or resist change, the decision should occur before there is evidence of the potential need for change. At this time, when the organization is performing well, a decision to implement change may produce confusion (Figure 2, shaded area) among members of an organization who wish to maintain their current performance and those who wish to capitalize on the potential benefits and opportunities of future change. We argue that experimentation with new ideas at this time is crucial for the future success of an organization.

So, what's the trick? How can organizations continue to innovate, grow, and improve their success without losing time and depleting their resources too early? We believe that organizations must be anticipatory; they must rethink and re-evaluate what they are doing and how they function regularly, even if they seem to be functioning seamlessly and appear to be on the right trajectory with their organizational performance metrics. Organizations can do this by utilizing multiple strategies and processes that enable

On the Evolution of Organizations continued

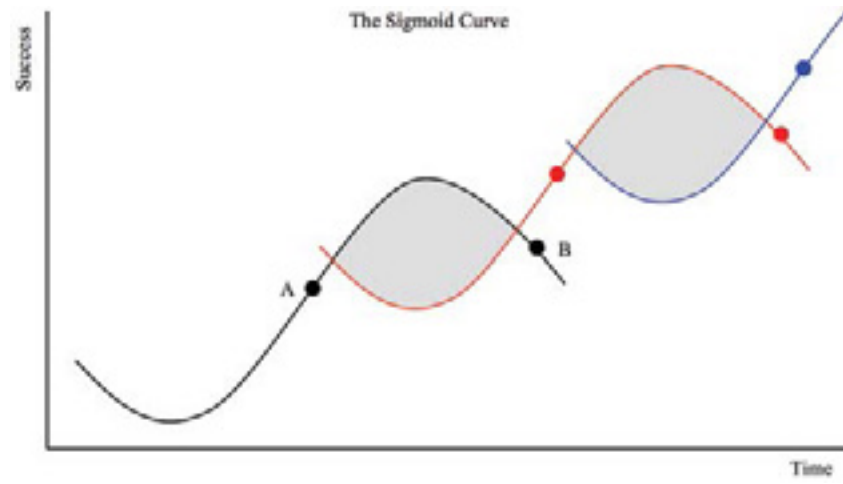


Figure 2. The sigmoid or S-shaped curve, adapted from Charles Handy in *The Age of the Paradox*. The black curve represents the evolution of organizations that choose to anticipate future change and take action at the right time (point A) or choose to maintain their current performance until it can be too late for organizations to persist or simply survive (point B). The red and blue curves represent the continuing growth and success of organizations that choose to anticipate future change and take action at the appropriate time. The shaded area represents the confusion and chaos that can occur between individuals within organizations.

their members to think about future change in the context of their organization and the environment in which they currently live, as well as the one they project to live in. If an organization regularly considers future change and, concurrently, needed organizational evolution, then the organization is more likely to be better prepared to transition to a new growth period. As such, the organizational evolution cycle continues; slow growth, followed by rapid growth, followed by declines that can lead to the demise of an organization or, if an organization is prepared, can lead to new growth opportunities. The choice is yours!

TAKE RISKS

As is evident from the sigmoid curve metaphor, organizations should anticipate change and monitor changes in trends in their environment if they wish to remain successful. Sometimes, in an effort to anticipate change and remain successful in a changing environment, organizations have to take risks that have uncertain outcomes. Though it is true that taking risks can occasionally end in unfortunate circumstances for an organization, there are some significant advantages to “smart” risk-taking or risk-taking that is deliberate in stretching organization members outside of their comfort zones. “Smart” risk-taking can lead to unforeseen opportunities and benefits. For example, in the 1990s, as former chief of the Fisheries Division of the Michigan Department of Natural Resources, I (J. Robertson) wanted to understand why salmon populations were collapsing in Lake Michigan. At the time, there had not been much research done on the salmon fisheries in the Great Lakes, and as a result, I made a decision and risked a significant portion of my division’s program funds, staff, and time to begin a close working relationship with university researchers in the state of Michigan to understand the dynamics and drivers of salmon production in the Great Lakes for improved future management. Though this decision was met with opposition from my division initially, we were soon successful in establishing partnerships and collaborating on research, program development and implementation, and education initiatives. In the end, these partnerships led to a wealth of new knowledge on salmon populations in the Great Lakes and more effective fisheries management programs.

Additionally, appropriate risk-taking demonstrates confidence, belief in yourself and your organization, and a determination to achieve an end goal or objective that can improve the organization in the future. It does

not pay to play it safe here. All in all, even though it can be scary and certainly uncomfortable, risk-taking is, at its core, a learning experience that allows organizations to develop new ideas and chart new paths as they move forward in the future, offering new products and ways of thinking.

DEPEND ON VISION AND MISSION STATEMENTS

In times of change, an organization should routinely reflect on its vision and mission statements. Here, a vision statement is defined as the ideal, overarching goal that an organization hopes to achieve over time, and a mission statement is defined as the current state or purpose of an organization.

Developing ownership among the members of an organization of its vision and mission statements is important for the organization for several reasons. First, it will help ensure that all members of an organization, including its leaders, believe in and are working toward a common goal. Without vision and mission statements, an organization could easily fragment and fail due to conflicting interests and priorities among organization members. Additionally, the lack of vision and mission statements within an organization could result in disorganization and confusion both inside the organization and to the outside world. When this occurs, organization members risk falling prey to the “demand of the hour” or the most pressing and urgent need rather than reflecting on their organization’s vision or mission statements to help them consider the long-term picture: the broader goal or objective of the organization. As the executive secretary of the Great Lakes Fishery Commission (GLFC), a binational commission that facilitates fisheries management in the Great Lakes basin, I (R. Lambe) am often in a position to take action on a myriad of issues that impact fisheries resources and aquatic ecosystems basinwide. However, to ensure the effective use of my organization’s time and resources, the members of my organization and I regularly reflect on the GLFC’s vision and mission statements, guided by the Convention on Great Lakes Fisheries, which founded the commission, for direction. Thus, in accordance with these guiding documents, I can make an informed decision about whether to take on a lead, advisory, or observatory role given the issue at hand.

Lastly, strong and bold vision and mission statements that enable an organization to grow and evolve over time can bring people with similar passions and like-minded goals together and, most importantly, instill in them a sense of determination and enthusiasm that enables an organization to move forward to make a positive impact in the world.

