Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 045-B**

Developing a Map of Arsenic Risk in Groundwater

Category: B. Water Resources

Total Project Budget: $ 550,000

Proposed Project Time Period for the Funding Requested: 4 years, July 2018 to June 2022

Summary:

Over 20% of private wells in west- and south-central Minnesota exceed the arsenic standard. Proposed arsenic risk map will transform 20 years of arsenic research into access to cleaner groundwater.

Name: G.-H. Crystal Ng

Sponsoring Organization: U of MN

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Location

Region: Central, Metro, Northwest, Southwest, Southeast

County Name: Becker, Blue Earth, Brown, Carver, Clay, Clearwater, Douglas, Grant, Hennepin, Kandiyohi, Le Sueur, Mahnomen, McLeod, Meeker, Nicollet, Norman, Otter Tail, Pope, Redwood, Renville, Scott, Sibley, Stevens, Traverse, Wilkin, Wright

City / Township:

Alternate Text for Visual:

Top: Title is “Arsenic threat in Minnesota’s groundwater resources.” State map shows percentage of private wells in each county with arsenic concentrations exceeding EPA’s limit of 10 micrograms of arsenic per liter of water. Many counties in west-central and south-central have >20% wells exceeding the limit. List of effects from long-term consumption of elevated arsenic: “increased risk of bladder, liver, and lung cancers; reduced intelligence in children; nervous system problems; high blood pressure; and skin damage.” Bottom: Title is “Proposed solution.” Subtext is: “Arsenic Risk Map and Well-installation Guidance for arsenic-prone regions of Minnesota.” Arrows pointing to west-central and south-central areas highlighted on state map. Flow diagram showing: “Activity 1: Develop arsenic risk map in arsenic-prone regions using statistical modeling and strategic field measurements.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Developing a Map of Arsenic Risk in Groundwater

I. PROJECT STATEMENT

About **100,000 families across Minnesota use private wells that contain arsenic** concentrations greater than the U.S. Environmental Protection Agency's drinking water standard of 10 micrograms of arsenic per liter of water. Drinking water with elevated arsenic concentrations causes an **increased risk of certain cancers and other developmental and health problems**. Arsenic contamination in groundwater is particularly acute in the west-central and south-central parts of the state (see map), where 300,000 Minnesotans rely on private well water, and over 20% of private wells exceed the arsenic standard. To help protect against arsenic exposure, the Minnesota Department of Health (MDH) now requires each new drinking water well to be tested for arsenic. Unfortunately, the information comes only after the well has been drilled. Currently no resources exist to help homeowners and well-drillers in advance to avoid arsenic in wells; our project will **enable proactive and cost-effective installation of safer wells**. Through strategic field measurements and state-of-the-art modeling, we will create **maps of arsenic risk in the state's most arsenic-prone regions** and provide **guidance for accessing clean groundwater** – one of Minnesota's most vital natural resources.

Our project will build on more than 20 years of arsenic data and research completed by state agencies, the University of Minnesota (UMN), and the U.S. Geological Survey (USGS). It will extend and transform scientific findings by the project PIs into usable information for guiding well installations. The goal is to help Minnesotans place their wells where the probability of safe drinking water aquifers is highest. To accomplish this, we propose to map locations of high arsenic risk in Minnesota using a statistical model currently developed by the USGS, which will be validated and enhanced through new sediment and groundwater measurements and process-based hydrogeochemical modeling. The outcome of this research will be a web-based, three-dimensional interactive map showing arsenic risk to inform policy makers, homeowners, and well-drillers in the most arsenic-prone regions of Minnesota.

- Arsenic in drinking water affects the health of hundreds of thousands of Minnesotans
- The sources and extent of arsenic in groundwater resources currently remain elusive
- Our project integrates previous State investments (e.g. County Geologic Atlas Program, Clean Water Fund) and applies novel approaches to a water quality issue for which there is no current solution
- Our goal is help Minnesotans place wells where the probability of clean groundwater is highest

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop arsenic risk map using statistical modeling and strategic field work Budget: $248,839

