# University of Wisconsin Water Resources Institute
# Annual Technical Report
# FY 2016

# Introduction

The University of Wisconsin Water Resources Institute (WRI) serves as the gateway to federal Water Resources Research Institute (WRRI) grants for all Wisconsin colleges and universities. While the WRI's federal base funding from the U.S. Geological Survey totals less than $100,000 per year, every federal dollar is matched with at least two nonfederal dollars. All WRRI grants are awarded on a competitive, peer-reviewed basis. WRI funds are leveraged with additional funding from the UW System Groundwater Research Program, part of Wisconsin's Groundwater Research and Monitoring Program. Faculty members and research staff who have achieved PI status from any UW System campus are eligible to apply for this funding. Guided by the Wisconsin Groundwater Coordinating Council (http://dnr.wi.gov/topic/groundwater/gcc/), this program is the mechanism whereby the UW System and the state departments of Natural Resources, Safety & Professional Services, and Agriculture, Trade & Consumer Protection pool limited state and federal resources to support a coordinated, comprehensive and multidisciplinary response to the state's critical water resource issues. Together, these programs have helped establish the University of Wisconsin as a national leader in groundwater research. The Wisconsin WRI funds an average of 15 short-term research projects of either a fundamental or applied nature that typically involve dozens of faculty, staff and students at a half-dozen campuses around the state each year. By supporting short-term projects, the institute is able to quickly respond to issues as they emerge. WRI annually provides about 30 graduate and undergraduate students in the UW System with opportunities for training and financial support while they work toward their degrees.

WRI research and other water-related information is readily accessible via a website (www.wri.wisc.edu) and the Water Resources Library (WRL), a nationally unique collection of documents covering every major water resource topic. The library's catalog is available online and searchable via the Internet, making the WRL a national and global resource. The WRL became the first academic library in the state to make its collection available online to the public when it launched the "Wisconsin Water Library" (www.aqua.wisc.edu/waterlibrary) in 2003. The portal permits Wisconsin residents to check out WRL books and other documents free of charge via their local libraries.

WRI also helps organize and cosponsor state and regional conferences on water issues. The WRI is housed in the UW-Madison Aquatic Sciences Center, which also houses the UW Sea Grant Institute, part of another federal-state partnership of 33 university programs that promote research, education, and outreach on Great Lakes and ocean resources. This unique administrative union of Wisconsin's federal Water Resources Research Institute and Sea Grant programs enables the Aquatic Sciences Center to address the full range of water-related issues in Wisconsin, from surface water to groundwater, from the Mississippi River to the shores of Lakes Michigan and Superior.

# Research Program Introduction

As established by Wisconsin's Groundwater Law of 1984, the state provides $270,000 annually to the UW System to support groundwater research and monitoring. In 1989, WRI became the UW System's lead institution for coordinating the proposal solicitation and review processes for prioritizing UWS groundwater project funding. WRI's priorities for groundwater research are established annually by the Wisconsin Groundwater Research Advisory Council (GRAC) made up of representatives from academia, federal and state agencies, and the private sector. The GRAC convenes annually to set priorities and to review and make recommendations to WRI on the selection of UW System-funded groundwater projects.

Also established in 1984, is the Wisconsin Groundwater Coordinating Council (GCC) (http://dnr.wi.gov/topic/groundwater/gcc/) which is made up of representatives of state agencies with groundwater protection responsibilities and state funding allocations, including the UW System and departments of Natural Resources, Safety & Professional Services, and Agriculture, Trade, & Consumer Protection. The GCC provides consistency and coordination among multiple state programs in funding groundwater monitoring and research to meet various program needs. To better target groundwater research funding, these state programs agreed to establish an annual Joint Solicitation for Wisconsin Groundwater Research and Monitoring. This solicitation is coordinated jointly to facilitate proposal writing, streamline the review process, curtail duplication, improve coordination among agencies and researchers, and enhance communication among the agencies and among principal investigators. WRI plays a lead role in coordinating the solicitation, a rigorous review process, project reporting and making all technical reports available through our institute's library and website. Collectively, since its inception and through state FY17 (July 1, 2016-June 30, 2017), this annual joint solicitation has funded 455 groundwater research and monitoring projects and has helped establish Wisconsin as an international leader in groundwater research. During state FY17, 14 groundwater projects totaling over $579k were funded through the Wisconsin Groundwater Research and Monitoring Program.

Although these projects are not funded with our 104(B) allocation, WRI is the administrator of the following UW System state-funded research projects. Below, we include these and other non-UW System state-funded projects that were submitted, vetted, and selected through the Joint Solicitation for the Wisconsin Groundwater Research and Monitoring Program:

State-funded projects through the Wisconsin Groundwater Research and Monitoring Program during state FY 2017 (July 1, 2016-June 30, 2016), including title, investigators, affiliation, contract period, funding agency, and amount:

Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping. Jean Bahr, Madeline Gotkowitz, UW-Madison and UW-Extension. 7/1/15-6/30/17. University of Wisconsin System. $19,088.

Phosphorus & Arsenic Sensors for Real Time Environmental Monitoring. Daniel Noguera, Marc Anderson, UW-Madison. 7/1/15-6/30/17. University of Wisconsin System. $48,674.

Engaging Stakeholders to Improve the Use of Groundwater Flow Models for Decision Making. Kenneth Genskow, Kenneth Bradbury. UW-Madison and UW-Extension. 7/1/15-6/30/16. University of Wisconsin System. $ 34,406.

Predicting the locations of nitrate removal hotspots at the groundwater-surface water interface in Wisconsin streams. Robert Stelzer, UW-Oshkosh. 7/1/15-6/30/17. University of Wisconsin System. $16,783.

Anthropogenically driven changes to the metagenome of a shallow groundwater and its effect on aquifer reactivity. Tim Grundl, Ryan Newton, UW Milwaukee. 7/1/16 6/30/18. University of Wisconsin System. $59,696.

Investigating the impact of nitrate nitrogen contamination on uranium concentrations in Wisconsin groundwater. Amy Nitka, Paul McGinley, UW Stevens Point. 7/1/16 6/30/17. University of Wisconsin System. $28,773.

Geologic sources of radium to municipal wells in Wisconsin. Matthew Ginder Vogel, Madeline Gotkowitz, UW Madison. 7/1/16 6/30/18. University of Wisconsin System. $54,989.

Describing connected fracture flow with pressure waves oscillating flow interference testing. Michael Cardiff, UW-Madison. 7/1/15-6/30/17. Wisconsin Department of Natural Resources. $23,675.

Characterizing the timing and variability of enteric pathogen contamination within the dolomite aquifer in northeastern WI. Maureen Muldoon, UW-Oshkosh and Mark Borchardt, USDA/USGS. 7/1/16 6/30/17. Wisconsin Department of Natural Resources. $45,059.

Linking groundwater and climate to understand long term lake level fluctuations in Wisconsin. Noah Lottig, UW Madison. 7/1/16 6/30/18. Wisconsin Department of Natural Resources. $53,562.

Field verification of adenovirus assays for source tracking. Sharon Long, UW Madison. 7/1/16 6/30/17. Wisconsin Department of Natural Resources. $67,994.

Evaluating the effects of septic system density on groundwater quality in Southeastern Wisconsin. James A. LaGro, UW Madison. 7/1/16 6/30/17. Wisconsin Department of Natural Resources. $46,626.

Monitoring support for groundwater management in the Wisconsin Central Sands. George Kraft, UW Stevens Point. 7/1/16 6/30/17. Wisconsin Department of Natural Resources. $61,607.

Source investigation of nitrate contamination for private wells in Eau Claire County. Laura Suppes, UW Eau Claire. 7/1/16 6/30/18. Wisconsin Department of Natural Resources. $18,522.

TOTAL - $579,454

Beginning in 2010, WRI's annual 104(B) allocation was used to expand the scope of the Joint Solicitation to include research on the effects of climate change on Wisconsin's water resources. Priorities for climate change research were established through a partnership between the WRI and the Wisconsin Initiative on Climate Change Impacts (WICCI). Established in 2007, WICCI is a university-state partnership created to: (a) assess and anticipate the effects of climate change on specific Wisconsin natural resources, ecosystems and regions; (b) evaluate potential effects on industry, agriculture, tourism and other human activities; and (c) develop and recommend adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders. We believe these partnerships with other state agencies provides WRI with the ability to fund highly relevant research and allows our limited funds for 104(B) to be leveraged to the fullest extent. WRI has funded five research projects related to these priorities since 2010. WRI is now sponsoring WICCI's phase 2 with the goal of advancing climate adaptation projects related to water resources challenges in Wisconsin.

# Evaluating the Effectiveness of Surface Covers for Controlling Fluxes of Water and Radon at Disposal Facilities for Uranium Mill Tailings

## Basic Information

| | |
|---|---|
| **Title:** | Evaluating the Effectiveness of Surface Covers for Controlling Fluxes of Water and Radon at Disposal Facilities for Uranium Mill Tailings |
| **Project Number:** | 2015WI359S |
| **USGS Grant Number:** | |
| **Sponsoring Agency:** | Nuclear Regulatory Commission |
| **Start Date:** | 1/27/2015 |
| **End Date:** | 11/16/2017 |
| **Funding Source:** | 104S |
| **Congressional District:** | |
| **Research Category:** | Not Applicable |
| **Focus Categories:** | None, None, None |
| **Descriptors:** | None |
| **Principal Investigators:** | Craig H Benson |

## Publications

There are no publications.

# Evaluating the Effectiveness of Surface Covers for Controlling Fluxes of Water and Radon at Disposal Facilities for Uranium Mill Tailings

**Reporting Period:** 3/1/2016 - 2/28/2017

**Project**
WR15R008 - Evaluating the Effectiveness of Surface Covers for Controlling Fluxes of Water and Radon at Disposal Facilities for Uranium Mill Tailings

**Principle Findings and Significance**
Project Objectives: This study is evaluating the effects of soil structure formation on the hydraulic conductivity and gaseous diffusivity of Rn barriers, how structural development varies with depth and thickness of the Rn barrier, and how structure influences transmission of radon and seepage carrying ground water contaminants.

Activities and Findings during Reporting Period:

1) Field Investigation: Field work was conducted at two UMTRCA surface barriers under surveillance by Department of Energy Legacy Management (LM): the Falls City, Texas site (primary field work conducted April 23, 2017 – April 30, 2017) and the Bluewater, New Mexico site (primary field work conducted June 19, 2007 – June 25, 2017). Goals of the field work were to (1) characterize the morphology of disposal cell cover soils to understand the natural processes that are changing engineering properties and to project the degree of change over decades and millennia, (2) measure the effects of soil-forming processes on gas diffusivity and soil hydraulic properties, (3) determine how changes in engineering properties vary with soil depth in cover profiles, and (4) measure and model how these changes influence radon flux rates and rainwater percolation. Field activities at the Falls City and Bluewater sites included soil sampling and installation of instrumentation to measure radon flux and at six (Falls City) and nine (Bluewater) tests pit locations. Most tests pits were paired with a corresponding control test pit selected to isolate potential influences of site-specific variables on measured radon flux and material properties (e.g., ponded location vs. location without ponding, vegetated location vs. non-vegetated location, high activity vs. low activity) Radon flux at each test pit was measured using flux chambers and electronic RAD7 devices to obtain radon buildup curves at the top surface of the radon barrier. Flux chambers with four different cross-sectional areas were installed to assess potential scaling effects associated with soil structure. At the Bluewater site, replicate measurements were obtained with each chamber to evaluate measurement repeatability. Additional radon flux measurements were obtained at the approximate contact between the top surface of the tailings and the radon barrier.

Sampling at the test pits included at least one large-diameter block samples of radon barrier material and at least two thin-walled Shelby tube samples of the radon barrier material. Continuous (stacked) block samples of radon barrier material were collected at test pit locations characterized by relatively a thick barrier to assess depth-dependent changes in soil properties. The block and tube samples are being evaluated in the laboratory for water retention characteristic curves, saturated hydraulic conductivity, radon diffusion coefficient, grain size, plasticity, and

in-situ water content profiles at the time of sampling. Two additional sites were selected for field work (Summer 2017) as part of ongoing efforts.

2) Laboratory Characterization: Laboratory test were conducted on soil materials sampled from the field site visits to characterize their in-service engineering properties. Measurements included grain size distribution, water content, Atterberg limits, saturated hydraulic conductivity, water retention curves, and radon diffusion coefficient.

3) Laboratory Diffusion Apparatus: A laboratory apparatus was developed for measuring effective radon diffusion coefficients of radon barrier materials. The apparatus will be used to quantify the effects of soil structure development on gaseous radon diffusion coefficient for materials sampled from LM field sites and laboratory-prepared samples subjected to various weathering mechanisms. Preliminary tests were conducted using six clays with varying plasticity compacted at moisture and density conditions representing initial placement conditions typical of radon barriers.

**Number of Personnel Involved**

3 Participating faculty/staff

0 Supported post-docs

**Students Supported**

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**Name**

Nick Stefani

**Affiliation**

University of Wisconsin-Madison

**Degree**

BA/BS

**Major/Specialization**

Geological Engineering

**Graduation**

8/2016

**Thesis Title**

Field and laboratory measurement of radon flux and diffusion for uranium mill tailings cover systems

**Job Placement**

Consulting

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**Name**

Alex Michaud

**Affiliation**

University of Wisconsin-Madison

**Degree**

BA/BS

**Major/Specialization**
Geological Engineering

**Graduation**
5/2018

## Conference Participation

**Title**
GeoChicago 2016: Sustainability, Energy, and the Geoenvironment

**Location**
Chicago IL

**Dates**
August 2016

**Number of supported students attending**
1

**Presentations by Students**
Stefani, N., Likos, W.J., and Benson, C.H., 2016, “Evaluation of two methods for measuring radon flux from earthen radon barriers,” Proc. GeoChicago 2016: Sustainability, Energy, and the Geoenvironment, Chicago, IL.

**Title**
Waste Management WM2017 Conference

**Location**
Phoenix AZ

**Dates**
March 5-9, 2017

**Presentations by Staff**
Benson, C.H., Albright, W.H., Fuhrman, M., Likos, W.J., Stefani, N., Tian, K., Waugh, W.J., Williams, M.M., 2017, "Radon fluxes from an earthen barrier over uranium mill tailings after two decades of service,” Proc. WM2017 Conference

## Journal Articles and Other Publications

**Title**
Pedogenic Process in Engineered Soil Systems: I. Emergence of Pedoturbation Induced Hydraulic Conductivity Gradients

**Type of Publication**
Book or Monograph (Peer-reviewed)

**Complete Citation**

Williams, M., Albright, W., Benson, C.H., Fuhrmann, M., Larsen, L., Likos, W., Waugh, J., "Pedogenic Process in Engineered Soil Systems: I. Emergence of Pedoturbation Induced Hydraulic Conductivity Gradients," Vadose Zone Journal, in review

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**Title**

Radon fluxes from an earthen barrier over uranium mill tailings after two decades of service

**Type of Publication**

Map or Chart (Peer-reviewed)

**Complete Citation**

Benson, C.H., Albright, W.H., Fuhrman, M., Likos, W.J., Stefani, N., Tian, K., Waugh, W.J., Williams, M.M., 2017, "Radon fluxes from an earthen barrier over uranium mill tailings after two decades of service," Proc. WM2017 Conference, March 5-9, 2019, Phoenix, Arizona, USA

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**Title**

Evaluation of two methods for measuring radon flux from earthen radon barriers

**Type of Publication**

Map or Chart (Peer-reviewed)

**Complete Citation**

Stefani, N., Likos, W.J., and Benson, C.H., 2016, “Evaluation of two methods for measuring radon flux from earthen radon barriers,” Proc. GeoChicago 2016: Sustainability, Energy, and the Geoenvironment, Chicago, IL.

## Awards and Achievements

No awards and achievements reported.

## Research Patent or Copyright

No research patents or copyrights reported.