UTILIZE A PROCESS

Organization members should determine and agree upon a process or set of processes to assist them in conceptualizing how their organization needs to change or evolve over time. Organizations and their visions and mission statements are unique, and therefore, there is not one universal process that functions effectively in facilitating change in an organization.

However, there are examples of general processes, ranging from straightforward and short-term to more complex and longer-term, which can be utilized to help members of an organization facilitate change. Clarity and Consequence: Leaders of an organization might first ask its members to consider the consequences of any decision to change or a response to change in the organization. This process will give individual members in the organization an opportunity to ask questions, voice their concerns, and provide suggestions about the need for change and how the organization might most effectively evolve over time. This process could additionally stimulate discussion about legitimate consequences of an organization’s choices; if the potential consequences are deemed to be overly negative, then perhaps the choice to change is not warranted at this time. Without these clarifying discussions of consequences, it can be all too easy for an organization to choose a course of action without fully thinking about the potential results of their actions on the organization and its members.

Horizon Scanning: An organization and its members might choose to utilize a process called horizon

On the Evolution of Organizations continued

or environmental scanning to facilitate organizational self-reflection. Scanning of this type, known primarily as SWOT analysis (strengths, weaknesses, opportunities, and threats), is flexible, which allows leaders of organizations to think in categories that are best suited to the current organizational moment and frame of change. In my role as a facilitator, I (J. Beck) often utilize the process of horizon scanning when I am working with an organization that wants to understand a very broad range of environmental factors that may have an impact on that organization in the future; such an analysis is meant to truly free those involved to think of the future without the strictures of current realities. This often enables organization members to be more creative, which may push the boundaries of the current organization, redefining its vision and mission to better function in the future. With this information, it becomes more feasible for an organization to plan and facilitate change to address threats, overcome challenges, and take advantages of opportunities sooner (at point A of the sigmoid curve) rather than later.

Though organizations might acknowledge that change and evolution over time may be necessary to meet the anticipated threats, challenges, and opportunities of the future, organizations should be cautious about facilitating too much change. Not all change is positive, and organizations that commit to too much too hastily may lose sight of their overall vision and mission, leading to ineffectiveness, discontent, and, potentially, failure. Therefore, an organization might utilize a process to determine what current responsibilities or actions may be “in” or “out” in terms of priority to that organization. This process, which is founded upon the vision and mission of an organization, results in a common understanding within an organization about the scope of its work (what it should do and what it should not do), its role in the broader community, and its priorities and responsibilities now and in the future. This process also provides an opportunity for an organization to check that its goals and objectives are in sync with its prime function, and it identifies previously unknown interests in, and highlights opportunities to pursue, different priorities and responsibilities in the future.

ASK FOR HELP

It is evident that various processes or strategies can provide critical support and structure to an organization that acknowledges and facilitates change in response to changes in the environment. What may be even more critical, though, is external assistance—help from outside of the organization. Leaders of an organization might approach these efforts with tunnel vision, refusing to explore options outside of their lines of sight or comfort zones, or they may neglect to consider options or alternatives that stray too far from whatever, historically, has been needed to maintain and grow the organization’s success. Oftentimes an unrelated, objective voice is the most critical voice in the room, for an individual who is external to an organization, but who can adequately lead the discussion within an organization, is not afraid to ask questions, challenge others, and raise controversial views or points. These types of people—trained professionals or facilitators—and the processes they utilize, have the potential to drive the most change and evolution in an organization while still preserving its main purpose and its integrity.

EVALUATE THE PROCESS AND OUTCOMES

As in many fisheries and aquatic ecosystem management processes, one of the last and most important steps in the process of facilitating change in organizations and responding to change in the environment is evaluation. Evaluating any kind of process and its outcomes yields a greater understanding of what was actually accomplished, any lessons learned about the process that were selected and implemented, and necessary improvements that might streamline similar processes in the future. As long as an organization continues to anticipate change over time, responds to change on a regular basis, and evaluates the processes and outcomes of change on its vision and mission, the organization, unlike the frogs, will surely jump out of the pot before the water boils.

To Evolve or Not to Evolve? That is the Question

By Molly J. Good and William W. Taylor

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ROAD RACES AND REMINISCING

Just last month, I (M. J. G.) found myself on the course of the Fifth Third River Bank Run in downtown Grand Rapids, Michigan, dodging marathon runners, spectators, and police officers, as I attempted to maneuver myself from the outskirts of the city, through the marathon course, to the Amway Grand Plaza Hotel. It was there that I was planning to meet with my friend and former supervisor, Ralph Riley. Riley is an ecologist that I met 10 years ago. At that time, I was an outgoing and enthusiastic high school student, who was actively searching for opportunities and experiences that would help me learn more about and understand what I wanted to do professionally in the future. While in my guidance counselor’s office one day, I happened upon an application for a program dedicated to exposing students to scientific field work and data collection and analysis through intensive, short-term research experiences. With support and encouragement from my high school biology teacher, I applied for and was fortunate to receive this once-in-a-lifetime opportunity through Earthwatch Institute’s Student Challenge Awards Program (SCAP). I still remember the day I opened my program acceptance letter, for my Dad gifted me with a larger-than-life-size (a trophy size!) rainbow trout mylar balloon. Working alongside Riley and a team of five other high school students from all over the country, I traveled to the Puget Sound, where I was trained on the spot and quickly put to work gathering data and information about the ecology and geomorphology of salmon-bearing streams in the Pacific Northwest.

Since our first meeting in the SeaTac airport, I have maintained contact with Riley, one of my mentors, with whom I frequently discuss my interests and progress as an individual and a developing professional. In the last 10 years, my relationship with Riley and other mentors, along with a variety of my own opportunities and experiences, have allowed me to better define my interests, hone my skills, and successfully evolve as an individual and a developing professional, thus enabling me to contribute to the profession and to society in new and innovative ways. For example, over the course of this journey, I learned that one should not simply learn to learn, but instead strive to use what they learn to impact something or make a difference.

Recognizing the need to adapt and the desire to improve myself, while at times scary, has increased my capacity to learn through new opportunities and experiences and, above all, inspired me to evolve or morph with the times and provide meaningful leadership in future challenges.