Statistical modeling of arsenic, a promising method newly developed by the USGS, will serve as the launching point for our proposed map. Co-PI Erickson will lead an evaluation of the statistical modeling that will identify "regions-of-concern," where arsenic concentrations are correctly predicted as high or incorrectly predicted as low. Field-based investigations needed to address these regions-of-concern will be led by Co-PI Toner in collaboration with the Minnesota Geological Survey (MGS). MGS has offered access to sediments from archived cores and upcoming rotosonic coring from the County Geologic Atlas program. We will select about 6 drilling locations within regions-of-concern. Maximally leveraging investments in the County Geologic Atlas, we will aim to complete monitoring wells at 3 drilling locations. We will target low water-yielding aquitards, which are under-monitored but can be arsenic sources. Water chemistry data compiled by MDH and other state agencies will also be used. Paired analyses of core sediments, which release arsenic, and groundwater, where arsenic can impact wells, will provide the arsenic source information needed for mapping arsenic risk in aquifers.

Outcome	Completion Date
1. Preliminary map of predicted arsenic risk using statistical modeling	10/1/2018
2. Identification of regions-of-concern with high arsenic or poorly predicted risk	12/1/2018
3. Measurement of sediment arsenic sources to groundwater	1/1/2020
4. Field data-based corrections to the arsenic risk map in regions-of-concerns	7/1/2020

Activity 2: Provide guidance to well-drillers through hydrogeochemical modeling **Budget: $171,041**

PI Ng will lead process-based hydrogeochemical modeling to extend the arsenic risk map from Activity 1 and generate actionable recommendations for well installations. Using detailed field observations from Activity 1, we will develop a computer model that can further identify arsenic risk where detailed field data are unavailable and statistical models are uncertain. Augmenting information from the maps, simulations with different well depth configurations, implemented across arsenic-prone regions in the state, will lead to new guidelines that can aid in the installation and usage of safer drinking water wells.

Outcome	Completion Date
1. Development of process-based hydrogeochemical model of groundwater arsenic	12/1/2020
2. Extended arsenic risk map across arsenic-prone regions in Minnesota	5/1/2021
3. Well installation guidelines based on location, depth, and real-time observations	6/30/2022

Activity 3: Create web-based mapping tools for the public and well-drillers **Budget: $ 130,000**

Co-PI Erickson will lead enhanced statistical modeling that will incorporate new field data and process-based modeling results to generate an improved map of high groundwater arsenic concentration occurrences in arsenic-prone regions of Minnesota (west-central and south-central). The USGS's "story maps" will serve as a ready template that is proven to be effective for communicating with the public. Arsenic maps will be published as web-based, interactive maps of arsenic risk for use by policy makers, homeowners, and well-drillers.

Outcome	Completion Date
1. Development and online publication of an interactive arsenic risk map	6/30/2022

III. PROJECT STRATEGY

A. Project Team/Partners

Project team members requesting funds:

- PI Gene-Hua "Crystal" Ng (Assistant Professor, UMN): currently developing process-based hydrogeochemical model that can simulate arsenic fate and transport in groundwater
- co-PI Brandy Toner (Associate Professor, UMN): determined geochemical processes releasing arsenic to groundwater in Traverse-Grant and Upper Minnesota River Basin areas
- co-PI Melinda "Mindy" Erickson (Hydrologist, USGS): identified well placement as a contributing factor for arsenic in well water; currently leading the USGS's statistical modeling of arsenic risk

Project partner NOT requesting funds:

- Dale Setterholm (Associate Director, MGS): coordinates County Geologic Atlas program

B. Project Impact and Long-Term Strategy

The project will produce web-based arsenic risk maps and well installation guidelines that will allow homeowners and well-drillers to more efficiently access clean groundwater. Our map will serve 26 arsenic-prone counties in west-central and south-central Minnesota, including counties with high trends in recent private well installations. Over 2008-2016, Becker, Otter Tail, and Wright counties each tested over 1,000 new privates wells, and Douglas, Hennepin, and Kandiyohi counties also each tested over 500 new privates wells. Six of the counties currently use Red River water but are projected to shift to groundwater as surface waters become susceptible to changing climate. The proposed work will crucially provide a less-costly, proactive approach of safer well installations under continued and new groundwater development in west-central and south-central Minnesota. The hydrogeochemical model developed in the project will be a ready resource for future arsenic assessments throughout the state, and it can serve to evaluate other groundwater quality concerns, such as manganese.

C. Timeline Requirements

The proposed project will be completed in 4 years (July 2018-June 2022). Fieldwork and modeling will be completed in 3 years, but the 6-9 month USGS review process for publications necessitates a 4-year request.