# Application of Mercury Isotopes to Inform Ecosystem Restoration in the Great Lakes Region

## Basic Information

| | |
|---|---|
| **Title:** | Application of Mercury Isotopes to Inform Ecosystem Restoration in the Great Lakes Region |
| **Project Number:** | 2015WI360S |
| **USGS Grant Number:** | |
| **Sponsoring Agency:** | U.S. Geological Survey |
| **Start Date:** | 7/10/2015 |
| **End Date:** | 2/28/2017 |
| **Funding Source:** | 104S |
| **Congressional District:** | |
| **Research Category:** | Not Applicable |
| **Focus Categories:** | None, None, None |
| **Descriptors:** | None |
| **Principal Investigators:** | James Hurley |

## Publications


1. Grasby, S.E., W. Shen, R. Yin, J.D. Gleason, J.D. Blum, R.F. Lepak, J.P Hurley and B. Beauchamp. 2016. Isotopic signatures of mercury contamination in latest Permian oceans. Geology G38487.1
2. Yin R., D.P. Krabbenhoft, B.A. Bergquist, W. Zheng, R.F. Lepak and J.P. Hurley. 2016. Effects of Mercury and Thallium Concentrations on High Precision Determination of Mercury Isotope Composition by Neptune Plus Multiple Collector Inductively Coupled Plasma Mass Spectrometry. Journal of Analytical Atomic Spectrometry, DOI: 10.1039/C6JA00107F
3. Yin R., X. Feng, J.P. Hurley, D.P. Krabbenhoft, R.F. Lepak, S. Kang, H. Yang and X. Li. 2016. Historical Records of Mercury Stable Isotopes in Sediments of Tibetan Lakes. Scientific Reports. 6:23332.
4. Yin R., X. Feng, J.P. Hurley, D.P. Krabbenhoft, R.F. Lepak, R.Z. Hu, Q. Zhang, Z.G. Li, and X.W. Bi. 2016. Mercury Isotopes as Proxies to Identify Sources and Environmental Impacts of Mercury in Sphalerites. Scientific Reports. 6:18686
5. Yin R., R.F. Lepak, D.P. Krabbenhoft and J.P. Hurley. 2016. Sedimentary Records of Mercury Stable Isotopes in Lake Michigan. Elementa: Science of the Anthropocene 4.1: 000086.
6. Yin, R., C. Gu, X. Feng, J.P. Hurley, D.P. Krabbenhoft, R.F. Lepak, W. Zhu, L. Zheng, and T. Hu. 2016. Distribution and Geochemical Speciation of Soil Mercury in Wanshan Hg Mine: Effects of Cultivation. Geoderma. 272:32-38.

# Application of Mercury Isotopes to Inform Ecosystem Restoration in the Great Lakes Region

**Reporting Period:** 3/1/2016 - 2/28/2017

**Project**
WR15R011 - Application of Mercury Isotopes to Inform Ecosystem Restoration in the Great Lakes Region

**Principle Findings and Significance**
Our results initial results were focused mainly on the Fox River, Wisconsin for the first phase of the study. Results indicated relative to baseline, enhanced Hg sediment deposition began in the 1890s in Green Bay and was evident in the early 1800's in offshore Lake Michigan. Isotopic signatures allowed for the utilization of a binary mixing model reliant on HgT concentration and δ202Hg values (Yin et al. 2016). Model output confirmed that the contamination evident in Green Bay is most likely due to local sources that are mainly constrained to Green Bay whereas offshore elevations in HgT concentrations are more likely the result of increased Hg in the global pool. This study also showed an increase in odd isotope mass independent fractionation (MIF) from within Green Bay to offshore Lake Michigan. Greater positive odd MIF is likely indicative of both enhanced photoreduction in offshore regions as well as proportionally more atmospherically-derived Hg and proportionally less watershed-derived Hg in the offshore region. This is consistent with data from our comparative Great Lakes sediment study (Lepak et al. 2015).

A preliminary food web investigation of the Fox River was also conducted. For the study, baitfish (Emerald Shiner and Gizzard Shad), benthivores (Redhorse Sucker), and piscivorous fish (Walleye and Smallmouth Bass) were electroshocked in three locations along the Fox River: below the Little Rapids Dam, below the De Pere Dam and just outside the harbor walls in Green Bay. Isotopic Hg signatures in fish of these regions were compared to surface sediment from a nearby site in Green Bay to help determine whether Hg found in the food web resembled legacy Hg in Green Bay. As fish contain primarily methylmercury, sediment Hg speciation is typically dominated by inorganic Hg. The processes that convert a portion of an Hg pool from inorganic to the methylmercury found in fish (methylation, demethylation, photochemical reduction and photochemical demethylation) are highly complex and may result in Hg fractionation, mass-dependent and mass-independent, prior to organism uptake. For this reason, Hg isotope signatures found in biota may not be directly comparable to the legacy Hg found in the sediment.

We have also compared Hg isotopic composition of lake trout for the five Great Lakes related to this project. Previously, by measuring stable isotopes of Hg (δ202Hg, Δ199Hg, and Δ200Hg) in sediments across the Laurentian Great Lakes, we were able estimate source contributions of Hg. We identified isotopically distinct Hg signatures for Great Lake top predators. These fish represent some of the highest odd-mass independent fractionation (MIF) values in literature to date and span a large range (2.27 - 6.73‰). Temporal variability and inner-lake basin specific signatures were not evident with the exception of Lake Erie. Concentrations of MeHg in predator fish do not correlate with isotopic Hg signatures or sedimentary HgT concentrations. The large odd-MIF range is explainable by euphotic depth (2-43m), where Hg is most likely incorporated into the food web. Fish even-MIF, a potential binary tracer for precipitation, appears disconnected from local sedimentary sources and comparable in magnitude across the Great Lakes. Comparing isotopic Hg signatures in sediment and MeHg in fish we infer MeHg

bioaccumulated into fish tissue reflects precipitation more so than local sediments and conclude the degree of photochemical processing of Hg at the entry point into the food web is largely responsible for the observed odd-MIF.

**Number of Personnel Involved**

1 Participating faculty/staff

1 Supported post-docs

**Students Supported**

**Name**

Ryan Lepak

**Affiliation**

University of Wisconsin-Madison

**Degree**

PhD/DSci

**Major/Specialization**

Environmental Chemistry and Technology

**Graduation**

12/2018

**Conference Participation**

**Title**

International Association for Great Lakes Research 59th ANNUAL CONFERENCE ON GREAT LAKES RESEARCH

**Location**

University of Guelph

**Dates**

June 6-10, 2016

**Number of supported students attending**

1

**Presentations by Staff**

none

**Presentations by Students**

R.L. Lepak, D.P. Krabbenhoft and J.P Hurley. Utilizing Hg Stable Isotope Ratios to More Fully Resolve Hg Processes an Sources in the Great Lakes

## Journal Articles and Other Publications

**Title**
Isotopic signatures of mercury contamination in latest Permian oceans.

**Type of Publication**
Book or Monograph (Peer-reviewed)

**Complete Citation**
Grasby, S.E., W. Shen, R. Yin, J.D. Gleason, J.D. Blum, R.F. Lepak, J.P Hurley and B. Beauchamp. 2016. Isotopic signatures of mercury contamination in latest Permian oceans. Geology G38487.1

**Title**
Effects of Mercury and Thallium Concentrations on High Precision Determination of Mercury Isotope Composition by Neptune Plus Multiple Collector Inductively Coupled Plasma Mass Spectrometry.

**Type of Publication**
Book or Monograph (Peer-reviewed)

**Complete Citation**
Yin R., D.P. Krabbenhoft, B.A. Bergquist, W. Zheng, R.F. Lepak and J.P. Hurley. 2016. Effects of Mercury and Thallium Concentrations on High Precision Determination of Mercury Isotope Composition by Neptune Plus Multiple Collector Inductively Coupled Plasma Mass Spectrometry. Journal of Analytical Atomic Spectrometry, DOI: 10.1039/C6JA00107F

**Title**
Historical Records of Mercury Stable Isotopes in Sediments of Tibetan Lakes.

**Type of Publication**
Book or Monograph (Peer-reviewed)

**Complete Citation**
Yin R., X. Feng, J.P. Hurley, D.P. Krabbenhoft, R.F. Lepak, S. Kang, H. Yang and X. Li. 2016. Historical Records of Mercury Stable Isotopes in Sediments of Tibetan Lakes. Scientific Reports. 6:23332.

**Title**
Mercury Isotopes as Proxies to Identify Sources and Environmental Impacts of Mercury in Sphalerites

**Type of Publication**
Book or Monograph (Peer-reviewed)

**Complete Citation**
Yin R., X. Feng, J.P. Hurley, D.P. Krabbenhoft, R.F. Lepak, R.Z. Hu, Q. Zhang, Z.G. Li, and X.W. Bi. 2016. Mercury Isotopes as Proxies to Identify Sources and Environmental Impacts of Mercury in Sphalerites. Scientific Reports. 6:18686

**Title**

Sedimentary Records of Mercury Stable Isotopes in Lake Michigan

**Type of Publication**
Book or Monograph (Peer-reviewed)

**Complete Citation**
Yin R., R.F. Lepak, D.P. Krabbenhoft and J.P. Hurley. 2016. Sedimentary Records of Mercury Stable Isotopes in Lake Michigan. Elementa: Science of the Anthropocene 4.1: 000086.

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**Title**
Distribution and Geochemical Speciation of Soil Mercury in Wanshan Hg Mine: Effects of Cultivation.

**Complete Citation**
Yin, R., C. Gu, X. Feng, J.P. Hurley, D.P. Krabbenhoft, R.F. Lepak, W. Zhu, L. Zheng, and T. Hu. 2016. Distribution and Geochemical Speciation of Soil Mercury in Wanshan Hg Mine: Effects of Cultivation. Geoderma. 272:32-38.

## Awards and Achievements

No awards and achievements reported.

## Research Patent or Copyright

No research patents or copyrights reported.

## Completion Summary

Our sedimentary work from cores in Green Bay and offshore Lake Michigan allowed for comparison of a contaminated site with an offshore site that integrated three types of input (atmospheric, industrial, watershed). Historical trends of total Hg (THg) concentrations, influxes and influx ratios show that Hg contamination is evident since the 1890s in Green Bay, whereas Hg pollution in the offshore of LM began about the early 1800s. Contaminated sediments in all cores show similar δ202Hg values (-1.0 to -0.5‰), comparable to isotopic signatures of Hg from anthropogenic sources. Deep core sediments show much lower δ202Hg values (-1.7 to -1.2‰), which may represent the geochemical background Hg source. Using a simple binary mixing model based on δ202Hg signatures, the relative impact of anthropogenic Hg contribution in each core was estimated. Model output confirms that Green Bay is more contaminated by anthropogenic Hg than the offshore of LM. Interestingly, a dramatic increase in positive Δ199Hg values (-0.02 to +0.27‰) with Δ199Hg: Δ201Hg of ~1 was observed from inner Green Bay to the offshore of LM, which may indicate increased input of atmospheric Hg and enhanced Hg(II) photo-reduction in the water column. Overall, this phase of the study suggested that sedimentary Hg isotopes can be a useful tracer in understanding Hg sources and history of Hg contamination in large lakes.

The work conducted on this project continues through other subsequent USGS grants, including graduate student Ryan Lepak's fellowship. We are currently hosting Dr. Chuanwei Zhu from the Chinese Academy of Sciences, who will continue to work with our group on sediments and biota studies. Our initial work on Great Lakes sediment through this project has led to multiple related exploratory projects in lakes and sedimentary deposits in China and Canada and Dr. Zhu will be able to continue with this collaborative work. We have also established connections with Dr. Daniel Engstrom from the University of Minnesota, who has provided sediment cores from his global sediment collection to further develop our models for sources apportionment.

All told, this project was extremely successful in that it led to six peer reviewed publications, including an Editor's Choice and open source designation for the publication (Lepak, R.F., R. Yin, R., D.P Krabbenhoft, J.M. Ogorek, J.F. DeWild, T.M. Holsen, and J.P. Hurley. 2015. Use of Stable Isotope Signatures to Determine Mercury Sources in the Great Lakes. Environmental Science and Technology Letters 2:335–341).

# Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping

## Basic Information

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|---|---|
| **Title:** | Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping |
| **Project Number:** | 2016WI349B |
| **Start Date:** | 3/1/2016 |
| **End Date:** | 2/28/2017 |
| **Funding Source:** | 104B |
| **Congressional District:** | 2 |
| **Research Category:** | Water Quality |
| **Focus Categories:** | Groundwater, Solute Transport, Water Quality |
| **Descriptors:** | None |
| **Principal Investigators:** | Jean Bahr, Madeline Beth Gotkowitz |

## Publications

There are no publications.

# Long Term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping

**Reporting Period:** 3/1/2016 - 2/28/2017

**Project**

WR15R002 - Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping

**Principle Findings and Significance**

During this project period, flow and particle tracking simulations were completed with an existing, regional groundwater flow model for Dane County, Wisconsin (Parsen et al, 2016). The simulations assess changes in groundwater flow directions within the unconfined and confined aquifers as well as changes in fluxes of water between the groundwater system and surface water bodies. Parsen et al. (2016) had estimate that, under pre-development conditions, streams in Dane County contributed approximately 4 million gallons per day to the groundwater system and received approximately 402 million gallons from the groundwater system, resulting in a net daily stream recharge of approximately 398 million gallons of groundwater. Under current conditions, daily net groundwater discharge to streams was reduced to roughly 355 million gallons. Lakes in the model area showed a similar trend. Building on those findings, we performed mass balance analysis focused on Lake Mendota, which indicate that it received 5.9 million gallons of groundwater per day and made no contribution to the groundwater system under pre-development conditions. This shifted under current conditions, with approximately 0.5 million gallons of lake water intruding into the groundwater system and groundwater contributions to Lake Mendota declining to approximately to 1.2 million gallons per day. Mass balance results also demonstrated that volumetric flow across the Eau Claire aquitard is impacted by pumping practices. Increased downward flow, across the aquitard, was visible throughout Dane County in simulations under current conditions and was particularly noticeable along the Madison Isthmus. Under pre-development conditions, approximately 150 million gallons of groundwater per day flowed downward through the Eau Claire aquitard into the confined system in the model area. Under current conditions, approximately 174 million gallons of groundwater per day reach the confined system. Geochemical modeling, also completed during this project period, simulated the effects of mixing of water from different portions of the aquifer along with sorption and precipitation dissolution reactions, was used to identify controls on chromium, iron and manganese concentrations in water from multi-aquifer wells. While simulations involving mixing of shallow and deep groundwater alone suggest that observed chromium concentrations in some wells could be explained by this process, such mixing models do not do a good job of reproducing observed concentrations of iron and manganese. Models that include sorption and precipitation-dissolution reactions provide significantly better matches to observations. An important constraint on Cr(aq) values was adsorption to goethite, which removed more than 90% of mobilized chromium. In fact, when goethite was removed as a surface species, all added chromite was released into the groundwater system in the model simulations. This illustrates the critical role that naturally-occurring iron in the Mount Simon plays in preventing even higher Cr(aq) in the municipal water supply. Additionally, simulations showed that either oxygen or nitrate at the concentrations measured in the shallow aquifer were individually capable of facilitating the mobilization of chromium from the confined aquifer. Simulations showed Mn(aq) to be very responsive to changes in DO, particularly at low DO concentrations. Mn(aq) was slightly mobile under conditions measured for all tested DO values, with Mn(aq) increasing slightly with decreasing DO.

However, a significant increase in Mn(aq) mobilization occurred at a DO concentration of 0.014 mg/L. These results support the trend observed from sampling of port 5 of a multi-port monitoring well, located in the upper Mount Simon, that indicates manganese is highly mobilizable near the boundary between oxic and anoxic conditions.

Reference:

Parsen, M.J., K.R. Bradbury, R.J. Hunt, and D.T. Feinstein. 2016. The 2016 Groundwater Flow Model for Dane County, Wisconsin. Wisconsin Geological and Natural History Survey Bulletin 110 56.