To us, formal and informal education along with the presence of good mentors, is paramount in readying developing professionals for success in a changing environment and an evolving profession. But, one cannot or



William W. Taylor and Molly Good

may not be willing to take advantage of new experiences and opportunities alone, for they are often unfamiliar, uncomfortable, and anxiety-producing as the outcome is not always predictable. Great mentors, however, provide the necessary encouragement to pursue and the guidance to navigate through the uncertainties of change, enriching one's learning experiences. Through this process mentors also serve as a source of intellectual and personal support and a much-needed safety net in times of this uncertainty or misunderstanding.

FOR THE TIMES THEY ARE A-CHANGIN'

Just as we have evolved as developing professionals and engaged citizens in our community over our lives, so has the fisheries profession. To stay relevant and to help chart the path to a more sustainable future, one requires an understanding of the skills that one should experience and master in order to deal with a rapidly changing environment, in which emerging issues and threats to fisheries and aquatic ecosystem sustainability are inevitable. When these challenges arise, professionals should have the skills that allow them to feel secure, be confident, and function effectively in teams to address these changing needs meaningfully. In light of the challenges our fisheries resources and profession will face in the coming years, not to mention our own personal challenges that life provides each of us, fisheries professionals will need to work in interdisciplinary teams, which include not only fisheries-related scientists and managers, but also policymakers, legislators, and the public. All of these people will need to work together to mitigate and prevent damage to our fisheries resources in the future. Additionally, the profession will require new skills and disciplines that allow for the engagement of new types of individuals including more innovative and novel thinkers, strategists, problem solvers, politicians, and effective communicators to address future problems our fishery resources and society will face.

Whether or not all educational institutions are working to develop future professionals to be what the profession truly needs now and in the future may be debated. What cannot be debated, however, is that new knowledge and skills learned throughout one's lifetime are necessary if one is to make a continuing difference in the future sustainability of fisheries and aquatic ecosystems.

Thus, if we care about our future, then we must take advantage now of education, in whatever form it comes, for us to evolve to be impactful and successful in an ever-evolving profession. For example, the American Fisheries Society (AFS) is one organization that has provided opportunities for me (W.W. T.) to learn throughout my life. Over time, and with encouragement and support from my colleagues and mentors, I transitioned from being an active AFS member at the state and division to the national and international domains, eventually becoming the president of AFS. In these roles, not only did I learn more about fisheries and aquatic ecosystems, but I also learned hard life lessons about teamwork, inclusivity, leadership, communication, and the value that each and every individual brings to the team in solving problems at all levels of governance. I was able to seamlessly bring the unique set perspectives and skills I had acquired, often through the school of hard knocks, into my next role as an educator and administrator at Michigan State University (MSU). My involvement in AFS and other professional societies and community organizations facilitated my learning in ways that could not have been achieved through other means, and it has allowed me to, in return, provide mentoring to other developing professionals like Good.

Broadly speaking, the fisheries science and management profession appears to be evolving to consist of diverse professionals with wide-ranging knowledge bases, varied skillsets, and rich educational and life experiences. We hope that this evolution continues, for it brings together a variety of professionals of different ages, life history experiences, educational backgrounds, genders, and races to act toward the common goal of enhancing the status of fisheries and aquatic resources throughout the world. In reality, the fisheries science

and management profession has evolved into a true mosaic of all segments of society including, most notably, students, educators, scientists, managers, academics, policymakers, law enforcement officers, legislators, and communicators, who must combine their knowledge, skillsets, and experiences to ensure sustainable and productive fisheries and aquatic ecosystems.

HERE'S WHAT YOU NEED TO SUCCEED

Current and future professionals have a responsibility to continue their lifelong learning, and motivate others to learn, in order to adapt to the ever-evolving fisheries science and management profession. This type of learning can be achieved by pursuing relevant educational opportunities and experiences, identifying and establishing mentor-mentee relationships, and participating in leadership and personal development trainings or workshops.

RELEVANT EDUCATIONAL OPPORTUNITIES AND EXPERIENCES

Formal and informal types of education can lead individuals to take advantage of opportunities and experiences that they would not discover elsewhere. For example, I (M. J. G.) was able to further my learning about forest ecology and salmon biology with the Earthwatch Institute through an opportunity I first heard about in my high school biology class. This educational experience not only introduced me to the sciences at a young, impressionable age, but it also helped me understand that a future career in this field was possible. Up until this point in my life, I simply knew that I enjoyed spending most of my childhood days up to my knees in muck, wrangling and observing frogs, newts, and fish- basically, anything I could get my hands on. How fortunate was I, at seventeen years old, to realize that I had found my lifelong passion?

MENTOR-MENTEE RELATIONSHIPS

It is impossible to take advantage of educational and life opportunities and experiences without the support and guidance from a great set of mentors. The best kind of mentor recognizes the strengths and the potential to evolve in his or her mentees and, thus, encourages his or her mentees to pursue new things. The best mentors not only allow but advocate for their mentees to continue their lifelong learning by identifying and engaging in new and exciting (although, at times, stress-inducing!) ventures with a goal to be impactful or make a difference in the profession and society. Great mentors also encourage their mentees to take on new challenges while still providing necessary guidance and support in unfamiliar or uncomfortable situations. Effective mentoring, though challenging, is worthwhile to all because it always works both ways; just as a mentee will learn from his or her mentor, a mentor will undoubtedly learn from his or her mentee as well.

LEADERSHIP EXPERIENCE AND PERSONAL DEVELOPMENT TRAINING

Additionally, developing professionals in the fisheries science and management profession should actively seek out educational opportunities and experiences that bolster their leadership skills. Leadership skills take time to develop, and the best way to work on acquiring more leadership experience is by pursuing leadership positions or participating in other training or workshops. AFS, for example, offers many positions for developing professionals and current professionals that provide leadership experience, whether you wish to work as part of the AFS Student Subsection for a Chapter or for the Society. AFS also offers many opportunities to comfortably build one's skillsets and improve his or her personal and professional development. Over time, these types of educational opportunities and experiences can lead to the growth of a network of people with diverse personalities, cultural backgrounds, and skillsets, which will be best equipped to handle changes in the environment and the profession.