2018 Detailed Project Budget

Project Title: Developing a Map of Arsenic Risk in Groundwater

IV. TOTAL ENRTF REQUEST BUDGET **4 years**

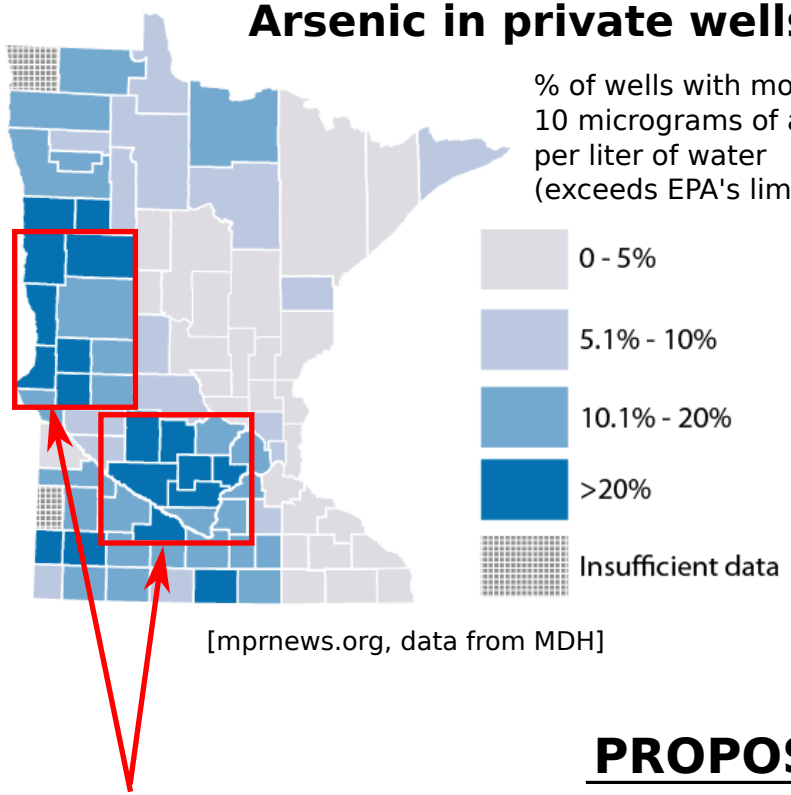
BUDGET ITEM	AMOUNT
Personnel	$485,630
Dr. G.-H. Crystal Ng, lead PI (professor, UMN-TC, Dept of Earth Sciences), 6% FTE (4 summer weeks in Yrs 1-3), 75% salary, 25% benefits. Will lead Activity 2 and advise graduate students. **$34,932.**	
Dr. Brandy Toner, co-PI (professor, UMN-TC, Dept of Soil, Water and Climate), 4% FTE (3 summer weeks in Yrs 1-3), 75% salary, 25% benefits. Will lead field work and advise graduate students. **$31,815.**	
Dr. Mindy Erickson, co-PI (research hydrologist, USGS), 4% FTE, 73% salary, 27% benefits. Will lead statistical modeling and Activity 3. **$36,100.**	
2 graduate students in each year, 50% FTE, 42% salary, 58% benefits (includes tuition). Student #1 (#2) will primarily carry out Activity 1 (2). Both will contribute to all Activities. **$268,883.**	
2 USGS staff scientists 1 hydrologist (9% FTE) - statistical model, 1 GIS technician (8% FTE) - interactive maps (73% salary, 27% benefits). **$113,900.**	
Professional/Technical/Service Contracts: Sediment and groundwater analyses at UMN-TC. Sediment surface imaging $3000. Sediment core and groundwater chemistry at internal rates (100 sediment samples at $84/sample, 24 groundwater samples at $64/sample).	$ 12,936
Equipment/Tools/Supplies:	$ 26,305
Groundwater wells at MGS's rotosonic sites - no additional drilling costs. Per well: installation $4,850; MDH permit $235; well sealing $2,500. 3 wells. **$24,255.**	
Field Supplies. Beyond existing tools: mylar bags (IMPAK Sorbent Systems $100); oxygen scavengers (AnaeroPack $200); inert gas ($400); safety equipment ($200); plastic vials ($300), pump ($200). **$1,400.**	
Computer supplies. External hard drives for back-up, replacement parts for computers used for intensive modeling. **$650.**	
Travel:	$ 25,009
For sediment sampling and well installations. Trips for ~5 rotosonic core drillings, including well installations. If fresh cores unavailable, archived cores will be sampled at the DNR facility in Hibbing. Trips could include travel to Otter Tail, Wilkin, Traverse, Stevens, Grant, and Douglas Counties to correspond to MGS coring. Using Fergus Falls, Otter Tail County as a representative (362 miles round trip), 1 trip for 2 people, 5 days: U of M van ($61/day, $0.23/mile), and GSA per diem ($91/person/day lodging and $51/person/day meals). 5 trips. **$9,041.**	
For groundwater sampling. ~500 miles travel to all sites, estimated from 362 miles for direct round trip to Fergus Falls. U of M van: $61/day, $0.23/mile. 4 trips/yr over years 1-2. **$1,408.**	
To sediment analyses at Lawrence Berkely National Lab (CA). Highly specialized instrumentation (micro-probe XAS and XRD) to measure chemical forms. NOT AVAILABLE in-state. Instrument time is FREE, but funds needed for travel for 2 people for four 7-day trips. Airfare to San Francisco, car rental, and GSA per diem for lodging and meals: $3640/trip. **$14,560.**	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 549,880