**Number of Personnel Involved**

2 Participating faculty/staff

0 Supported post-docs

## Students Supported

**Name**

Joshua Olson

**Affiliation**

University of Wisconsin-Madison

**Degree**

MA/MS

**Major/Specialization**

Geoscience

**Graduation**

8/2017

**Thesis Title**

Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping

## Conference Participation

**Title**

Geological Society of America Annual Meeting

**Location**

Denver CO

**Dates**

Sept. 26-29 2016

**Number of supported students attending**

1

**Presentations by Students**

LONG-TERM ALTERATIONS IN GROUNDWATER CHEMISTRY INDUCED BY MUNICIPAL WELL PUMPING
OLSON, Joshua C., Geoscience, University of Wisconsin-Madison, Weeks Hall, 1215 W Dayton St, Madison, WI 53706, BAHR, Jean M., Department of Geoscience, University of Wisconsin-Madison, 1215 W. Dayton St, Madison, WI 53706 and GOTKOWITZ, Madeline B., Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, WI 53705, olsojc@gmail.com

**Journal Articles and Other Publications**

No journal articles and other publications reported.

**Awards and Achievements**

No awards and achievements reported.

**Research Patent or Copyright**

No research patents or copyrights reported.

**Completion Summary**

Objectives of this study were to explore the impacts of pumping on induced mixing of groundwater from shallow and deep aquifers and to identify geochemical processes resulting from such mixing. A variety of MODFLOW simulations, coupled to particle tracking with MODPATH, were performed that focused on determining the impact of municipal pumping and drawdown on groundwater flowpaths and mixing of water from different sources. PHREEQC was used to model the various geochemical scenarios caused by pumping, focusing on the mobilization of hexavalent chromium, manganese, and iron.

Results and Discussion:

The results of physical flow modeling, particle tracking and mass balance analyses indicate that the long-term, high capacity pumping occurring in Dane County affects the surface and groundwater systems. Groundwater flow has been rates redirected toward the pumping-induced cones of depression along the Isthmus. Downward migration of shallow, and presumably oxic, groundwater across the Eau Claire aquitard has increased throughout Dane County and is further enhanced at multi-aquifer wells. Gradient reversals have resulted in portions of Lake Mendota and Lake Monona (Bradbury et al., 2013) recharging the groundwater system rather than receiving groundwater discharge. These findings informed geochemical modeling that examined the possibility of mobilization of trace metals under varying pumping scenarios. Concentrations of hexavalent chromium measured in groundwater from multi-aquifer wells in the study area exceed those measured in confined aquifer wells (Personal communication from M.B. Gotkowitz, 2015). Conversely, manganese and iron values are higher in groundwater from confined aquifer wells with aqueous manganese concentrations highest near the boundary between oxic and anoxic conditions and iron most prevalent under completely anoxic conditions. Geochemical model simulations indicate that while chromium mobilization may be occurring in the confined system, aqueous chromium concentrations are limited by the sorption potential of iron in the Mount Simon formation. Additionally, whether the chromium is adsorbed onto the surface of sand grains or, instead, bound within the mineral structure may impact mobilization and release rates in the confined Mount Simon aquifer. Cumulatively, these findings suggest that in this hydrogeologic setting, well construction, pumping practices, and alterations to redox conditions could affect the mobility of hexavalent chromium, manganese, and iron.

Conclusions/Implications/Recommendations:

Public water managers need strategies to address water quality impacts of long term pumping. Because iron mobilization is restricted to anoxic conditions, introducing oxygen to the confined system could result in a slight decline in iron concentrations over time. Manganese, however, is less predictable. Modeling indicates that aqueous manganese values are highest near the boundary between oxic and anoxic conditions, thus introduction of oxic water to the Mount Simon could alter water chemistry. For chromium mobilization, multi-aquifer wells and increased drawdown create concern, as they increase downward flow across the Eau Claire aquitard, oxygenating the confined system. Spatially balancing withdrawals more evenly across the county could reduce the largest cones of depression and potentially have a marginal benefit. However, based on current withdrawal rates, it is unlikely that drawdowns will reverse in the near future. Exposure to aqueous chromium though municipal water supply, currently at concentrations on the order of a few parts per billion at some wells, could be reduced by using only confined aquifer wells, thus limiting Cr(aq) inputs from wells completed in the upper aquifer. However, this would increase dependence on wells with elevated iron and manganese and would result in greater drawdown in the Mount Simon. Ultimately, there is no single aquifer management strategy that addresses all water quality concerns.

Reference:

Bradbury, K., Parsen, M., Feinstein, D., Hunt, R., 2013, A new groundwater flow model for Dane County, Wisconsin. AWRA Annual Meeting, Wisconsin.

University of Wisconsin Water Resources Institute

USGS 104(b) Research Projects

Project Completion Report

Project Number WR15R002

Period of Contract: March 1, 2016 – February 28, 2017

# Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping


| | |
|---|---|
| Principal Investigator: | Dr. Jean Bahr, Professor<br>University of Wisconsin – Madison,<br>Department of Geoscience |
| Co-Principal Investigator: | Dr. Madeline Gotkowitz, Hydrogeologist<br>Wisconsin and Geological History Survey,<br>UW Extension |
| Research Assistant: | Joshua Olson, M.S. Candidate<br>University of Wisconsin – Madison,<br>Department of Geoscience |

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PROJECT SUMMARY

Title: Long-term Alterations in Groundwater Chemistry Induced by Municipal Well Pumping

Project ID: WR15R002

Investigators:


| | |
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| Co-Principal Investigator: | Dr. Madeline Gotkowitz, Hydrogeologist<br>Wisconsin and Geological History Survey,<br>UW Extension |
| Research Assistant: | Joshua Olson, M.S. Candidate<br>University of Wisconsin – Madison,<br>Department of Geoscience |


Period of Contract: March 1, 2016 – February 28, 2017

Background:

Dane County, Wisconsin, hosts a number of high-capacity, multi-aquifer wells that were drilled through the regional Eau Claire aquitard and draw from both the confined and unconfined aquifers. These wells are excellent study sites in which to test hypotheses related to pumping-induced changes in redox conditions and mobilization of trace elements. Simulations with a recently revised county-scale flow model indicate that the presence of multi-aquifer wells and drawdown in the confined aquifer generated by decades of pumping have changed interactions between the confined and unconfined aquifers and between the surface and groundwater systems. Additionally, historical groundwater sampling of Madison Water Utility wells has revealed elevated hexavalent chromium, iron, and manganese in the groundwater from certain wells.

Objectives:

Objectives of this study were to further explore the impacts of pumping on induced mixing of groundwater from shallow and deep aquifers and to identify geochemical processes resulting from such mixing.

Methods:

A variety of MODFLOW simulations, coupled to particle tracking with MODPATH, were performed that focused on determining the impact of municipal pumping and drawdown on groundwater flowpaths and mixing of water from different sources. PHREEQC was used to model the various geochemical scenarios caused by pumping, focusing on the mobilization of hexavalent chromium, manganese, and iron.

Results and Discussion:

The results of physical flow modeling, particle tracking and mass balance analyses indicate that the long-term, high capacity pumping occurring in Dane County is impacting the surface and

groundwater systems. Groundwater flow rates are accelerated under current conditions and have been redirected toward the pumping-induced cones of depression along the Isthmus. Downward migration of oxic groundwater across the Eau Claire aquitard has increased throughout Dane County and is further enhanced at multi-aquifer wells. Groundwater contributions to surface waters are declining, and gradient reversals have resulted in portions of Lake Mendota and Lake Monona recharging the groundwater system rather than receiving groundwater discharge. These findings helped inform geochemical modeling that examined the possibility of mobilization of trace metals under varying pumping scenarios. Concentrations of hexavalent chromium measured in groundwater from multi-aquifer wells in the study area exceed those measured in confined aquifer wells. Conversely, manganese and iron values are higher in groundwater from confined aquifer wells with aqueous manganese concentrations highest near the boundary between oxic and anoxic conditions and iron most prevalent under completely anoxic conditions. Geochemical model simulations indicate that while chromium mobilization may be occurring in the confined system, aqueous chromium concentrations are limited by the sorption potential of iron in the Mount Simon formation. Additionally, whether the chromium is adsorbed onto the surface of sand grains or, instead, bound within the mineral structure may impact mobilization and release rates in the confined Mount Simon aquifer. Cumulatively, these findings suggest that in this hydrogeologic setting, pumping practices and alterations to redox conditions are impacting the mobility of hexavalent chromium, manganese, and iron.

Conclusions/Implications/Recommendations:

Public water managers need strategies to address water quality impacts of long term pumpin. Because iron mobilization is restricted to purely anoxic conditions, introducing oxygen to the confined system should result in a slight decline in iron concentrations over time. Manganese, however, is less predictable. Because aqueous manganese values are highest near the boundary between oxic and anoxic conditions, water managers will need to know when that boundary is approaching a high-$Mn_{(s)}$ portion of the Mount Simon. For chromium mobilization, multi-aquifer wells and increased drawdown create the greatest concerns, as they accelerate downward flow across the Eau Claire aquitard, oxygenating the confined system. Water managers in Dane County could try to spatially balance withdrawals more evenly across the county to reduce the worst cones of depression. This could potentially have a marginal benefit. However, based on current withdrawal rates, it is unlikely that drawdowns will reverse in the near future. Aqueous chromium concentrations in municipal water supplies could be significantly reduced by using only confined aquifer wells, limiting $Cr_{(aq)}$ inputs from the shallow aquifer and mobilization from the Mount Simon at multi-aquifer wells, but this would likely make iron and manganese issues more prevalent and lead to even greater drawdown in the Mount Simon. Ultimately, there is no single solution that addresses all the concerns, so operating cost or water quality concessions will likely need to be made in the future.

Keywords: multi-aquifer wells, municipal pumping, chromium, manganese, iron, trace metal mobilization, gradient reversal

Related Publications: This work is the subject of a M.S. thesis in Geoscience that will be submitted in June 2017. Preparation of a journal article based on that work is anticipated in the future

Funding: UWS and USGS, Student scholarship from Minnesota Ground Water Association

## INTRODUCTION

Municipalities in Dane County, Wisconsin, have been using groundwater to meet public demand for more than a century. As populations have grown, the rate of withdrawal has greatly increased. Madison alone now pumps 10 billion gallons of groundwater each year from a network of 22 supply wells (Madison Water Utility, 2016). This pumping has resulted in significant alterations to groundwater gradients. The confined Mount Simon aquifer, from which all the municipal, high-capacity wells draw water to some extent, has experienced substantial drawdown, particularly at the Madison Isthmus, where municipal pumping is most concentrated (Bradbury et al., 2013). As a stacked aquifer system, these changes in gradient have a direct impact on groundwater interactions throughout Dane County.

Of the 22 Madison Unit wells operated by the Madison Water Utility, 8 are confined aquifer wells that pump exclusively from the Mount Simon (Fig. 1). The other 14 are multi-aquifer wells that were drilled through the regional Eau Claire aquitard, often all the way to the top of the Precambrian basement, but only cased through part of the upper aquifer. This creates a borehole connection between the upper and lower aquifers, which results in wells drawing from both the confined and unconfined systems and downward flow during periods of non-pumping.

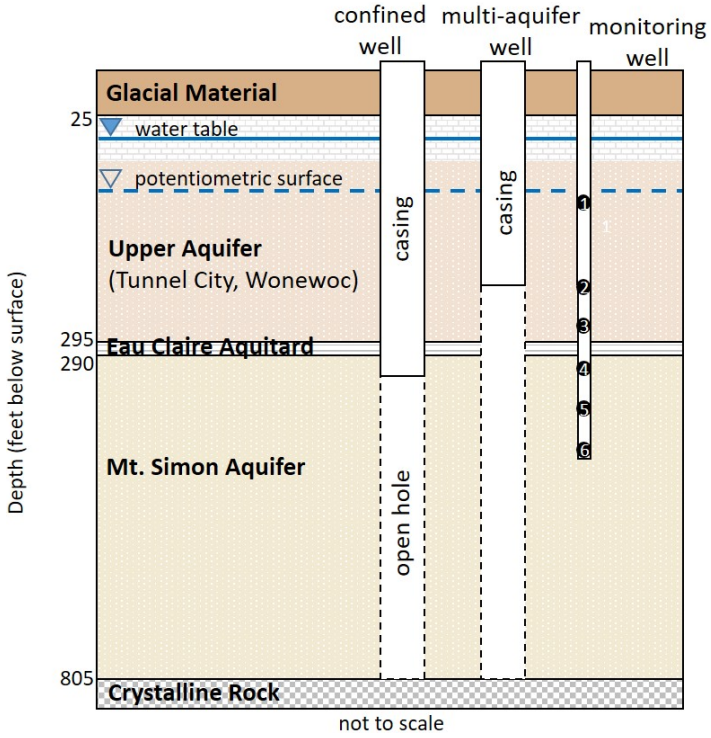


Figure 1. Construction diagrams of confined aquifer, multi-aquifer, and monitoring wells

Mixing groundwater from distinct sources creates new geochemical environments, which impact the potential for mobilization of naturally-occurring trace metals from the aquifer matrix (Ayotte et al., 2011). This is evidenced in the Madison wells by variations in chromium (Gotkowitz et al., 2012), manganese, and iron concentrations between confined aquifer and multi-aquifer wells (Personal communication with M.B. Gotkowitz, 2015a). While chromium is typically below detection limits in groundwater sampled from confined-aquifer wells (Fig. 2), it is commonly observed in groundwater from multi-aquifer wells. As aqueous chromium

concentrations are higher in the unconfined system, simply mixing groundwater from the shallow aquifer with the groundwater from the confined system could lead to higher chromium concentrations in multi-aquifer wells. However, in Dane County, the introduction of oxic water into the anoxic, confined system may further exacerbate the problem by mobilizing additional chromium, known to be present in the mineral phase in the Mount Simon (Personal communication with M.B. Gotkowitz, 2017).

Iron, by contrast, is typically mobile under anoxic conditions (Fig. 2), and primarily observed in confined aquifer wells in Dane County (Personal communication with M.B. Gotkowitz, 2015a). Manganese is also generally detected at higher concentrations in confined wells in Dane County (Fig. 2), but has also been an issue in a few multi-aquifer wells (Personal communication with M.B. Gotkowitz, 2015a). Research in a meromictic lake, containing layers of water that remain unmixed, in Norway found that aqueous manganese mobilization was less impacted than iron by increases in dissolved oxygen (Hongve, 1997). This likely explains the presence of aqueous manganese and lack of iron in groundwater from some multi-aquifer wells in Dane County. The variability of concentrations of chromium, manganese, and iron suggest that a range of geochemical conditions is being created in Dane County municipal wells.

Impacts of pumping in Dane County extend beyond the aquifer system. Substantial changes have occurred in the baseflow to streams and springs as well as discharge to Lakes Mendota and Monona, particularly along the Madison isthmus, where vertical hydraulic gradients have actually reversed from predevelopment conditions in which groundwater discharged to the lakes, to current conditions in which lake water infiltrates to the aquifer in some areas of the lake beds (Bradbury et al., 2013). The regional Eau Claire aquitard is thought to be partially absent in parts of central Dane County where a pre-glacial bedrock valley extended into the Mount Simon Sandstone (Swanson et al., 2001). This includes the area beneath the lakes of the Yahara watershed (Bradbury et al., 1999). Gradient reversals in the areas where the aquitard is absent have a magnified impact on groundwater-surface water interactions.

In assessing the situation in Dane County, this project focused on three primary objectives: evaluating how pumping-induced changes in gradient have impacted interactions between the unconfined and confined aquifers and between the surface water and groundwater systems, determining if the new geochemical environments created by these interactions impact aqueous chromium, manganese, and iron concentrations, and investigating the mobilization potential of these trace metals in the groundwater system. These issues were examined using a combination of modeling and lab-based techniques. A variety of MODFLOW simulations were performed that focused on determining the impact of municipal pumping and drawdown on groundwater flowpaths and mixing of water from different sources. These simulations helped inform geochemical modeling that examined the possibility of mobilization of trace metals under varying pumping scenarios, emphasizing the potential issue of mobilization of aqueous chromium from the Mount Simon aquifer in the presence of shallow, oxic groundwater. Mobilization potentials of chromium, manganese, and iron were further investigated by performing laboratory extractions on samples from the Tunnel City, Wonewoc, and Mount Simon formations to assess total metals concentrations (Results are pending, and therefore, not included in this report). These studies provided valuable insight into the current and future issues municipalities will need to consider if current pumping practices continue.