Managing California's Groundwater under SGMA: Implications for a Sustainable Future

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Michigan State University

Executive Summary

Over the course of the last century, reliance on groundwater aquifers enabled a large portion of California to transform from a harsh, semi-arid environment to a landscape of bustling communities and robust agricultural production. This rapid growth has raised serious concerns about the sustainability of the groundwater resources in the state. To address these challenges, in 2014, the state legislature passed a series of laws collectively known as the Sustainable Groundwater Management Act (SGMA). This report discusses the state of groundwater in California under SGMA. A particular focus is given to the Central Valley region of the state, an important agricultural and population center. Intensive groundwater withdrawals have caused a negative water budget in the Central Valley aquifer system. This has led to problems such as reduced water availability, increased pumping costs, land subsidence and changes in chemical properties of groundwater. Environmental engineering technologies are discussed as potential solutions. The detailed policy frameworks and institutional arrangements set by SGMA are analyzed with emphasis on how the social and natural science elements interact. The analysis shows that a comprehensive representation of stakeholder groups' interest is pivotal to sustainable management of this common pool resource. State intervention is highly recommended in the groundwater sustainability association (GSA) formation phase to guarantee a balanced representation of stakeholders. Environmental stewardship is currently not well-represented in many GSAs. GSAs are given high discretions in enacting local groundwater sustainability plans (GSP) and it is recommended that they use groundwater monitoring and natural science modeling to assist policy design. This report concludes by addressing the applicability of SGMA and the state of groundwater in California to our own state of Michigan.

1. Introduction

There is a saying that “water is life” and perhaps, there is no place where this applies more than the U.S. state of California. Over the course of the last century, the large-scale transfer of surface water along with heavy reliance on groundwater aquifers enabled a large portion of the state to transform from a harsh, semi-arid environment to a landscape of bustling communities and robust agricultural production. Today, California is the most populous state in the nation and accounts for 17.3% of total U.S. agricultural output (1). This rapid growth, however, along with the projected impacts of global climate change, have raised serious concerns about the future of water in California. Many of these concerns revolve around groundwater, which is used by 85% of the state's population and much its 45 billion dollar agriculture industry (2). The state of groundwater in California has been criticized as largely unregulated and lacking cooperative management and accessible and reliable data which could help manage it sustainably (3).

To address these challenges, in 2014, the state legislature passed a series of laws collectively known as

the Sustainable Groundwater Management Act (SGMA). The intent of this act is to bring various stakeholders together to plan a more sustainable future for the state's groundwater basins. The act requires the California Department of Water Resources to identify groundwater basins experiencing conditions of critical overdraft characterized by seawater intrusion, land subsidence, and groundwater depletion (4). Stakeholders and water users within these basins are then required to form a groundwater sustainability association (GSA) by July 2017 and establish corresponding groundwater sustainability plans (GSPs) to be implemented by July 2020 or 2022 (depending on the basin) or face state intervention (5). These GSPs will then be regularly reviewed by the Department of Water Resources to assess their progress.

The majority of basins listed as experiencing critical overdraft are located in the Central Valley region of the state, an important agricultural and population center. As of 2013, this region's annual agricultural output totaled 43.5 billion U.S. dollars, roughly 8% of the whole U.S. agriculture GDP (6). The Central Valley also accounts for 75% of irrigated lands in California and 17% of irrigated lands nationally (7).

This report provides an overview of the state of groundwater use and management in California in the context of SGMA. A particular focus is given to the Central Valley region of the state due to the large scale of its reliance on groundwater and looming challenges. First, the natural science and engineering aspects are discussed. Then, social science concerns, such as management and policy challenges, are addressed. These approaches are then synthesized to understand the overarching challenges to groundwater sustainability in California and what role SGMA might play. Finally, this report concludes by addressing the applicability of SGMA and the state of groundwater in California to our own state of Michigan.

2. Natural Science

2.1 Hydrogeology

The Central Valley is bounded by the Coastal Ranges on the west and the Cascade Range and Sierra Nevada on the east. The climate is generally considered a hot Mediterranean climate, with hot and dry summers and cool, wet winters (8). The Central Valley has three main sources of water: the snow melts from the Sierra Nevada, the river systems and the aquifers. In normal years, surface water from rivers, ponds and canals accounts for two thirds of total irrigation water use, with groundwater being the supplement source. Snow melt from the Sierra Nevada is released during late winter, spring and early summer and is captured by reservoirs and dams at the base of the range. This water is then distributed by streams and canals throughout the valley.

The Valley has two major river systems flowing through it: the Sacramento River system and the San Joaquin River system. The Central Valley watershed is around 60,000 sq. miles and the runoff from this area drains into the Sacramento River, San Joaquin River and Tulare Lake region. The Sacramento River flows southwards through the Sacramento Valley, along with its main tributaries, the Feather River and American River, whereas the San Joaquin River flows northwest along with its tributaries, the Merced River, Tuolumne River, Stanislaus River and Mokelumne River. The two rivers meet at the Sacramento-San Joaquin Delta and proceed to flow into the Pacific Ocean. The amount of water carried by the Sacramento River is around 22 MAF (Million-acre-feet) of virgin annual runoff, whereas it is 6 MAF for the San Joaquin River (9). A significant portion of water demand is met by this surface water.

The remaining water demand is supplemented by groundwater. The percentage of groundwater used for irrigation ranges from 40% to 60% in drought years (10). Not only does the agricultural sector depend heavily on groundwater, but municipalities, domestic users, and industry also rely on groundwater as their primary water source in many high and/or medium-priority groundwater basins assigned by California Statewide Groundwater Elevation Monitoring Program (CASGEM) (11). However, groundwater availability is highly dependent on the location, leading some areas to be dependent more on groundwater and some

Managing California's Groundwater continued

solely on surface water (12). The aquifer system is a basin-fill aquifer system. The aquifer system of the Central Valley has both confined, semi-confined and unconfined aquifers, which primarily consist of sand, gravel, silt, and clay (13). The Central Valley aquifer system consists of a single aquifer system which is heterogeneous in nature and contains water in unconfined conditions in the upper regions and in confined conditions as depth increases (14). Most of the water is extracted from the upper 1000 ft. of deposits, but freshwater with less than 2,000 mg/L of dissolved solids are found at depths greater than 3000 ft. Most of this freshwater is found west of the Sacramento Valley and the south of the San Joaquin Valley. Saline water is present below this freshwater zone (15).