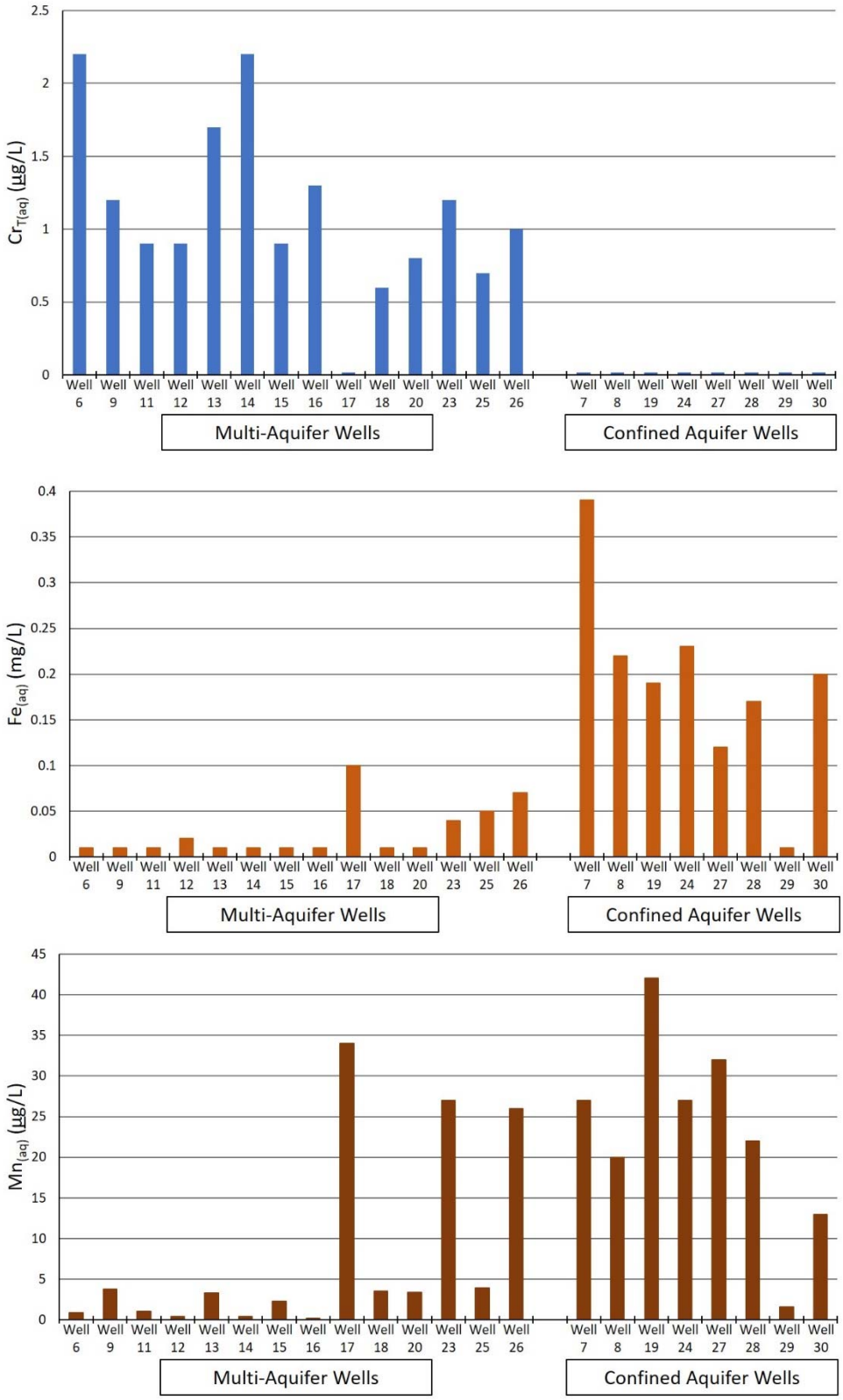


Figure 2. Comparison of aqueous chromium, iron, and manganese concentrations in Madison Water Utility multi-aquifer and confined aquifer supply wells, as measured in 2013

## PROCEDURES AND METHODS – PHYSICAL FLOW MODELING

The 2016 Groundwater Flow Model for Dane County, Wisconsin (Parsen et al., 2016) was utilized to run steady-state MODFLOW simulations under current and pre-development conditions. All wells were active for simulations of current conditions and deactivated for pre-development simulations. Comparisons of the two scenarios were made using backward particle tracking in MODPATH. Broad particle releases were used to examine flow variations in the Mount Simon aquifer around and below Lake Mendota, as well as along the Isthmus. Particles were released from the top and bottom of model layer 12 (Mount Simon) to examine flow across the Eau Claire aquitard and in the deep Mount Simon. Broad and feature-focused mass balances were used to examine changes in volumetric groundwater flow rates across the aquitard, as well as changes in groundwater contributions to surface waters.

Focused particle releases in the areas surrounding municipal wells were used to evaluate local scale flow dynamics caused by high-capacity pumping. Madison Unit Wells 15, 23, 6, and 25 were selected for particle releases, as they represent a range of $Cr_{(aq)}$ concentrations observed at multi-aquifer wells during a 2013 sampling round. At each of the four identified wells, particle circles of 6 particles were released at the top, middle, and bottom of the Mount Simon in the area immediately surrounding the well and then backward-traced for varying travel times. Particle travel paths were then compared under current and pre-development conditions.

## RESULTS AND DISCUSSION – PHYSICAL FLOW MODELING

Particle releases in the Mount Simon along the Madison Isthmus and Lake Mendota area reveal that pumping practices have significantly accelerated and shifted flow in the deep aquifer toward the Isthmus. Under pre-development conditions, Lake Mendota was the primary groundwater discharge point in the area and groundwater recharge along the Isthmus discharged to Lake Mendota (Fig. 3). Additionally, groundwater from the middle and upper portions of the confined system flowed upward across the aquitard near the Isthmus. These flow dynamics were significantly altered when pumping was introduced to the system. Under current conditions, pumping-induced drawdown has reversed vertical gradients, causing Lake Mendota water to flow into the groundwater system. Groundwater flow in the middle and upper portions of the confined system near the Isthmus is now also downward. This shift in flowpaths and intrusion of surface water into the groundwater system was further confirmed by mass balance analysis.

Previous studies found that, under pre-development conditions, the model estimated that streams contributed approximately 4 million gallons to the groundwater system and received approximately 402 million gallons from the groundwater system each day (Parsen et al., 2016), resulting in a net stream recharge of approximately 398 million gallons of groundwater per day in Dane County. Under current conditions, stream contributions to groundwater were approximately 6 million gallons per day, and groundwater flow to streams was approximately 361 million gallons per day (Parsen et al., 2016), resulting in a net groundwater discharge to streams in Dane County of roughly 355 million gallons per day. Lakes in the model area showed a similar trend and were even more significantly impacted. Under pre-development conditions, approximately 5 million gallons of lake water flowed into the groundwater system compared to 19 million gallons of groundwater flowing into lakes (Parsen et al., 2016), resulting in a net groundwater discharge to lakes in Dane County of approximately 14 million gallons per day. Under current conditions, lake contributions to the groundwater system increased and groundwater discharge to the lakes decreased. Simulations estimated 6 million gallons of lake

water flowing into the groundwater system and 12 million gallons of groundwater discharging daily to lakes (Parsen et al., 2016), resulting in a net groundwater discharge to lakes in Dane County of approximately 6 million gallons per day. That is a reduction of over 40% in net discharge to lakes under current pumping conditions.

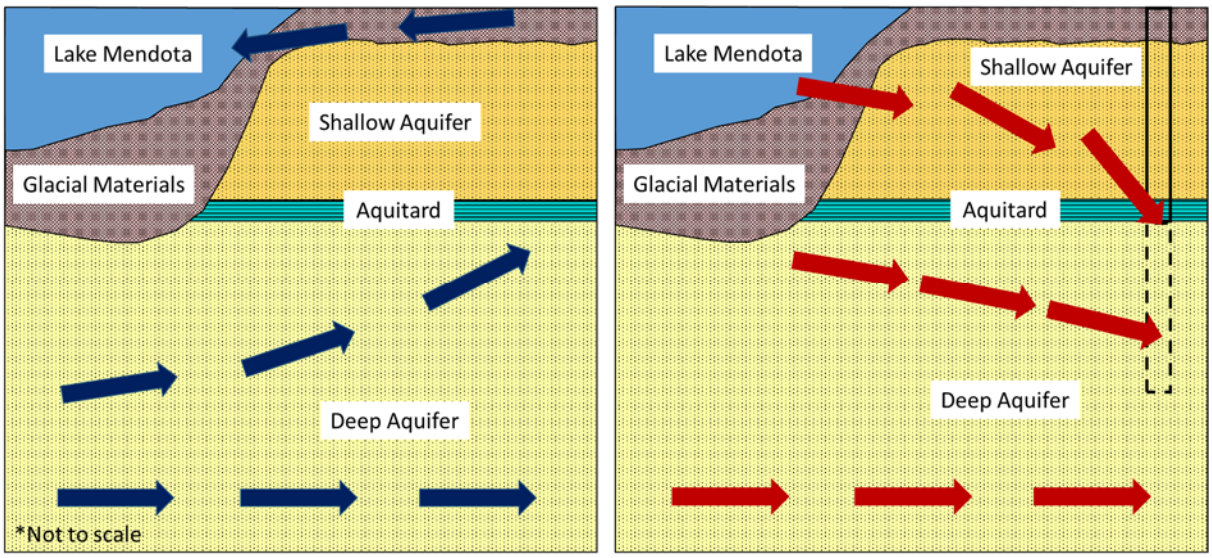


Figure 3. Compiled illustration of pre-development (blue arrows) and current groundwater flow conditions (red arrows) near the Madison Isthmus based on simulation results

Impacts to Lake Mendota are a primary component of the trend of declining groundwater inputs to Dane County lakes. Mass balance simulations that targeted Lake Mendota estimated that Lake Mendota received 5.9 million gallons of groundwater per day and made no contribution to the groundwater system under pre-development conditions. This shifted under current conditions, with approximately 0.5 million gallons of lake water intruding into the groundwater system. Additionally, groundwater contributions to Lake Mendota declined to approximately 1.2 million gallons per day, with a net discharge of groundwater to Lake Mendota of roughly 0.7 million gallons per day.

Mass balance results also demonstrated that volumetric flow across the Eau Claire aquitard is impacted by pumping practices. Increased downward flow, across the aquitard, was visible throughout Dane County in simulations under current conditions and was particularly noticeable along the Madison Isthmus. Under pre-development conditions, approximately 150 million gallons of groundwater per day flowed downward through the Eau Claire aquitard into the confined system. Under current conditions, approximately 174 million gallons of groundwater per day reach the confined system.

Locally-focused particle tracking at Madison Unit Wells 15, 23, 6, and 13 showed similar impacts on groundwater flowpaths from pumping. At Unit Well 15, located northeast of the Isthmus, groundwater flow under pre-development conditions was relatively straight and slow, traveling less than half a mile in a hundred years. Flow was nearly horizontal with a slight upward gradient in the shallow and middle portions of the Mount Simon under pre-development conditions. Under current conditions, flow is still horizontal at the base of the Mount Simon, but is downward throughout the middle and upper portions of the confined system. This results in groundwater migration from shallow system that did not occur before pumping. Flowrates are

also significantly higher in all layers in the area around Unit Well 15 under current conditions and flowpaths are curved. Simulations at Unit Wells 23, 6, and 25 show similar patterns of accelerated flow rates and disturbed, curved flowpaths under current pumping conditions, confirming that migration of oxic groundwater from the unconfined aquifer across the Eau Claire aquitard is enhanced under current pumping.

## PROCEDURES AND METHODS – GEOCHEMICAL MODELING

### Mixing Simulations

Madison Unit Wells 15 and 23 were chosen as target wells for the first round of geochemical simulations. Unit Well 15 is considered a relatively low $Cr_{(aq)}$ multi-aquifer well ($Cr_{(aq)}$ <1 µg/L), and Unit Well 23 is considered to have moderate $Cr_{(aq)}$ for a multi-aquifer well (1 µg/L < $Cr_{(aq)}$ < 2 µg/L). To assess the likelihood of chromium mobilization from the deep aquifer, PHREEQC was utilized to create a straightforward equilibrium model to determine if it is possible to achieve the chromium concentrations observed in Unit Wells 15 and 23 simply by mixing water from the unconfined and confined units without mobilizing any additional chromium from the sandstone in the confined aquifer. To do this, simple batch-reactions were run in PHREEQC with six mixing solutions based on values observed at a Madison monitoring well, referred to as the Sentry Well (Fig. 1), capable of depth-discrete monitoring. Chloride and sodium were used to estimate shallow system contributions and functioned with chromium, iron, and manganese as primary calibration parameters for the simulations.

### Mobilization and Sorption Simulations

For the second round of simulations, Madison Unit Wells 6 and 25 were used as the target wells. Unit Well 6 is considered a relatively high $Cr_{(aq)}$ multi-aquifer well (2 µg/L < $Cr_{(aq)}$). The $Cr_{(aq)}$ concentration of 2.2 µg/L measured at Unit Well 6 was tied for the highest concentration observed in any multi-aquifer well during the 2013 sampling (personal communication from M.B. Gotkowitz, 2015a). Unit Well 25 is a relatively low $Cr_{(aq)}$ multi-aquifer well ($Cr_{(aq)}$ < 1 µg/L). It has very low chloride and sodium concentrations, indicating it represents a multi-aquifer well with a lesser input from the unconfined aquifer. To more accurately mimic the complexities of the actual groundwater system, chromite, goethite, and manganese dioxide were added as equilibrium phases for a model that included sorption and dissolution processes (Fig. 4). The simulations mimic the downward migration of shallow groundwater in the borehole into the confined system that occurs when multi-aquifer wells are not pumping. This is represented by the mixing of waters from ports 1-5. That mixed composite

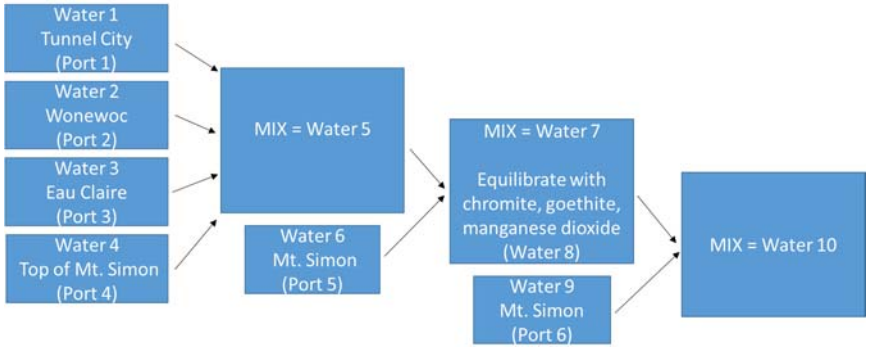


Figure 4. Conceptual model for PHREEQC chromium mobilization and sorption simulations

is then equilibrated with the chromite, goethite, and manganese dioxide, simulating the potential to mobilize trace metals by dissolution or desorption from the confined aquifer when shallow groundwater adds oxygen to the previously anoxic environment. Finally, water from port 6 is added to the mix to simulate groundwater from the deep Mount Simon that remains under anoxic conditions until it is withdrawn along with the overlying oxygenated groundwater when the well resumes pumping. Rock analysis data from Madison Unit Well 29, the nearest municipal well to the Sentry Well, had been collected in a previous study (Montgomery Associates and RMT, Inc., 2007). These data were used to determine goethite and manganese dioxide input concentrations for the simulations. The Madison Unit Well 29 study did not include chromium values, so chromite input for initial simulations was based on a separate 2012 WGNHS analyses. The input concentration was gradually reduced until simulated values more closely matched concentrations observed in multi-aquifer wells. To simulate potential chromate adsorption, goethite was defined as a surface species and given surface properties.

### Manganese Simulations

Manganese concentrations in groundwater from port 5 of the monitoring well (Fig. 1) have consistently been significantly higher than values from samples at any other port. Iron concentrations were more variable than manganese over time. Port 5 is near the boundary of anoxic and oxic conditions in the confined aquifer. To examine the impact of DO on manganese mobilization in the confined aquifer, simulations were run using groundwater values from only port 5 (water 5 in figure 4) with aqueous manganese initially removed. The solution was equilibrated with chromite, goethite, and manganese dioxide, using the previous experimentally defined and calculated values for those solid phases, under concentrations of DO ranging from 0 to 9 mg/L. To focus exclusively on the impact of DO on manganese mobilization, nitrate was also removed from the system. Final aqueous manganese values were then plotted against DO.

## RESULTS AND DISCUSSION – GEOCHEMICAL MODELING

### Mixing Simulations

Madison Utility Well 15, considered a relatively low chromium multi-aquifer well at 0.9 μg/L, was the first well modeled. Through a process of trial and error, a composite mixture of 25% port 1, 20% port 2, 15% port 3, 15% port 4, 15% port 5, and 10% port 6 (25/20/15/15/15/10) was found to generate results similar to those observed from Madison Utility Well 15. Simulated results approximated the primary match parameters except manganese, which was off by roughly an order of magnitude. Based on these results, it seems plausible that relatively low (~1 μg/L) chromium concentrations observed in multi-aquifer wells could be produced without mobilizing any additional chromium from the confined aquifer.

The second mixing simulation modeled an intermediate $Cr_{(aq)}$ value of 1.2 μg/L, as observed in Madison Unit Well 23. After a variety of simulations, a $Cr_{(aq)}$ value of 1.21 μg/L was obtained using a composite mix of 55/20/10/10/5/0. While chromium matches well, using port 1 as the majority contributor results in simulated chloride and sodium values that are too high. Additionally, manganese and iron, which are higher in the confined aquifer, are underestimated by this model. These are all indications that it is necessary to include additional contributions from the confined aquifer in the model to more closely simulate conditions at Well 23. However, incorporating more groundwater from the deep aquifer reduces simulated $Cr_{(aq)}$. Thus, a reasonable composite for Well 23 cannot be created using the mixing model alone.

## Mobilization and Sorption Simulations

The first mobilization and sorption model simulated conditions in Madison Unit Well 6, which had the highest $Cr_{(aq)}$ concentration measured during the 2013 inorganic sampling at 2.2 µg/L. Well 6 also has relatively high concentrations of chloride and sodium at 49 mg/L and 16 mg/L, respectively. These values indicate significant contribution from the shallow system (port 1). As Well 6 is cased to near the bottom of the Wonewoc but not through the Eau Claire, the presence of shallow groundwater deeper in the system may indicate the presence of vertical fractures, which have been documented in the Wonewoc and Tunnel City units in Dane County (Gellasch et al., 2013) It is also possible that there is a leak along the casing allowing accelerated downward migration of shallow groundwater. Using a 24% contribution from port 1, the chloride value was closely matched. Contributions for ports 2 and 3 were then apportioned approximately based on transmissivity values for the upper aquifer at Well 6 in the 2016 Dane County Regional Groundwater Flow Model (Parsen et al., 2016). Contributions from the Mount Simon, ports 4-6, were then adjusted until the primary match parameters were close to those measured at Well 6. The final composite mix was 24/19/18/12/25/2. Under such conditions, the model simulated substantial mobilization of chromium from the deep aquifer, allowing the observed concentration of 2.2 µg/L to be matched by the simulation.

An important constraint on $Cr_{(aq)}$ values was adsorption to goethite, which removed more than 90% of mobilized chromium. In fact, when goethite was removed as a surface species, all added chromite was released into the groundwater system in the model simulations. This illustrates the critical role that naturally-occurring iron in the Mount Simon plays in preventing even higher $Cr_{(aq)}$ in the municipal water supply. Additionally, simulations showed that either oxygen or nitrate at the concentrations measured in the shallow aquifer were individually capable of facilitating the mobilization of chromium from the confined aquifer. Simulations were initially run with a chromite input of 6.1x10-4 mol/L based on prior analysis, as previously mentioned. This input concentration was found to be much too high for reasonable results, so chromite input was gradually reduced. A final value of 2.4x10-7 mol/L, 0.04% of the calculated input, was eventually found to produce simulations that approximated observed concentrations.

The second mobilization and sorption simulation examined Madison Unit Well 25. In contrast to Well 6, Well 25 has very low chloride and sodium levels, 3.2 mg/L and 2.8 mg/L, respectively. These values indicate that there is minimal contribution of groundwater from above the Wonewoc. This is reflected in the calibrated composite of 0/0/25/5/10/60, which attributes the majority of groundwater contribution to the Mount Simon. The results closely matched all primary parameters, except for manganese, which is higher in the simulation than observed. This may be caused by the fact that port 6 of the Sentry Well is not very deep in the Mount Simon and quite close to port 5, which has high manganese concentrations. It is possible that a more accurate representation of the deeper Mount Simon would have lower manganese values due to the decrease in DO with depth.

## Manganese Simulations

Simulations showed $Mn_{(aq)}$ to be very responsive to changes in DO, particularly at low DO concentrations (Fig. 5). $Mn_{(aq)}$ was slightly mobile under conditions measured for all tested DO values, with $Mn_{(aq)}$ increasing slightly with decreasing DO. However, a significant increase in $Mn_{(aq)}$ mobilization occurred at a DO concentration of 0.014 mg/L. While simulated $Mn_{(aq)}$ was only 0.000213 µg/L for a DO of 0.015 mg/L, it rose dramatically to 1.87 µg/L when DO was

0.014 mg/L. $Mn_{(aq)}$ continued to steadily increase as DO was further reduced, with simulated $Mn_{(aq)}$ concentrations peaking at approximately 50 µg/L for DO concentrations between 0.0001 and 0 mg/L. These results support the trend observed from sampling of port 5 of the monitoring well (Fig. 1) that indicates manganese is highly mobilizable near the boundary between oxic and anoxic conditions.

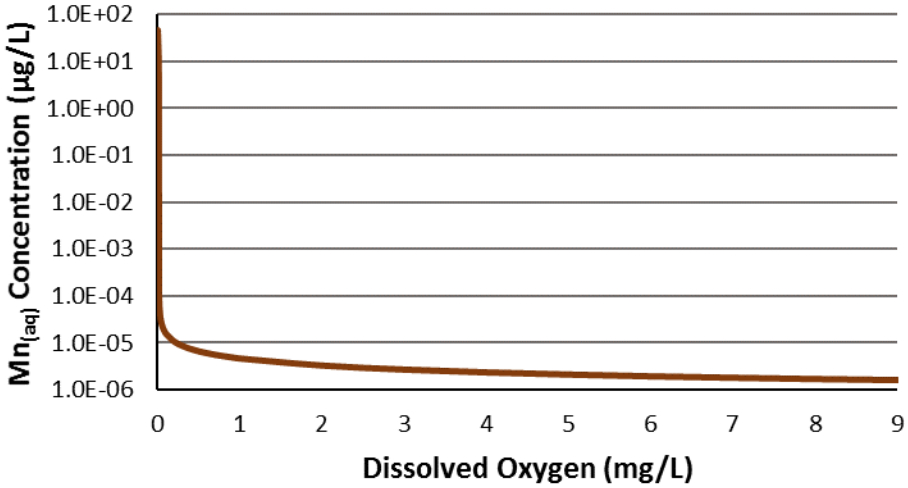


Figure 5. Simulated mobilization of $Mn_{(aq)}$ from the Mount Simon under varying DO

## CONCLUSIONS AND RECOMMENDATIONS

The results of the physical flow and geochemical modeling all indicate that the long-term, high capacity pumping occurring in Dane County is impacting the surface and groundwater systems. Groundwater flow rates are accelerated under current conditions and have been redirected toward the pumping-induced cones of depression along the Isthmus. Downward migration of oxic groundwater across the Eau Claire aquitard has increased throughout Dane County and is anthropogenically enhanced at multi-aquifer wells, impacting mobilization of trace metals. Groundwater contributions to surface waters are declining, and gradient reversals have resulted in portions of Lake Mendota and Lake Monona recharging the groundwater system rather than receiving groundwater discharge.

Public water managers will need to have a strategy in place to address water quality impacts that are likely to be exacerbated by continued pumping. Because iron mobilization is restricted to purely anoxic conditions, introducing oxygen to the confined system should theoretically result in a slight decline in $Fe_{(aq)}$ concentrations over time. Manganese, however, is less predictable. Because $Mn_{(aq)}$ values are highest near the boundary between oxic and anoxic conditions, water managers will need to know when that boundary is approaching a high-Mn(s) portion of the Mount Simon, such as the interval from 540-560' below ground surface in Unit Well 6, which has over 800 mg/kg of manganese. These intervals could be avoided by adjusting pumping rates, or the resultant mobilized manganese could simply be filtered, as is the current practice.

For chromium mobilization, multi-aquifer wells and increased drawdown create the greatest concerns, as they accelerate downward flow across the Eau Claire aquitard, oxygenating the confined system. A recent study of multi-aquifer wells in Albuquerque, New Mexico, and Modesto, California, found that water quality diminished during periods of low pumping rates,

such as winter, when water supply was almost exclusively being drawn from a lower quality aquifer (Yager and Heywood, 2014). The authors concluded that balancing seasonal pumping rates could improve the situation. Rather than a temporal balance, water managers in Dane County could try to spatially balance withdrawals more evenly across the county to reduce the worst cones of depression. This could potentially have a marginal benefit. However, based on current withdrawal rates, it is unlikely that drawdowns will reverse in the near future. Aqueous chromium concentrations in municipal water supplies could be significantly reduced by using only confined aquifer wells, limiting $Cr_{(aq)}$ inputs from the shallow aquifer and mobilization from the Mount Simon at multi-aquifer wells, but this would likely make iron and manganese issues more prevalent and lead to even greater drawdown in the Mount Simon. Ultimately, there is no single solution that addresses all the concerns, so operating cost or water quality concessions will likely need to be made in the future.

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APPENDIX A

## Publications

No published document has yet resulted from this study. However, it will be the basis of Joshua Olson's master's thesis, and the investigators intend to submit it for consideration for publication in the future.

## Presentations

Olson, J. (April 14, 2016) Long-term alterations in groundwater chemistry induced by municipal well pumping, UW – Madison Department of Geoscience Graduate Student Symposium, Madison, WI, poster presentation

Olson, J. (September, 25, 2016) Long-term alterations in groundwater chemistry induced by municipal well pumping, GSA Annual Meeting – Denver, CO, oral presentation

Olson, J. (April 27, 2017) Long-term alterations in groundwater chemistry induced by municipal well pumping, UW – Madison Department of Geoscience Graduate Student Symposium, Madison, WI, poster presentation

## Funded Student

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## Impact

Trace metals, specifically chromium, manganese, and iron, in Dane County municipal water supplies have been an ongoing source of health concerns and treatment costs. However, the mechanisms responsible for releasing these contaminants are not sufficiently understood. This project examined the natural occurrence of trace metals in the confined and unconfined sandstone aquifers beneath Dane County. Using groundwater flow simulations, the impacts of high-capacity pumping in Dane County were examined, particularly the widespread mixing of groundwater from the confined and unconfined aquifers, as well as from surface and groundwater sources. These interactions result in altered geochemical conditions, some of which were found to increase the potential release of trace metals from the sandstone aquifers. As there are multiple metals of concern, each of which require a different management strategy to address, this project does not provide a single solution to the current issues being faced. However, it does define the problem and the variety of causes in a way that will help municipal water managers make informed decisions regarding the ramifications of chosen pumping regimes, and hopefully, lead to strategies that maximize protection of citizens and minimize treatment costs.

# Wisconsin Inititative on Climate Change Impacts: Water Resources Working Group

## Basic Information

| | |
|---|---|
| **Title:** | Wisconsin Inititative on Climate Change Impacts: Water Resources Working Group |
| **Project Number:** | 2016WI351B |
| **Start Date:** | 3/1/2016 |
| **End Date:** | 2/28/2017 |
| **Funding Source:** | 104B |
| **Congressional District:** | 2 |
| **Research Category:** | Social Sciences |
| **Focus Categories:** | Climatological Processes, Management and Planning, Water Quantity |
| **Descriptors:** | None |
| **Principal Investigators:** | Daniel J. Vimont, David S Liebl |

## Publications

There are no publications.

# Wisconsin Initiative on Climate Change Impacts (WICCI) Water Resources Working Group Workshop

**Reporting Period:** 3/1/2016 - 2/28/2017

**Project**
WR16R003 - Wisconsin Inititative on Climate Change Impacts: Water Resources Working Group

**Principle Findings and Significance**
This project is for establishing the Wisconsin Initiative on Climate Change Impacts (WICCI) Water Resources Working Group. Funding will support convening the Water Resources Working Group, including one day-long meeting to identify vulnerabilities, impacts, and information needs related to water resources and climate change in Wisconsin and the Great Lakes region. The workshop will be conducted that brings together researchers, practitioners, and stakeholders from around the Wisconsin and the Great Lakes region to identify vulnerability, impacts, and information needs related to climate change in Wisconsin and the Great Lakes region. Funding will be used to reimburse travel and venue costs associated with the workshop, and to provide supplies for the workshop.

To date, activities on this grant have focused on identifying content and participants for the proposed workshop. Initial meetings with potential working group chairs occurred throughout 2016 and early 2017. These scoping meetings identified the following possible focus areas (among others) for a Climate Change and Water Resources Workshop:

a. Climate change impacts on small lakes in the Upper Midwest
b. Scales of water resource issues (big rivers vs. small streams / big vs. small lakes etc.)
c. Management of aquatic resources
d. Place-based examples

Overall progress toward convening a Water Resources Working Group has been strongly affected by uncertainty with the Wisconsin Department of Natural Resources priorities. We are moving on under the assumption that DNR employees will likely be unable to participate in a leadership role for the Water Resources Working Group.

Next steps for the project include:

1. Solidifying a date for a meeting that sets the agenda for the workshop, and identifies potential participants.
2. Planning and carrying out the workshop
3. Writing up results

We are hoping to hold the workshop in Fall, 2017 or early Spring, 2018 at the AWRA Wisconsin Section annual meeting.

**Number of Personnel Involved**
2 Participating faculty/staff
0 Supported post-docs

**Students Supported**
No students reported.

**Conference Participation**

**Title**
Water@UW-Madison Poster Session

**Location**
Madison, WI

**Dates**
October 28, 2016

**Journal Articles and Other Publications**
No journal articles and other publications reported.

**Awards and Achievements**
No awards and achievements reported.

**Research Patent or Copyright**
No research patents or copyrights reported.

# Detection of sewage contamination in urban areas of the Great Lakes

## Basic Information

| | |
|---|---|
| **Title:** | Detection of sewage contamination in urban areas of the Great Lakes |
| **Project Number:** | 2016WI354G |
| **USGS Grant Number:** | |
| **Start Date:** | 9/1/2016 |
| **End Date:** | 8/31/2019 |
| **Funding Source:** | 104G |
| **Congressional District:** | WI-004 |
| **Research Category:** | Water Quality |
| **Focus Categories:** | Non Point Pollution, Wastewater, Water Quality |
| **Descriptors:** | None |
| **Principal Investigators:** | Sandra McLellan, Steve Corsi |

## Publications

There are no publications.

# Detection of sewage contamination in urban areas of the Great Lakes

**Reporting Period:** 3/1/2016 - 2/28/2017

**Project**
WR16R005 - Detection of Sewage Contamination in Urban Areas of the Great Lakes

**Principle Findings and Significance**
Report on NIWR grant. (Funding received September 1, 2016)

This project contributes to three goals of our laboratory: 1) understand the extent to which untreated sewage (i.e. wastewater) contaminates stormwater 2) develop tools to detect and monitor sewage contamination so that management (such as TMDL implementation) can be more effective and 3) integrate sound scientific information into policy.

Objective 1 - To examine the confounders of sewage detection by the beta version of a USGS portable optical sensor:
Currently, we see about 20% of results as incongruent between the expected optical signal for sewage and the human alternative indicators in up-the-pipe stormwater samples. Approximately half of these are cases where the optical signal was not detected, and approximately half of these were inconclusive, suggesting interfering compounds were present. To further characterize the samples with confounding results, 77 samples with mismatch human fecal markers and 20 control samples were selected from the 2016 USGS-GLPF Portable Sewage Sensor project. The samples were analyzed for additional host-associated markers, including human Lachnospiraceae3, Dog, and Raccoon. The additional host-associated markers are not only helping to refine microbial source tracking methods and conclusions, but also to analyze the complicated upstream sewage sensor optical signals. In upstream (pipe) sources fecal contamination is not pooled into the more reproducible fecal indicator signature seen farther downstream (in receiving waters). Therefore, subdividing the dataset into more accurate human vs. non-human categories may help define sewage versus non-sewage sensor signals.