Intensive groundwater extraction has lowered water levels and this has changed the inter-basin flow from the natural flow directions. A water budget analysis accounts for the water movement in a hydrological system. The water budget for pre-development times showed a balanced water budget, implying that the inflows and outflows were balanced. But now, that is not the case. A loss of storage in the aquifer is brought about by withdrawals which are more than the recharge. This loss of storage can lead to problems such as increase in cost of pumping, reduced water availability, land subsidence and changes in chemical properties of groundwater due to salinity and other reasons (15). To evaluate how sustainable the source is, the water budget can be conducted after the control boundaries are defined. Any aquifer is considered to have both inflows and outflows. To be considered are the water uses, the precipitation, the recharge mechanisms, the water supply (groundwater, surface and recycled water) and environmental water requirement.

The water budget was evaluated for the Central Valley Aquifer as shown in Table 1. The data showed that outflow due to all the water demands were lumped into one sum and the inflows were mainly due to stream-aquifer interaction and percolation of water from precipitation and irrigation (15).

Table 1: Groundwater Budget in Million Acre-Feet/Year

Processes	Avg. year (1962-2003)	Typical year (1975)	Dry year (1990)	Wet year (1998)
Outflow	-9.3	-8.3	-12.2	-5.9
Stream interaction	0.3	-0.5	-0.5	3.3
Recharge	7.8	7.1	3.7	15.5
Net storage change	-1.2	-1.7	-9	12.9

Land subsidence is a natural process, which occurs due to moisture loss. However, human-induced subsidence occurs due to increased withdrawals which lead to changes in storage of aquifers. These can be permanent in nature and cause damage to buildings, aqueducts, well casings, bridges, and various infrastructures. Subsidence, hence, has a significant cost, running into millions of dollars (14).

Another huge impact to look into is that when aquifer levels go down, the streams and rivers nearby also dry up. This is because of there is a transfer of water between the aquifer and the streams and one affects the other. This has significant implications as rivers dry up due to aquifer storage decline, ecological problems also arise, along with the above mentioned problems. These ecological problems have been discussed in detail in later sections.

2.2 Environmental Chemistry

Groundwater quality in California is monitored by hundreds of wells widespread in the state.

Both man-made and natural occurring constituents in groundwater and surface water impact the water supply, water usage and long-term water sustainability goals within the basins. EPA regulates the Maximum Contaminant Level (MCL), the highest level of a contaminant that is allowed in drinking water in the National Primary Drinking Water Regulations (NPDWR) (16). Contaminants in water are categorized as disinfectant, organic and inorganic chemical, disinfection byproduct, microorganism especially enteric viruses and protozoa, and radionuclides. Potential health effects from long-term exposure above the MCL and common sources of contaminant in drinking water are identified by the NPDWR, as well (16).

Groundwater is a source of drinking water in the State of California, although may not be the major source, which depends on the surface water availability and drought condition in the area, thus monitoring and maintaining groundwater quality is important for both short-term and long-term sustainability goals. In the mean while, the SGMA defines “sustainable groundwater management” as the “management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results”, and one of the “undesirable results” described in the Act is “significant and unreasonable degradation of water quality” (17).

High concentrations of nitrate in groundwater are a major concern for drinking water supply. Potential health effects from long-term exposure above the nitrate levels (16). High nitrate concentrations are typically found in shallower groundwater. Possible sources of excessive amount of nitrate include agricultural fertilizers, sewer effluent, septic tank effluent, and animal waste (18).

Data retrieved from GeoTracker GAMA, which is a groundwater information system that provides water quality data State Water Board programs and other resources (19), indicates that in past 1 year, nitrate is still a widespread contaminant in groundwater in California (see Figure 1a). Wells that detected higher than MCL concentration of nitrate are mostly along the coastline, in central valley area, and near big cities. Northern part of the state has much fewer wells detected excessive concentration of nitrate (20). Nitrate in irrigation water acts as fertilizer, thus it is not a major concern for most of crops. However, high concentration of nitrate may have negative effects on permanent crop production such as grape vineyards (18).

The public health concern on effect of nitrates in human life is serious. Many studies have been done in human and this have showed that nitrate interferes with the ability of red blood cells to carry oxygen. Infants and young children are more at risk of nitrate poisoning than older children or adults. The main symptom is where the babies turn “blue” especially when there is no enough oxygen being circulated in their blood. This is referred to as “blue baby syndrome” or in scientific world “methemoglobinemia” which is a serious condition that can cause brain damage or death to the affected population (21).

Nitrate levels in drinking water has also been shown to increase factors that lead to thyroid dysfunction (22). Recurrent respiratory tract infection has also been shown to increase in areas where there is increased nitrate levels (23). High levels of nitrate in drinking water may also lead to maternal exposure and adverse reproductive and developmental outcomes in the population (24).

Arsenic concentration in water has a MCL of 0.10 mg/l. Negative health effects from long-term exposure to higher concentration of arsenic include skin damage or problems with circulatory system, and may have increased the risk of cancer (16). Geotracker GAMA shows that wells that detected higher arsenic concentration than its MCL in past 1 year are also widespread in the state, and are more than those wells that detected excessive amount of nitrate (see Figure 1b). Areas near large cities have more wells detected high arsenic concentration.

Trichloroethylene (TCE) is a major contaminant of groundwater supplies in California, because of improper storage and disposal. It is usually used as a solvent for dyes, rug cleaners and as a degreaser for metal parts (18). Past 1 year data in Geotracker GAMA showed that higher concentration of TCE (>5 ug/L) are mostly found in wells close to big cities, especially in Los Angeles and San Diego area (see Figure 1c). Some wells in central

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valley also detected higher amount of TCE. Methyl-tertiary-butyl-ether (MTBE) is a mandatory gasoline additive to reduce air emission (18). It has been found in wells in various locations across the state (see Figure 1d). It is highly mobile and highly soluble in water (18). It is not regulated by EPA, but is identified as one of the top ten chemicals by Geotracker GAMA database.

Other groundwater concerns include, but not limited to: 1) salinity, which is measured by total dissolved solids (TDS) (see Figure 1e). Under natural pressure, the saline groundwater migrates upward through permeable sedimentary rocks, as well as through wells, faults and fractures. Pumping from deep wells may result in more rapid mixing of brine with fresh water underground; 2) bacteria. Bacteria contamination may be attributed to inadequately constructed and improperly located, destroyed, or abandoned water wells, general deterioration of wells, inadequate maintenance of wells, and improper waste disposal in water wells; 3) pesticides, such as 1,2 Dibromoethane (EDB). Geotracker GAMA data shows that EDB contamination is not as severe as nitrate or arsenic, with only 13 wells detected EDB concentration higher than MCL (0.05 ug/L) in the state in past 1 year (18).