96 samples are in the process being sequenced (Illumina - MiSeq) to further describe the bacterial communities that are found in stormwater pipe samples.

Objective 2 - Validate in situ stream sewage sensor:
Preliminary data show sewage optical signal is more consistent in streams than in the up-the-pipe samples of neighborhoods with failing infrastructure. This objective will assess the limit of detection of the USGS in situ stream sewage sensor and the optical signals in relation to pathogens and OWCs using our alternative indicators as the ‘gold standard’ measure of sewage contamination. The in stream sensors have not been deployed yet, but field season prep is underway and USGS water collection at the two proposed Menomonee sites begins in April 2017. This work is done in collaboration with the Milwaukee Metropolitan Sewerage District.

Objective 3 – Translation and dissemination of findings:
The potential of utilizing the in situ stream sensor to validate TMDL implementation strategies was discussed in a meeting with Wisconsin Department of Natural Resources (WDNR) in January 2017. Update meetings will continue with WDNR. Additionally, meetings with TMDL and sensor technology stakeholders will be scheduled after processing data gathered during summer 2017 field season.

Objective 4 – Training water resource scientists:
A new McLellan Lab MS graduate student has started working on this NIWR project as of September 2017.

**Number of Personnel Involved**
4 Participating faculty/staff
0 Supported post-docs

**Students Supported**

**Name**
Alexis McAdams

**Affiliation**
University of Wisconsin-Milwaukee

**Degree**
MA/MS

**Major/Specialization**
Freshwater Sciences

**Graduation**
12/2018

**Conference Participation**
No conferences reported.

**Journal Articles and Other Publications**
No journal articles and other publications reported.

**Awards and Achievements**
No awards and achievements reported.

**Research Patent or Copyright**

No research patents or copyrights reported.

# Engaging Great Lakes Teachers in the Visualize Your Water Mapping Challenge

## Basic Information

| | |
|---|---|
| **Title:** | Engaging Great Lakes Teachers in the Visualize Your Water Mapping Challenge |
| **Project Number:** | 2016WI367S |
| **USGS Grant Number:** | G16AP00029 |
| **Sponsoring Agency:** | U.S. Geological Survey |
| **Start Date:** | 1/5/2016 |
| **End Date:** | 7/4/2016 |
| **Funding Source:** | 104S |
| **Congressional District:** | None |
| **Research Category:** | None |
| **Focus Categories:** | |
| **Descriptors:** | None |
| **Principal Investigators:** | |

## Publications

There are no publications.

**Engaging Great Lakes Teachers in the Visualize Your Water Mapping Challenge**
University of Wisconsin Sea Grant Institute and Minnesota Sea Grant
Final Report
July 21, 2016

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## Background

The Visualize Your Water Challenge was launched on January 13, 2016. The University of Wisconsin Water Resources Institute and Minnesota Sea Grant participated in planning for the challenge beginning in November 2015, and continue to participate in discussions about the future of the challenge. In addition to developing outreach materials for all challenge participants, the investigators hosted a webinar and a workshop targeted at teachers and students in the Great Lakes region.

## Deliverables

**Develop screencasts to provide examples of visualizing water quality and nutrient challenges and how to use ArcGIS.com to integrate maps and water data from distributed sources.**

Four screencasts were developed to provide examples of visualizing local water quality issues and to demonstrate how to obtain data and use it in ArcGIS Online. The first two screencasts showed examples of story maps that were developed to visualize water quality issues in Lake Erie and the Chesapeake Bay. The third screencast was developed to show a resource for visualizing and accessing nutrient data. The fourth screencast brought viewers through three major steps in the process of developing a map in ArcGIS Online: obtaining data, manipulating

the data in Excel, and adding the data to a map. An additional resource, in the form of a pdf document, was developed to aid participants in selecting and using data sources listed in the Getting Started Guide. The screencasts A Resource Out of Place; Cleaner Air, Cleaner Bay; and Visualizing Great Lakes Water Quality Data were included in the Getting Started Guide (https://esri.app.box.com/v/vywgettingstartedguide), as was the document Tips for Data Sources and Visualizations.

**A Resource Out of Place Screencast** (1 min, 51 sec)
https://youtu.be/_JTun9_PPTM
This screencast shows an example of using a story map to visualize the role of nutrients on water quality by exploring the map "A Resource Out of Place," which was developed by Landscape Metrics.

**Cleaner Air, Cleaner Bay Screencast** (1 min, 26 sec)
https://youtu.be/ShKkb_Dn4II
This screencast of the "Cleaner Air, Cleaner Bay" Story Map Journal developed by the Chesapeake Bay Program visualizes how air pollution affects water quality in the Bay.

**SPARROW Mapper Screencast** (2 min, 40 sec)
https://youtu.be/6vJO3-XZHOU
This screencast of the "SPARROW Mapper" developed by the U.S. Geological Survey for the Great Lakes and Upper Mississippi River basins introduces viewers to the mapper as a way to visualize the origin and fate of phosphorus and nitrogen pollution.

**Visualizing Great Lakes Water Quality Data** (9 min, 58 sec)
https://www.youtube.com/watch?v=c-1ttKS1G04
Uploaded on Feb 5, 2016
This screencast in support of the "Visualize Your Water" Challenge shows the mechanics of obtaining, manipulating, and visualizing Great Lakes water quality data. It shows how to download data from the "Great Lakes Monitoring" website, manipulate it using Excel, and visualize it using ArcGIS Online.

**Tips for Data Sources and Visualizations** (pdf)
http://www.cgll.org/wp-content/uploads/2016/01/Tips-for-Data-Sources_Visualize-Your-Water.pdf
This document was developed to provide additional information about and tips for using the data sources listed in the Getting Started Guide.

**Create mapping challenge resources sections in the Learn section of the Wisconsin Coastal Atlas and the Center for Great Lakes Literacy website.**
The resources developed for the challenge were added to the Learn section of the Wisconsin Coastal Atlas (http://www.wicoastalatlas.net/Default.aspx?tabid=65) and the Center for Great Lakes Literacy (CGLL) website. Both sites offered additional access points to the Visualize Your Water challenge.gov page. The CGLL website posted the challenge on its Educators Professional Development page (http://www.cgll.org/opportunities/visualize-your-water-high-school-

challenge-introductory-webinar/) and hosted the archived webinar (http://www.cgll.org/for-educators/webinar-archive/visualize-your-water-challenge-webinar/). The webinar page also included links to the resources developed by the University of Wisconsin Water Resources Institute and.

**Conduct a webinar on the mapping challenge for Great Lakes teachers.**
The University of Wisconsin Water Resources Institute and Minnesota Sea Grant developed and hosted a 1.5 hour webinar using WebEx on January 26, 2016. The webinar was viewed across the Great Lakes region, including at least one group of students who viewed the webinar with their teacher. An outline of the webinar content is below. The webinar was indexed and archived on the CGLL website (http://www.cgll.org/for-educators/webinar-archive/visualize-your-water-challenge-webinar/) and included in the Getting Started Guide so participants could view it at any time.

Webinar Outline
1. Introduction/ about the challenge (5 minutes)
2. About nutrient pollution (8 minutes)
3. Examples, ideas and tools (25 minutes)
    a. GLEI-GLEAM tool and Great Lakes Monitoring website (8 minutes)
    b. More resources (5 minutes)
    c. Screencasts (12 minutes)
4. Build a Story Map (40 minutes)
5. Question and answer session (13 minutes)

**Conduct a workshop on the mapping challenge for teachers and students in the Duluth/Superior region.**
A 3 hour workshop was hosted at the University of Minnesota-Duluth on February 2, 2016. It was attended by 6 people, including an EPA employee and a high school student mentee. The first half of the workshop roughly followed the format of the webinar. Following dinner provided for attendees, the second half of the workshop was dedicated to using ArcGIS Online to learn how to build a story map. Participants were able to use provided computers to practice using ArcGIS Online while the workshop hosts were available to guide them and answer questions.

Workshop Outline
1. Introduction/ about the challenge (15 minutes)
2. Ideas (10 minutes)
3. How to access data and get started with ArcGIS Online (30 minutes)
4. Education resources from Esri (5 minutes)
5. Dinner (30 minutes)
6. Building a story map journal (20 minutes)
7. Build your own story map (65 minutes)
8. Additional questions (5 minutes)

**Prepare for future water quality mapping challenges.**
Throughout this year's challenge, Sea Grant documented materials developed and gathered for the challenges. As mentioned above, the materials developed by the University of Wisconsin Water Resources Institute and Minnesota Sea Grant are archived on the CGLL website. In preparation for future challenges, participants reflected on opportunities for improving the challenge in the future including clarifying the challenge objectives and increasing participation. Their concerns and recommendations are detailed in a short report titled "An Evaluation of Engaging Great Lakes Teachers in the Visualize Your Water Mapping Challenge." The report also shares results of an online survey developed by Minnesota Sea Grant and sent to challenge participants. Though the future of the Visualize Your Water Challenge is uncertain, the University of Wisconsin Water Resources Institute and Minnesota Sea Grant intend to continue participating in discussions regarding the challenge.

**Additional challenge support**
In addition to developing outreach materials and hosting events, the investigators worked to bring additional support to the challenge by encouraging members of the Wisconsin Land Information community and Minnesota GIS/LIS Consortium to advertise the Challenge and serve as GeoMentors, as well as connecting Ms. Sarah Wilkins, the coordinator for the Chesapeake Bay Sentinel Site Cooperative with Maryland Sea Grant, to the team guiding the challenge.

# Analytical Services for Use of Mercury Isotopes to Inform Human Health and Ecosystem Health Decisions

## Basic Information

| | |
|---|---|
| **Title:** | Analytical Services for Use of Mercury Isotopes to Inform Human Health and Ecosystem Health Decisions |
| **Project Number:** | 2016WI369S |
| **USGS Grant Number:** | G16AP00135 |
| **Sponsoring Agency:** | U.S. Geological Survey |
| **Start Date:** | 5/1/2016 |
| **End Date:** | 4/0/2017 |
| **Funding Source:** | 104S |
| **Congressional District:** | None |
| **Research Category:** | None |
| **Focus Categories:** | |
| **Descriptors:** | None |
| **Principal Investigators:** | |

## Publication

1. Rothenberg, S.E., R. Yin, J.P. Hurley, D.P. Krabbenhoft, Y. Ismawati, C. Hong and A. Donohue. 2017. Stable Mercury Isotopes in Polished Rice (Oryza sativa L.) and Hair from Rice Consumers. Environmental Science and Technology. In press. DOI: 10.1021/acs.est.7b01039.

# Use of Mercury Isotopes to Inform Human Health and Ecosystem Health Decisions

**Reporting Period:** 7/1/2016 - 6/30/2017

**Project**
AAB2192 - Use of Mercury Isotopes to Inform Human Health and Ecosystem Health Decisions

**Principle Findings and Significance**
Our results initial results were focused mainly on the Fox River, Wisconsin for the first phase of the study. Results indicated relative to baseline, enhanced Hg sediment deposition began in the 1890s in Green Bay and was evident in the early 1800's in offshore Lake Michigan. Isotopic signatures allowed for the utilization of a binary mixing model reliant on HgT concentration and δ202Hg values (Yin et al. 2016). Model output confirmed that the contamination evident in Green Bay is most likely due to local sources that are mainly constrained to Green Bay whereas offshore elevations in HgT concentrations are more likely the result of increased Hg in the global pool. This study also showed an increase in odd isotope mass independent fractionation (MIF) from within Green Bay to offshore Lake Michigan. Greater positive odd MIF is likely indicative of both enhanced photoreduction in offshore regions as well as proportionally more atmospherically-derived Hg and proportionally less watershed-derived Hg in the offshore region. This is consistent with data from our comparative Great Lakes sediment study (Lepak et al. 2015).

A preliminary food web investigation of the Fox River was also conducted. For the study, baitfish (Emerald Shiner and Gizzard Shad), benthivores (Redhorse Sucker), and piscivorous fish (Walleye and Smallmouth Bass) were electroshocked in three locations along the Fox River: below the Little Rapids Dam, below the De Pere Dam and just outside the harbor walls in Green Bay. Isotopic Hg signatures in fish of these regions were compared to surface sediment from a nearby site in Green Bay to help determine whether Hg found in the food web resembled legacy Hg in Green Bay. As fish contain primarily methylmercury, sediment Hg speciation is typically dominated by inorganic Hg. The processes that convert a portion of an Hg pool from inorganic to the methylmercury found in fish (methylation, demethylation, photochemical reduction and photochemical demethylation) are highly complex and may result in Hg fractionation, mass-dependent and mass-independent, prior to organism uptake. For this reason, Hg isotope signatures found in biota may not be directly comparable to the legacy Hg found in the sediment.

Lastly, an initial assessment of the St. Louis River was conducted using archival sediment and biota samples provided by the USGS Mercury Research Lab (Middleton, WI) and US EPA (Duluth, MN), respectively. A simple sediment-mixing model for the St. Louis, encompassing the lower estuary to Thomson Reservoir, identifies that legacy hotspots are isotopically heavier in δ202Hg and can be clearly distinguished from light δ202Hg background sediments with lower concentrations. Mercury isotope compositions in fish tissue from the St Louis were also easily separated between riverine and open water sources, despite all individuals being collected in the St Louis River. Highly enriched isotope values (δ202Hg= 0.8-1‰ and Δ199Hg= 1-2‰) for sub-populations of walleye and white suckers were attributed to the Superior food web due to the elevated Δ199Hg, as observed in the Great Lakes, and further supported by δ13C isotopes indicating an open water food source. Calculations were performed to correct for photochemical demethylation in fish tissues in order to estimate the starting signature of the source Hg. Results

showed a strong overlap between estimates for riverine fish and sediment compositions for δ202Hg, indicating that the legacy sediment is still a major Hg contributor to lower estuarine food web. Fish with the Superior Hg signature do not reflect sediment isotope compositions after this correction, supporting a secondary source in Lake Superior.

**Number of Personnel Involved**

1 Participating faculty/staff

1 Supported post-docs

**Students Supported**

**Name**

Ryan Lepak

**Affiliation**

University of Wisconsin-Madison

**Degree**

PhD/DSci

**Major/Specialization**

Environmental Chemistry and Technology

**Graduation**

6/2018

**Conference Participation**

**Title**

Determination of MeHg Sources to Fish in the St. Louis River, MN, USA, using Hg Stable Isotopes

**Location**

International Association for Great Lakes Research, Detroit, MI

**Dates**

May 15 - 19, 2017

**Number of supported students attending**

1

**Presentations by Staff**

KRABBENHOFT, D.P., JANSSEN, S.E., LEPAK, R.L., HOFFMAN, J.C., MONSON, B,, OGOREK, J.M., DEWILD, J.F., and TATE, M.T.

**Title**

Use of Mercury Stable Isotope Signatures to Ascertain Sources to Piscivorous Great Lake's Fish.

**Location**

International Association for Great Lakes Research, Detroit, MI

**Dates**
May 15-19, 2017

**Number of supported students attending**
1

**Presentations by Students**
LEPAK, R.L., YIN, R., JANSSEN, S.E., KRABBENHOFT, D.P., OGOREK, J.M.,DEWILD, J.F., TATE, M.T., HOLSEN, T.M., and HURLEY, J.P.

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**Title**
Changes in Stable Isotope Composition in Lake Michigan Trout - a 40 year perspective.

**Location**
International Association for Great Lakes Research, Detroit, MI

**Dates**
May 15-19, 2017

**Number of supported students attending**
1

**Presentations by Students**
LEPAK, R.L., HOFFMAN, J.C., JANSSEN, S.E., KRABBENHOFT, D.P., OGOREK, J.M., DEWILD, J.F., BABIARZ, C.L., TATE, M.T., YIN, R., MURPHY, E.W., and HURLEY, J.P.

## Journal Articles and Other Publications

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**Title**
Stable Mercury Isotopes in Polished Rice (Oryza sativa L.) and Hair from Rice Consumers

**Type of Publication**
Book or Monograph

**Complete Citation**
Rothenberg, S.E., R. Yin, J.P. Hurley, D.P. Krabbenhoft, Y. Ismawati, C. Hong and A. Donohue. 2017. Stable Mercury Isotopes in Polished Rice (Oryza sativa L.) and Hair from Rice Consumers. Environmental Science and Technology. In press. DOI: 10.1021/acs.est.7b01039.

## Awards and Achievements
No awards and achievements reported.

## Research Patent or Copyright
No research patents or copyrights reported.

**Completion Summary**

The recent advancement in instrumental capability of high-resolution mass spectroscopy, allowed us to measure natural Hg isotope abundances in environmental samples and essentially “fingerprint” varying Hg sources. These protocols were applied to two EPA-designated Areas of Concern to conduct preliminary assessment of sources of Hg bioaccumulating in fish. The initial work, while focusing on the St. Louis and Fox Rivers, showed significantly different patterns in isotopic composition of predatory fish residing within the river versus those from lake populations in the nearshore regions. We further compared Hg isotopic composition of lake trout for the five Great Lakes related to this project. Previously, by measuring stable isotopes of Hg (δ202Hg, Δ199Hg, and Δ200Hg) in sediments across the Laurentian Great Lakes, we were able estimate source contributions of Hg. We identified isotopically distinct Hg signatures for Great Lakes top predators among the five Great Lakes.

During this project, we were fortunate to collaborate with a researcher from North Carolina who was able to obtain samples of rice and hair samples from distinct regions of China, U.S., and Indonesia. Since rice has been shown to contain low levels of methyl Hg due to its cultivation in wetted soils, it is important to track the fate of this isotopically distinct bioaccumulative form of Hg. Results from that study suggest that Hg isotopes (especially mass independent fractionation) in human hair can be used to distinguish methylmercury intake from rice versus fish.

We have now established an agreement to access the Great Lakes Fish Archive from the USEPA, as well as fish from the Wisconsin and Minnesota fish monitoring programs to determine trends in fish Hg isotopes from small inland lakes and the Great Lakes themselves. By combining the Hg fingerprinting results from the fish and human hair samples, we will be able to provide a new level of understanding of the most important factors leading to human Hg exposure. Our ongoing work builds from the significant results obtained during this phase of our research and directly related to significant issues in human health.

# Information Transfer Program Introduction

None.

# Wisconsin Water Resources Fellowship: Collaborating with Water Managers

## Basic Information

| | |
|---|---|
| **Title:** | Wisconsin Water Resources Fellowship: Collaborating with Water Managers |
| **Project Number:** | 2016WI348B |
| **Start Date:** | 3/1/2016 |
| **End Date:** | 2/28/2017 |
| **Funding Source:** | 104B |
| **Congressional District:** | 2 |
| **Research Category:** | Not Applicable |
| **Focus Categories:** | Groundwater, Education, Management and Planning |
| **Descriptors:** | None |
| **Principal Investigators:** | Jennifer Hauxwell |

## Publications

There are no publications.

# Wisconsin Water Resources Fellowship

**Reporting Period:** 3/1/2016 - 2/28/2017

**Project**
WR16E002 - WI Water Resources Fellowship

**Principle Findings and Significance**
State agencies often are challenged by the ability to attract and recruit professional talent that best suits their needs. Additionally, students with diverse scientific backgrounds oftentimes do not apply to positions in the public service sector. Many factors may account for this disconnect, including perceptions of limited salary flexibility, a sense of an inability to apply scientific knowledge and experience, the complexities of the hierarchical structure of state government, and/or a lack of awareness of career opportunities beyond the traditional academic path. This conflicts directly with employee job satisfaction and long tenures of many Wisconsin state employees who face considerable challenges in managing complex technical problems within a tapestry of diverse societal and political perspectives on water resource management issues. This program is intended to help attract some of the state's best graduate students and postgraduates in water resources management and analysis to gain key experience and perhaps consider
state agency careers. This opportunity will allow students to apply and grow both their technical abilities as well as their leadership skills. It also allows state agencies to benefit from knowledge gained by recent graduate students for sound resource management. We envision this investment as a cornerstone of a fellows program that will continue to expand and form a self-sustaining entity on a state level that is similar to the national Sea Grant Knauss Fellows Program.

We completed our first fellowship partnership with the Bureau of Drinking Water and Groundwater at the Wisconsin Department of Natural Resources for the 2015-16 academic year and have continued into the 2016-17 academic year with our second fellowship, this time with the Bureau of Water Quality. By both accounts (UW and DNR), this partnership has been fruitful. Our first Fellow (a doctoral candidate with a 50% project assistantship through WRI) provided critical support to the Wisconsin Groundwater Coordinating Council. This council, comprised of the heads of state agencies, is required by statute to prepare a report which "summarizes the operations and activities of the council..., describes the state of the groundwater resource and its management and sets forth the recommendations of the council." This fellow led the development of the FY16 Report to the Legislature and also significantly revamped the Council's website (http://dnr.wi.gov/topic/groundwater/gcc/). In addition, the fellow updated a key source for education the public on groundwater resources – "Groundwater – Wisconsin's Buried Treasure," and in particular, worked to incorporate the economic importance of groundwater. The fellow has also worked with professionals around the state and country to better analyze patterns in Wisconsin groundwater contaminants and has helped to inform our future student programming through connections to other students, blogs, and participation in student focus groups for WRI. More on the current fellow can be found at - http://www.wri.wisc.edu/pressroom/Details.aspx?PostID=1208.

During the 2016-17 academic year, we partnered 50:50 with the DNR's Bureau of Water Quality, both the Monitoring and Evaluation sections to support a full-time postdoctoral Fellow. This program has important science

needs on the water quality status and trends for Wisconsin's surface waters with a number of resource management and policy applications. This group also has a number scientist and policymaker mentors who are working with the Fellow to bridge the science-policy gap. The Fellow has led two analyses using DNR water quality monitoring data to work toward goals of quantifying the effects of total suspended solids on stream biota. First, he developed a daily model of TSS to characterize stream conditions. Second, he is using these characterizations to assess TSS effects on macroinvertebrate and fish communities. The Fellow is also implementing automatic reporting of site-level model results and training staff in R and statistics.

**Number of Personnel Involved**

1 Participating faculty/staff

1 Supported post-docs

**Students Supported**

No students reported.

**Conference Participation**

**Title**

University Council on Water Resources/National Institute for Water Resources Annual Water Resources Conference

**Location**

Pensacola Beach, FL

**Dates**

21 June 2016

**Presentations by Staff**

Hurley, J., J. Hauxwell, N. Garber, J. Galkiewicz, J. Eckman. (21 June 2016). Water Resources Fellowships at the Local Level: Using the Knauss Sea Grant Fellows Program as a Template. University Council on Water Resources/National Institute for Water Resources Annual Water Resources Conference. Pensacola Beach, FL.

**Title**

Water@UW-Madison Poster Reception

**Location**

Madison, WI

**Dates**

October 28, 2016

**Number of supported students attending**

1

**Presentations by Staff**

Latzka, A.W. & M. Diebel. Predicting daily TP and TSS from antecedent weather and reach attributes across

Wisconsin streams.

**Title**
American Water Resources Association - Wisconsin Section Annual Meeting

**Location**
Elkhart Lake, WI

**Dates**
March 2017

**Number of supported students attending**
1

**Presentations by Staff**
Latzka, A.W. & M.W. Diebel. Predicting daily total phosphorus and suspended solids across Wisconsin stream reaches for impairment assessment.

**Title**
DNR Water Resources Statewide Meeting and Training

**Location**
Wisconsin Dells, WI

**Dates**
February 15-17, 2017

**Number of supported students attending**
1

**Presentations by Staff**
Alex Latzka & Matt Diebel. Modeling daily stream total phosphorus and total suspended solids: Model summary & site reports Matt Diebel, Theresa Nelson, Aaron Ruesch, Alex Latzka. Water Quality Models & Data Analysis: A Peek Inside the Black Box

**Presentations by Students**

## Journal Articles and Other Publications
No journal articles and other publications reported.

## Awards and Achievements
No awards and achievements reported.

## Research Patent or Copyright
No research patents or copyrights reported.

**Completion Summary**

Our second fellow has surpassed expectations in these initial stages of developing a relationship with Wisconsin's natural resource management agency. Based on this initial success, DNR has committed to continued partnership with WRI 50:50 cost sharing in the next iteration of the fellowship.

Key Accomplishments by Water Quality Fellow:

- Extracted and cleaned a database of TSS measurements from SWIMS, resulting in 513 sites with a total 11,859 measurements that fit criteria needed to build a predictive model.
- Although the initial model was based on pre-processed daily weather data, the fellow has downloaded and summarized hourly precipitation and temperature datasets for each watershed in the state for a new hourly version of the model.
- A predictive model for daily stream TP using weather and watershed characteristics was previously developed by Matt Diebel was adapted for this project. We fit a mixed effects model to TP and TSS measurements across the state, where each is dependent on the agriculture and urban land use percentages, slope, soil permeability, contributing area, a seasonality effect, the anomaly of the 7-day average temperature, and an antecedent precipitation index. Antecedent precipitation is a weighted sum of precipitation in the contributing area on the 365 days prior, where each day's weight depends on how recently it occurred. We allowed the shape of the weighting function to vary depending on a watershed's slope and area, where larger and flatter watersheds had longer lag times less flashiness in response to precipitation, where the shape of this variation was controlled by an optimization routine. Uncertainty is being tracked via bootstrapping.
- Created automatically-generated PDF reports that display predictions from the TP and TSS models for each site in an easy-to-understand document complete with text, maps, and several graphs, using RMarkdown.
- Extracted macroinvertebrate and fish data for streams for all of Wisconsin to test for TSS effects.
- We have used the TSS model to calculate various summary statistics of TSS conditions at each site (mostly areas under the curve above certain TSS thresholds). We are combining these (and raw TSS measurements) with measured biological data, including macroinvertebrate and fish indexes of biotic integrity based on DNR stream monitoring and available in the SWIMS database. We have fit preliminary general additive models to assess how these IBIs respond to these TSS characteristics. In all cases, we see strong negative effects of TSS, although threshold types of responses are not common across all IBIs or TSS indicators tested.
- Gave presentations at several conferences and meetings. Conference presentations are listed above. Additional presentations in DNR team settings included presentations on the TP/TSS model to the DNR water quality modeling technical team, on the fellow's past and current work at a DNR informal seminar, on the model and site reports to the DNR streams technical team, and on new R-based methods for acquiring and processing gridded data for Wisconsin's watersheds to the DNR water quality modeling technical team.
- Submitted an abstract which was accepted to give a presentation on this work at the Society of Freshwater Sciences in a special session on Macrosystems in Raleigh, NC in June.
- Began preparation of two manuscripts and one additional grant proposal related to the research completed

# Information Transfer

## Basic Information

| | |
|---|---|
| **Title:** | Information Transfer |
| **Project Number:** | 2016WI350B |
| **Start Date:** | 3/1/2016 |
| **End Date:** | 2/28/2017 |
| **Funding Source:** | 104B |
| **Congressional District:** | 2 |
| **Research Category:** | Not Applicable |
| **Focus Categories:** | Education, Climatological Processes, Groundwater |
| **Descriptors:** | None |
| **Principal Investigators:** | Moira Harrington |

## Publications


1. White, Elizabeth; et al. 2016 40th Annual Meeting Program and Abstracts 40 Years of Wisconsin Waters: Quantity, Quality, Technology, American Water Resources Association, Wisconsin Section. 65 pages. http://state.awra.org/wisconsin/2016meeting/AWRAProgram2016.pdf
2. White, Elizabeth; Marie Zhuikov, Aaron Conklin, Moira Harrington, Anne Moser. 2016 Volume 1, Aquatic Sciences Chronicle 12 pages http://www.aqua.wisc.edu/chronicle
3. White, Elizabeth; Marie Zhuikov, Aaron Conklin, Moira Harrington, Anne Moser. 2016 Volume 2, Aquatic Sciences Chronicle 12 pages http://www.aqua.wisc.edu/chronicle
4. White, Elizabeth; Marie Zhuikov, Aaron Conklin, Moira Harrington, Anne Moser. 2016 Volume 3, Aquatic Sciences Chronicle 12 pages http://www.aqua.wisc.edu/chronicle
5. White, Elizabeth; Marie Zhuikov, Aaron Conklin, Moira Harrington, Anne Moser. 2016 Volume 4, Aquatic Sciences Chronicle 12 pages http://www.aqua.wisc.edu/chronicle
6. Moser, Anne; Elizabeth White. 2016 Once Upon a Pond STEM Kit, 16 pages http://waterlibrary.aqua.wisc.edu/wp-content/uploads/WWL_ponds16.pdf
7. Conklin, Aaron; Marie Zhuikov, Moira Harrington. 2016 Facebook.com/UWiscSeaGrant
8. Conklin, Aaron; Marie Zhuikov, Moira Harrington. 2016 @UWiscSeaGrant Twitter account
9. Harrington, Moira. 2016 Five New Studies Aim to Protect and Better Manage Wisconsin's Water Wealth. news release. 2 pages.
10. Harrington, Moira. Jan. 28, 2016, Water Display Makes Its Way to New Berlin. http://www.seagrant.wisc.edu/Home/AboutUsSection/PressRoom/Details.aspx?PostID=2261
11. Harrington, Moira. May 23, 2016 Walter E. Olson Memorial Library to Host Wisconsin Water Photo Display.
12. Harrington, Moira. June 24, 2016 Caestecker Public Library to Host Wisconsin Water Photo Display.
13. Harrington, Moira. July 27, 2016 Wisconsin Maritime Museum to Host Wisconsin Water Photo Display
14. Harrington, Moira. Oct. 5, 2016 West Bend Hosts Water Display Photography Exhibit in October http://wri.wisc.edu/pressroom/Details.aspx?PostID=1242
15. Harrington, Moira. Oct. 28, 2016 In Muskego? Visit the Traveling Water Exhibit http://wri.wisc.edu/pressroom/Details.aspx?PostID=1244
16. Harrington, Moira. Nov. 21, 2016 Learn About Wisconsin's Water Wealth at the Sauk Prairie Library http://wri.wisc.edu/pressroom/Details.aspx?PostID=1246
17. Zhuikov, Marie. Aug. 22, 2016 Switching From Lakes to Streams: Alex Latzka, New Water

Resources Policy Fellow
http://www.seagrant.wisc.edu/Home/AboutUsSection/PressRoom/Details.aspx?PostID=2435
18. Harrington, Moira. September 2016 Wisconsin Water Library Improves Its Online Presence
http://www.seagrant.wisc.edu/home/Default.aspx?tabid=561&PostID=2449&Mode=View
19. Conklin, Aaron. March 6, 2016 Farewell, Mr. Potter - But Not Goodbye
http://wri.wisc.edu/pressroom/Details.aspx?PostID=1226
20. Conklin, Aaron. April 5, 2016 Solidifying Stakeholder Engagement
http://wri.wisc.edu/pressroom/Details.aspx?PostID=1229
21. Conklin, Aaron. July 20, 2016 Unraveling the Radium Riddle
http://wri.wisc.edu/pressroom/Details.aspx?PostID=1234
22. Harrington, Moira. Oct. 6, 2016 Art and Science and Water Talk on Madison Campus
http://wri.wisc.edu/pressroom/Details.aspx?PostID=1241
23. Conklin, Aaron. Sept. 21, 2016 How Very Meta
http://wri.wisc.edu/pressroom/Details.aspx?PostID=1239
24. Harrington, Moira. Nov. 21, 2016 Thanksgiving for Wisconsin's Waters
http://wri.wisc.edu/pressroom/Details.aspx?PostID=1245
25. Zhuikov, Marie. Dec. 12, 2016 New Project Attacks Urban Water Contamination Through Science and Policy http://wri.wisc.edu/pressroom/Details.aspx?PostID=1247
26. Harrington, Moira. July 28, 2016 Three New Studies Aim to Protect and Better Manage Wisconsin's Water Wealth http://wri.wisc.edu/pressroom/Details.aspx?PostID=1235

The University of Wisconsin Water Resources Institute (WRI) Information Transfer Program promotes research and training to address—in an effective manner—water resources challenges. It has a complementary communications program that supports and illuminates the work of the University of Wisconsin Sea Grant Institute. Sea Grant shares the WRI mission of building water literacy to engender greater stewardship of water resources. Great efficiencies are achieved by advancing the branding and information transfer work of the two water programs.