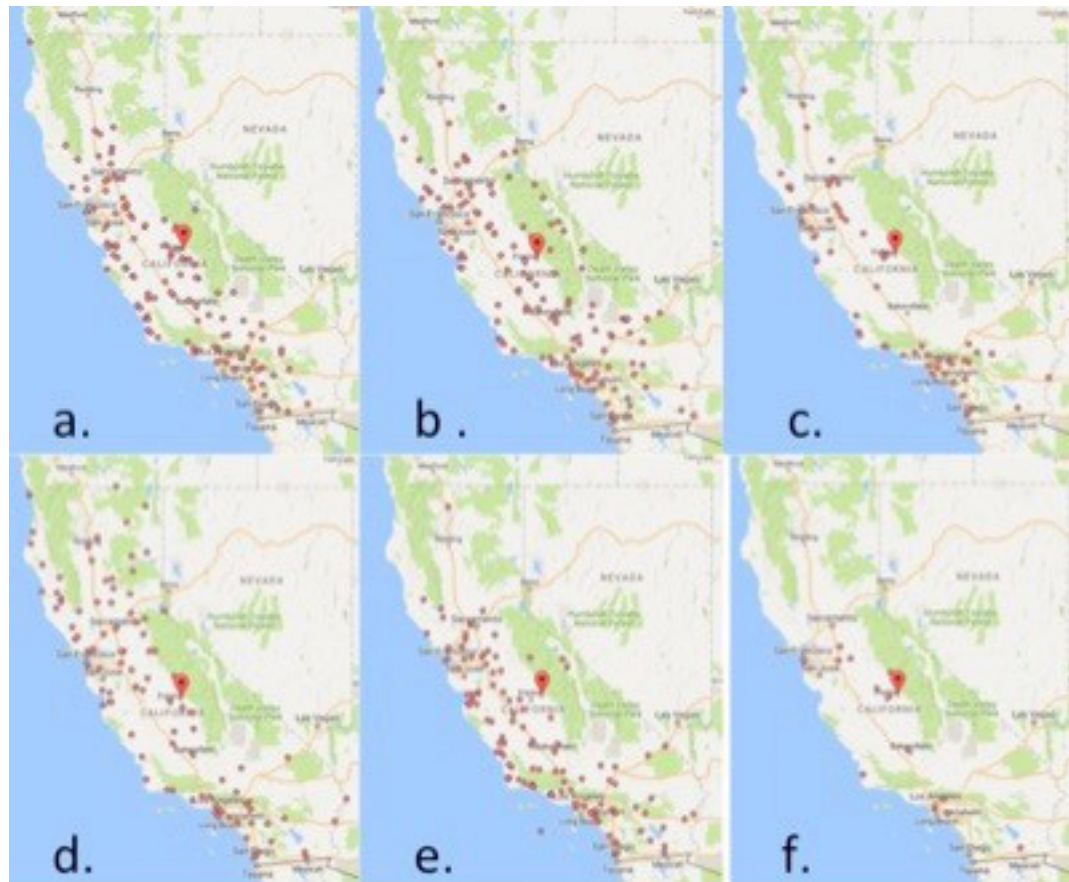


Figure 1. Wells with groundwater chemical data that recorded higher concentration than comparison value within past 1 year in GeoTracker GAMA Online Database. a. Nitrate as N, compared to MCL= 10 mg/L; b. Arsenic, compared to MCL= 10 ug/L; c. Trichloroethene (TCE), compared to MCL =5 ug/L; d. Methyl-tert-butyl-ether (MTBE), compared to 5 ug/L; e. Total Dissolved Solids (TDS), compared to 1000 mg/L; f. 1,2 Dibromoethane (EDB), compared to MCL=0.05 ug/L.

hence, needs a minimum amount of water flow. This minimum water flow is known as environmental flow or environmental water requirement for the river. In the case of Central Valley, such a situation can occur in many regions. Another similar problem is caused due to the repercussion of the reduced flow (25). The estuary located at the Sacramento-San Joaquin Delta is the largest spawning ground for certain fish species, such as the Chinook salmon (25). The conditions are ideal due to the optimum mixing of freshwater with saltwater. However, due to the diversion and storage of freshwater upstream for various reasons, the optimum mix is no longer available depriving many species their spawning ground. Another issue is the flow of large amounts

2.3 Impact on Ecology
A huge impact of aquifer storage decline is the drying up of associated rivers and streams. This drying leads to loss of plant and animal communities dependent on the river (25). The health of a river is dependent on the flow through it and

of pollutants, such as pesticides, selenium, ammonia and mercury. Many of the native fish species are now threatened, endangered or extinct. Phytoplankton and zooplankton populations have also declined along with an increase in many invasive species (26).

As there are stream-aquifer interactions, any contamination in one can affect the other. Looking mainly at nitrate concentrations, higher nitrate concentrations lead to high growth of algae, leading to unstable amounts of dissolved oxygen that will create stressful conditions for aquatic animals like fish. This limits their growth and reproduction therefore leading to high mortality of fish. Excess plants and algae will also create conditions where organic matter accumulates.

2.4 Advanced Technologies in Environmental Engineering

In the State of California, potable and non-potable water reuse continues to garner acclamation for its potential in the augmentation of existing public water supplies. To meet the criteria and guidelines for water reuse various contaminants of public health concern need to be fully characterized. These contaminants included microbial pathogens, chemical pollutants and antibiotic resistant genes that can cause detrimental effect to human. The advanced technology can remove these contaminants in wastewater.

To save groundwater subsidence and overdraws in the California, the Central Valley and its water sub-basin, new technology need to be employed. The major challenge lies with the farmers and agricultural farms that are using the water in large numbers to irrigate their produce. There is need to change their behaviors and adapt new and more advanced technologies that will be more efficient. This technology includes adopting the use of reclaimed water that is treated in advanced wastewater treatment plants that can be used for safe irrigation and groundwater recharge. Though the cost of building this advanced wastewater treatment plant is expensive (27). The State and the federal government can invest in this technology.