Core to any information transfer effort is an understanding of and service to audiences. The WRI audiences are researchers, policy makers, decision makers, water managers, students and, in certain instances, members of the general public.

To enhance credibility and be seen as a source of water knowledge, WRI builds on its attributes of being community focused, science focused, academically grounded and fulfilling the mission of training the next generation of water-science leaders. The Information Transfer Program also strives to identify WRI with the goal of addressing the critical issues of water quantity, quality and management in Wisconsin.

To operationalize these principles and meet audience needs, an annual Information Transfer Program strategy is developed. Tactics and products are deployed throughout the year to implement the strategy. The tactics and products for 2016-17 are outlined in this report.

**Tactics and Products**

Much of WRI's information is shared via an online publication store, *http://aqua.wisc.edu/publications*. A fact sheet about groundwater drawdown was the most popular WRI download in the publications store. There were about 1,000 downloads in this reporting period.

Another publication to note is the Aquatic Sciences Chronicle, which is produced and distributed quarterly. It highlights water research and the people who conduct water research and outreach. The Chronicle's dedicated readers consist of roughly 5,400 online and print subscribers, which includes local and state water management agencies, and water-related non-governmental organizations. Readers are found in Wisconsin and across the country. The newsletters are also posted online. At *aqua.wisc.edu/chronicle*, all issues of the publication are archived and searchable. There were nearly 37,000 online visitors to the newsletter in the last year.

Social media facilitates engagement with audiences. WRI is active on Facebook and Twitter. Through the Twitter account, for example, one analytical tool shows that WRI has the potential to deliver about 700,000 impressions a week. WRI also uses the social media tools Flickr, YouTube, Pinterest and Sound Cloud.

WRI's video catalog includes "What's a Spring," "Streams Neutralize Nitrates in Groundwater," "A New Measure of Groundwater Flow," "Got Oaks" and "Drought in Southwest Wisconsin as Told by Oaks." "Testing Well Water for Microorganisms" is the most popular video in the catalog. To date, it has nearly 10,500 views, which is a large number for a video on a scientific topic. It was first posted in 2011. All of the videos are shared through the program's website and its YouTube channel, *http://www.youtube.com/user/UWASC/*.

WRI has also created 11 videos highlighting the protocols of in-laboratory water testing. The video segments were shot at two U.S. Geological Survey labs, a regional and a national one; the Wisconsin State Laboratory of Hygiene to focus on algal toxins and metals analysis; and the Racine Public Health Laboratory to explore Great Lakes issues.

WRI's director has used the video in classroom instruction and will do so again in the future. He has received positive feedback from students. That is important since tight budgets mean some laboratory equipment is not being purchased and used as frequently as in the past. Students may not typically be exposed the equipment. In the absence of the opportunity for hands-on interaction, the videos can at least provide a chance to see the equipment.

At *http://www.seagrant.wisc.edu/home/Default.aspx?tabid=601&AudioGroupID=33*, visitors can download a WRI-sponsored seven-part audio podcast series. "Water, Wisconsin and the Mercury Cycle" details mankind's historic uses of mercury, Wisconsin's water resources and mercury in Wisconsin waters. A major part of the series also focuses on WRI-funded research on mercury.

WRI also produced an eight-episode "Aquifers and Watersheds" audio podcast series, which demystifies for general audiences these geological formations and the geoscience involved in studying them. Episodes are at bit.ly/1e5a1jQ.

Finally, in this reporting period, a new audio podcast series was completed. It is called "Undercurrents: The Hidden Knowledge of Groundwater." It has already won an international award from a competition known as AVA Digital.
*http://www.seagrant.wisc.edu/home/Default.aspx?tabid=601&AudioGroupID=52*

The WRI website *http://www.wri.wisc.edu* orients visitors to the Wisconsin program. One of the site's main audiences is researchers. To that end, the site provides a clear navigable path to the WRI project listing, project reports, a groundwater research database, funding opportunities and conference information sections. The areas are updated on a regular basis to ensure currency of information transfer. The WRI site had 69,977 visitors in this reporting period.

**AWRA 2016 Annual Conference – Another Communication Tool**

The Wisconsin Section of the American Water Resources Association conducts an annual meeting. WRI assisted with meeting planning and provides printed material. That means WRI took the lead on writing, editing, providing graphic design, printing and mailing of a conference registration brochure, and the writing, editing, graphic design and printing of the conference program. WRI joined other conference sponsors—the University of Wisconsin-Stevens Point Center for Watershed Science and Education, Wisconsin Department of Natural Resources, Wisconsin Geological and Natural History Survey and the U.S. Geological Survey's Wisconsin Water Science Center—to stage the event that attracted about 200 people.

**Post-Secondary Students Engaged in Water Education-An Audience Served**

During this reporting period, WRI staff were also integral to the content-population of *http://www.water.wisc.edu*. The site is a portal to the breadth and depth of water-related work on the University of Wisconsin System's flagship campus, the University of Wisconsin-Madison, and serves as the first stop for anyone interested in water research. Additionally, graduate

students can search for departments offering courses and degrees that fit their interests, and staff and faculty can search for colleagues working on topics that align with their own to facilitate greater interdisciplinary collaboration and exploration. The site had 35,421 visitors in this reporting period.

Building off this website and the collaborative nature of its contributors, WRI staff provided leadership in launching Water@UWMadison – A Wisconsin Idea Symposium, an event designed to bring water researchers and faculty from around the UW-Madison campus together to build awareness and collaboration.

In 2016, 50 water and water-related investigators from all divisions on campus presented to an audience of fellow academicians, elected officials and interested members of the public, including those representing water-centric non-governmental organizations. There were approximately 150 people in the audience. A white paper resulted from that symposium and in it was a recommendation to the chancellor that a water coordinator position be created to capitalize on the value of water scholarship. That position was filled in this reporting period. In 2017, another symposium was held, just beyond this reporting period, in May 2017. It drew more than 100 people who participated in a half-day program that featured presentations and ample networking opportunities.

**Wisconsin's Water Library as the Means to Transfer Information**

The Wisconsin Water Library is a unique resource for researchers, resource managers and all Wisconsin citizens. It contains more 30,000 volumes of water-related information about the Great Lakes and other waters of Wisconsin. The library includes a curricula collection, dozens of educational videos, children's collection, journals and newsletters. Each year, more than 1,000 publications circulate among interested patrons.

Wisconsin's Water Library continues to catalog all groundwater research reports from WRI projects into WorldCat and MadCat, two library-indexing tools. This ensures WRI's cutting-edge water exploration is broadly available locally, regionally, nationally and globally.

In addition to archival benefits, the library provides outreach by answering many in-depth reference questions on a wide range of water-related topics. It also provides a water research guide *http://researchguides.library.wisc.edu/waterscience*.

It is active on social media. It prepares recommended reading lists on topics such as climate change, groundwater, water conservation and water supply.

In partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator's Association (WWOA), the library has continued its long-term assistance to current and future drinking water and wastewater operators in Wisconsin. The library has cataloged the essential technical manuals into the library's collection and provides loans to WWOA members around the state in support of their required state license examinations as well as in support of the educational needs of their daily work.

The library's website, *http://www.aqua.wisc.edu/waterlibrary* was redesigned and relaunched in this reporting period. There were 111,152 visitors.

In addition to its website, Wisconsin's Water Library employs other technology tools to reach library patrons. Using email, the library sends out a bimonthly "Recent Acquisitions List" to about 500 contacts. The message also includes recent updates to the library website and contact information for users to ask any water-related question. The library also supports an email account at *askwater@aqua.wisc.edu*, which is monitored daily.

Finally, the library maintains an extensive curriculum collection of guides with innovative approaches and other educational materials for teaching water-related science in K-12 classrooms. The curricula are available for checkout by all teachers and residents in Wisconsin. The librarian also has extensive experience providing programming to Pre-K children. She has put that experience to use in developing field-tested science, technology, engineering, art and math (STE(A)M) activities and packaging them into curriculum kits. Each kit contains several books, tips on a guided water-science experiment and other themed activities. The kits will eventually number 27 on topics such as the water cycle, aquatic invasive species, art and water, and pond science. In the last year, the librarian estimates that 1,670 students were exposed to the material.

**Outreach Events**

To build water literacy, information transfer staff reached approximately 50 Wisconsin residents through six events conducted at public libraries in this reporting period. Staff also directly engages in or offers enrichment to Wisconsin K-12 teachers—207 in this reporting period, so that those teachers can take water information back into their classrooms. This represents a multiplying effect for the water literacy since one teacher can potentially share the knowledge with more than 40 or 50 students. In this reporting period, staff also facilitated teacher learning on two different Great Lakes research/educator cruises that involved 17 Wisconsin teachers.

**Notable Accomplishments**

The Information Transfer Program created an eye-catching traveling photography display, which also featured information related to Wisconsin's water assets as a means to expose larger and more diverse audiences to WRI's accomplishments. The display was installed in 24 venues around Wisconsin over a two-year period. Follow-up surveys indicated that a minimum of 119,274 people saw the display at its installations. News releases were distributed prior to the installation. An analysis of earned media related to the display provides an estimate of 611,511 people who were exposed to the messages of the display. A final note about audiences: The goal was to reach the very general audience of members of the public. However, exposure to influential state legislators was also a goal. Therefore, the display was booked in nine of the districts of members of the state's budget-writing committee. There are 16 members of that committee so more than half had constituents who would have seen the display and potentially been in touch with their representatives' offices to voice support for water-related polices.

# USGS Summer Intern Program

### Basic Information

| | |
|---|---|
| **Start Date:** | 3/1/2016 |
| **End Date:** | 2/28/2017 |
| **Sponsor:** | USGS Wisconsin Water Science Center |
| **Mentors:** | Charles P Dunning |
| **Students:** | Luke Loken |

### Internship Evaluation

| Question | Score |
|---|---|
| Utilization of your knowledge and experience | Good |
| Technical interaction with USGS scientists | Acceptable |
| Treatment by USGS as member of a team | Very Good |
| Exposure and access to scientific equipment | Very Good |
| Learning Experience | Good |
| Travel | About Right |
| Field Experience Provided | About Right |
| Overall Rating | A- |

### Additional Remarks

My interaction with the USGS in Middleton is fairly limited in my position. I don't think is necessarily a bad thing as I have developed my own connections with several USGS staff at other centers.

## Basic Information

| | |
|---|---|
| **Start Date:** | 7/1/2016 |
| **End Date:** | 2/28/2017 |
| **Sponsor:** | USGS Wisconsin Water Science Center |
| **Mentors:** | David P. Krabbenhoft |
| **Students:** | Ryan Lepak |

## Internship Evaluation

| Question | Score |
|---|---|
| Utilization of your knowledge and experience | Good |
| Technical interaction with USGS scientists | Good |
| Treatment by USGS as member of a team | Good |
| Exposure and access to scientific equipment | Good |
| Learning Experience | Good |
| Travel | About Right |
| Field Experience Provided | About Right |
| Overall Rating | A+ |

## Additional Remarks

I've thoroughly enjoyed this process.

| Student Support | | | | | |
|---|---|---|---|---|---|
| **Category** | **Section 104 Base Grant** | **Section 104 NCGP Award** | **NIWR-USGS Internship** | **Supplemental Awards** | **Total** |
| **Undergraduate** | 0 | 0 | 0 | 2 | 2 |
| **Masters** | 1 | 1 | 0 | 0 | 2 |
| **Ph.D.** | 1 | 0 | 2 | 1 | 4 |
| **Post-Doc.** | 1 | 0 | 0 | 1 | 2 |
| **Total** | 3 | 1 | 2 | 4 | 10 |

# Notable Awards and Achievements

University of Wisconsin Water Resources Institute Embraces Innovative Communication Tool to Build Water Literacy

The University of Wisconsin Water Resources Institute (WRI) has embraced the use of podcasting as an engaging and widely accessible means to share scientific concepts, along with news about WRI-funded research. In this reporting period, a new five-part audio podcast series was completed. It is called Undercurrents: The Hidden Knowledge of Groundwater http://www.seagrant.wisc.edu/home/Default.aspx?tabid=601&AudioGroupID=52. This series offers high production values and provides a comprehensive range of information about the hidden secrets of groundwater. It covers the earliest myths and conjectures about the mysterious waters that lie beneath our feet; scientific breakthroughs in comprehension of groundwater; and the frontlines alongside of the scientists, specialists and citizens who are working towards understanding and solving the daunting challenge of sustaining groundwater resources for future generations. The series has already won an international award from a competition known as AVA Digital. The AVA Digital Awards are conferred annually and attract an average of 2,500 entries from around the world. Entries come from the private sector, non-profit organizations, public entities and academic institutions. The awards are administered and judged by the Association of Marketing and Communication Professionals, which consists of several thousand production, marketing, communication, advertising, public relations professionals and freelance journalists. Podcasts offer great flexibility to their listeners, providing the option to play the material off a website or download episodes or the whole series to another device. The groundwater series is posted to the Wisconsin Sea Grant website, seagrant.wisc.edu, which is the sister organization to WRI. Other podcast offerings are series about aquifers and watersheds, mercury, aquaculture, and lakes Michigan and Superior. In 2016, the Wisconsin Sea Grant website had nearly 2.4 million visitors and the most frequently visited page was the aquaculture podcast page, with 179,799 visitors. The first episode in this new and award-winning groundwater podcast series was posted in July 2016. From then until the end of February 2017, there have been nearly 15,000 visitors to the page. Podcasts are a gateway to other material on the WRI and Wisconsin Sea Grant websites. Visitors come to access the podcasts and are afforded the opportunity to explore other online features.

University of Wisconsin Water Resources Institute Partners With Wisconsin Sea Grant to Reach Millions of People

Wisconsin s Water Resources Institute (WRI) and Sea Grant Institute are housed together administratively at the Wisconsin Aquatic Sciences Center (ASC). This structure enables synergies related to water impacts and outreach efforts. The communications team works to extend research results to the people of Wisconsin and beyond. This occurs in a variety of ways, by interacting with investigators and telling the stories of their work through writing, video and podcasts and then sharing these products in a variety of ways (website, social media, newspapers, campus news, television, community events, etc.). A list of 2016 WRI-specific and general ASC communications accomplishments (not including those outreach efforts that are exclusively related to Sea Grant; e.g. Sea Grant website and products) are below. Over the past year, our center, in some form, reached more than 7.5 million people in telling the stories related to Wisconsin s water resources.

WRI and ASC Communications team summary during 2016 WRI Website 59,959 ASC Earned media, 193 News Stories 7,495,567 ASC Chronicle, hard copy 2,400 ASC Chronicle, electronic copy 3,269 ASC Chronicle, online visitors 36,615 ASC Publications Store 29,007 ASC Social media 5,455

The University of Wisconsin Water Resources Center increases emphasis on science impacts through Actionable Science initiative

In federal FY16, we increased our emphasis on achieving societal impacts as a result of both federal- and state-funded projects. We maintained a series of Web pages on the concept of Actionable Science (http://www.seagrant.wisc.edu/home/Default.aspx?tabid=509) for Wisconsin investigators to highlight the opportunities and challenges associated with conducting stakeholder-engaged research, developed descriptive (gold, silver, bronze medal) standards for PIs in outreach, and added a section on outreach in the state-issued call for proposals, reviewer rating criteria, and a mechanism for submitting stakeholder support letters with proposals. Collectively, these actions resulted in notable improvements in the latest round of proposals we received. To provide student opportunities for Actionable Science, we continued with our second Water Resources Fellowship in partnership with the Wisconsin Department of Natural Resources (DNR). This 50:50 partnership funded a full-time postdoctoral fellow working on linking total suspended solids in streams to phosphorus loads.