This technology is used in a county like Orange County, CA, where their reclaimed water is being used for direct potable use through discharge of the groundwater and disinfection processes. Advanced technologies such as activated carbon adsorption, reverse osmosis, membrane bioreactor technology are also in use in the Orange County, CA (28). The water reclaimed from these technologies complies with both the clean water and the safe water drinking act. If adopted in other counties and especially in the area around the central valley, it can scale-up the already existing surface water that is used for recharge (Figure 1) (28).

For instance, Ion exchange is a process where one or more undesired ion is exchanged for another desired (or at least unobjectionable) ion. The exact ions exchanged depends on the resin of the ion exchange column. The influent water is run through a resin, where the ions are exchanged. Ion exchange columns are typically used to soften water and remove “hardness” or the calcium and magnesium ions.

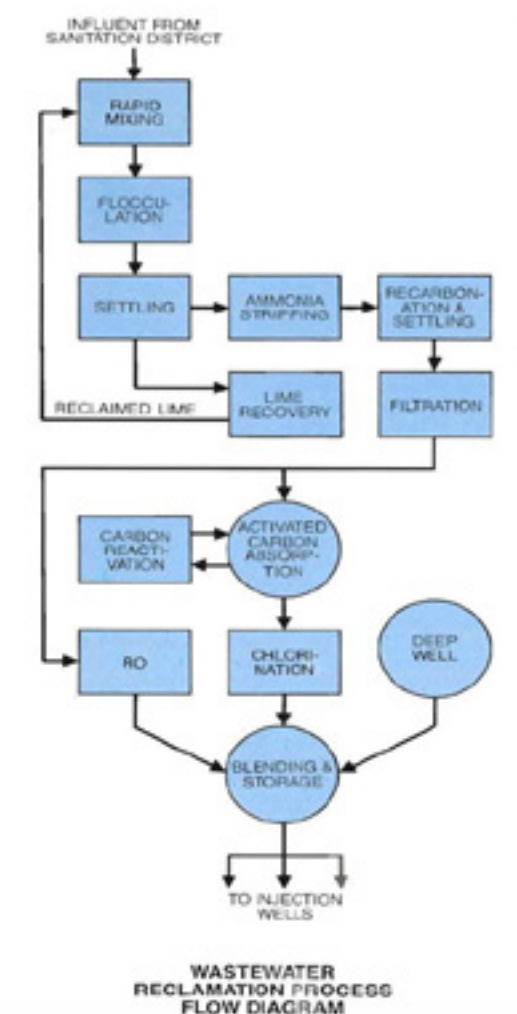


Figure 1: Advanced wastewater treatment plant: a water reclamation plant in Orange County, CA

This method can also be used to remove ions such as iron, sulfate, manganese, or nitrates. If this is employed most in wastewater treatment plant in addition to the membrane bioreactors filtration system that can help in reducing the amount of microbial pathogen to the required standard and the final effluent can be used to recharge the depleted groundwater.

Efficient irrigation technologies can also be encouraged. For instance, almost 40% of lands are irrigated by flood irrigation in California, while nearly all lands in other west states are irrigated using center pivot techniques, which is more efficient compared to flood irrigation (29).

The effect of using a water reclamation plant can be seen in the change in water budget. Presently, considering only 50% reclamation of the domestic wastewater leads to a significant change in the water budget as can be seen in Table 2. This would reduce the stress, even though it would not lead to net balanced water budget.

Table 2: Groundwater Budget in Million Acre-Foot/Year

Processes	Avg. year (1962-2003)	Typical year (1975)	Dry year (1990)	Wet year (1998)
Outflow	-9.3	-8.3	-12.2	-5.9
Water recycled	0.22	0.22	0.22	0.22
Stream interaction	0.3	-0.5	-0.5	3.3
Recharge	7.8	7.1	3.7	15.5
Net storage change	-0.95	-1.48	-8.83	13.12
Change from scenario	+20.83%	+12.94%	+1.88%	+1.71%

3. Social Science Factors and Its Interaction with Natural Science Factors

This section discusses policy frameworks and institutional arrangements set by SGMA. Potential social challenges facing GSAs/GSPs and how social factors interact with natural factors under the current policy framework are the major focus of this section.

3.1 GSA Formation and the Implementation of Groundwater Management Plans (GSPs)

California SGMA gives local agencies high discretions in managing local groundwater basins. Nelson & Perrone (2016) describes this degree of discretion as “unprecedented” in the south-west after comparing California GSAs’ role in managing “special permitting areas” (areas that are analogous to high and/or medium-priority groundwater basins in California) to six other southwest states. But high discretion level is always a double-edged sword:

First, GSA formation is voluntary -- any local public agencies with authority to manage groundwater in their basins could apply to be GSA. Perhaps not surprisingly, most GSA applicants listed in GSA formation table (31) when this report is finished are pre-existing agencies such as water districts, irrigation districts and counties. On the one hand, most pre-existing agencies have complete organization structures, which provides an efficiency bonus in forming GSA when the time window for GSA formation is short (the deadline is 2017). On the other hand, pre-existing agencies typically represent only a few stakeholder groups (e.g. a irrigation districts mostly represents farmers’ interests), but more stakeholder groups’ interests need to be expressed in each GSA to achieve sustainable management. State step-in is needed to ensure fairness of GSA management if

stakeholder participation balance is not shown in GSA formation notices (32). Stakeholder groups represented should include but not limited to those listed in Table 3. A problematic common trend found in GSA formation notifications is that environmental stewardships are not properly represented in many GSAs, probably because they have less power compared to other stakeholders and environmental benefits are always considered less directly linked to economic gains. But environmental problems like nitrate pollution and river flow rate drop will finally lead to diseases and fishing revenue loss in the long run, as described in the earlier sections. The state government should be forward looking and step-in to make GSAs fix this loophole.

Table 3: Stakeholder Groups and Their Major Concerns

Stakeholder Groups	Major Concerns
Agriculture	Decreasing water level Balance municipal and irrigation water supply
Municipal/Public/Domestic	Water quality; water level
Environmental Stewardship	Watershed quality & ecology Environmental Awareness
Local Authority	Balancing economic growth (need water) and water quality
Disadvantaged Communities	Affordability of water under more stringent water regulation

Second, GSAs could enact GSPs based on local conditions. Besides, they are also granted additional powers to change current water right schemes (e.g. suspending/limiting certain groundwater wells’ extractions or establishing new extraction allocation) (30) inside their borders given that it is necessary to achieve the goal of sustainable groundwater management (CWC s10726.4 (1)-(3)). However, the SGMA provides no direction and regulation on what kind of power should be exercised under different situations -- they are all left to the GSAs’ own choice. Whether or not a GSA could successfully exercise the additional powers to achieve sustainable groundwater management is likely to depend on how well the GSA represents different stakeholder groups’ interests and how well the communications among stakeholder groups goes on. If many stakeholder groups’ interest could not be expressed, those who are prevented from making serious proposals for changes may simply begin to cheat whenever they have the opportunity. Once cheating on rules becomes more frequent for some groups, others follow suit -- enforcement costs become very high or the system fails (33).

Another important aspect in local groundwater self-management is to have groundwater resource efficiently monitored and apply graduated sanctions to those who violate the rules agreed by GSA stakeholder groups (33). For one thing, monitoring water use by individuals helps the enforcement of GSP policies. For another, collection of high-quality groundwater data is also important in making good GSPs. For example, a highly recommended policy to reduce water use in the most costless way, from economists’ point of view, is to form a “cap-and-trade” groundwater market inside each GSA (34). The idea is to place an annual water use cap to each water user and allow them to trade groundwater with each other as long as their water use do not exceed their caps. As water users have more options to meet water use reduction goal set by the cap, the cap-and-trade program has the least social cost of water use reduction. However, unlike other resource regulated by cap-and-trade program, groundwater storage, recharge rate and interaction of groundwater with surface water is spatially heterogeneous. A good knowledge on these information is needed to design a better groundwater trading market. For example, the design of Nebraska groundwater trading market takes the effect of groundwater use on surface water at the selling and purchasing locations into consideration to discourage groundwater selling at points where the influence of groundwater extraction on surface water level drop is

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high (35). Complicated groundwater trade market designs like the one in Nebraska have to be built on a precise data collection of the whole aquifer and engineering efforts on water balance calculation.

3.2 Information Collection and Water Use Monitoring under SGMA

Unfortunately, the state has done a bad job in water use information collection before SGMA was signed into law in 2014: (a) Unlike most western states, individual water users (e.g. farmers and domestic water users) do not need to meter and report their water extraction to any agencies; (b) Irrigation well completion logs are collected by California Department of Water Resource, but are kept secret to the general public, and (c) Municipal water suppliers have the information on their clients' water use but the information are kept confidential to public.

A direct consequence of these bad practices is that no one has an accurate knowledge on the current capacity of the state's underlying aquifer (36). One of the reasons to implement SGMA is to facilitate the collection of groundwater related data to help making useful policies. Under SGMA, although again GSAs could choose whether to mandate water use metering and reporting in their GSP at their own discretions, a better practice is to exercise this power for the sake of pursuing a long-term stable groundwater management discussed in the last section.

However, even though GSAs mandate water use reporting, that information is still kept confidential to the public under the general SGMA policy due to the high pressure from farmers and private pumpers. If this pressure could be overcome locally (which is easier due to the smaller scales of local GSAs) and water use data could be publicly available, peer monitoring will make GSA regulations more transparent, making GSPs more reliable (37).

3.3 Social Barriers of Implementing Advanced Water Use Technologies

As discussed in the environment engineering section, advanced water use technologies such as high-tech wastewater treatment and more efficient irrigation systems have the potential to substantially reduce groundwater depletion rate. The engineering calculation assumes that the social system stays constant (i.e. total water demand stays constant) before and after the adoption of the technologies, which is unlikely to happen in the real world -- individuals will also adjust behaviors in response to technology changes. Three major social barriers of implementing these advanced technologies are identified: (a) water saving and water use efficiency increase could also mean more water at hand -- farmers are very likely to grow more water reliance crops that give them more profit or expand their farm acres. These actions will definitely increase water extraction for irrigation and thus counter the effect of water saving via advanced technologies -- proper institutional arrangements should be employed to help efficient irrigation technologies achieve water reduction; (b) Adopting more advanced wastewater treatment plants may require more land be allocated to the plant. However, in places like California, land rent might be very high. Without government subsidies, few people might want to invest in the plant; and (c) People might be reluctant to drink potable water that is produced by wastewater treatment.

3.4 Overlapping Regulations

Although GSAs are given great local discretions in groundwater management, some exceptions exist. SGMA is not the only groundwater management law in California. GSAs also have to comply to other laws like California Environmental Quality Act, water rights law, and local land use policies (32). GSAs might need to collaborate with the executing agencies of the various laws to come up with a sustainable management

plan.

4. Implications for Michigan

Examining the state of groundwater and SGMA in California raises several questions about the status of groundwater management in the state of Michigan. Should Michigan adopt such a policy? What is the current state of data on climate, management, and collaboration? At first glance, it seems that the cases of Michigan and California are quite different. As opposed to much of California, Michigan has abundant water resources, most notably the Great Lakes, the largest surface freshwater system on the planet (38). Underneath these lakes is the Great Lakes Basin, which stores a large amount of groundwater (39). Groundwater is an important resource in Michigan as 43% of its residents rely on it for drinking water, as well as much of the state's agricultural economy (39). As such, there is a need for sound groundwater management and data collection in order to protect this important resource.

A recognition of this led the Michigan legislature to pass Public Act 148 in 2003, which mandated the creation of a publically available groundwater inventory and maps that display this data (40). This initiative between the state's Department of Environmental Quality, the U.S. Geological Survey, and Michigan State University provided a comprehensive look at the status of the state's groundwater. Data demonstrate that some portions of the state have experienced groundwater overdraft in excess of 15 feet. Groundwater contamination from nitrates and other hazardous compounds has also been identified as a problem. These data demonstrate that while water is easy to take for granted in Michigan, groundwater resources are still threatened. However, Public Act 148 has since expired and the availability of recent and reliable data is limited. Therefore, there is still a need for large-scale and consistent data collection to protect this resource. It should also be noted that the Great Lakes Basin is a large groundwater system that extends into multiple states. Thus, stakeholders from other states need to be considered in attempts of collaborative management.

In conclusion, the nation is watching SGMA and whether it will be effective in improving groundwater management in California. If improvements are realized, then it is to be expected that other states may adopt similar policies, including Michigan where water resources are taken for granted but nonetheless, threatened.



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