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT
Other Non-State $ To Be Applied To Project During Project Period: USGS cooperative matching funds for indirect costs not paid by ENRTF requested funds.	$ 50,000
Other State $ To Be Applied To Project During Project Period: N/A	$ -
In-kind Services To Be Applied To Project During Project Period: In-kind UMN-TC facilities corresponding to Indirect costs not paid by ENRTF requested funds.	$ -
Past and Current ENRTF Appropriation: N/A	$ -
Other Funding History: N/A	$ -

ARSENIC THREAT IN MINNESOTA'S GROUNDWATER RESOURCES

Arsenic in private wells



[mprnews.org, data from MDH]

Long-term Consumption of Elevated Arsenic

- Increased risk of bladder, liver, and lung cancers
- Reduced intelligence in children
- Nervous system problems
- High blood pressure
- Skin damage

PROPOSED SOLUTION

Arsenic Risk Map and Well-Installation Guidance
for arsenic-prone regions of Minnesota

Activity 1
Develop arsenic risk map in arsenic-prone regions using statistical modeling and strategic field measurements

Activity 2
Extend arsenic risk map and provide guidance to well-drillers through hydrogeochemical modeling

Activity 3
Create web-based, interactive mapping tools to help the public access cleaner groundwater

Project Manager Qualifications & Organizational Description

Gene-Hua "Crystal" Ng
Assistant Professor of Hydrogeology
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Professor Ng joined the Department of Earth Sciences at the University of Minnesota in April 2014 following a position as a Research Hydrologist at the US Geological Survey (USGS) in Menlo Park, CA. She is also a graduate advisor in the Water Resources Sciences program at the University of Minnesota. Her research focuses on integrating computational models and field data to understand interactions among climate, vegetation, biogeochemical processes, groundwater, and surface water systems.

In past work, she evaluated groundwater recharge impacts due to grassland conversion to crops in the Southern High Plains. She also modeled recharge changes in that region under different climate scenarios. In the Mojave Desert, she implemented a model to identify hydrogeological feedbacks relating shrub growth and rainfall patterns. Her past work has also included groundwater contamination studies, including one examining impacts of the 1979 oil spill near Bemidji, MN, and another evaluating aquifer recovery below a former wastewater disposal site on Cape Cod, MA.

Since arriving at the U, Professor Ng has started a number of Minnesota-focused projects. She has been developing coupled groundwater / geochemical models to investigate the role of groundwater-surface water interactions in how sulfate impacts wild rice in northeastern Minnesota. She has also developed a groundwater / geochemistry model to predict sulfate levels leaving a taconite mining basin on the Iron Range. This past year, she began collaborating with project PI Brandy Toner on preliminary development of a groundwater / geochemical model that can simulate arsenic in sediments and groundwater. Her newest project funded by the LCCMR (started 7/1/17) will produce a model that estimates state-wide recharge under changing vegetation. Her previous and on-going projects on water quality and hydrogeological modeling provide the qualifications needed for the proposed project on arsenic release in Minnesota aquifers.

In addition to her commitment to research, Ng is passionate about her General Hydrogeology and Hydrogeology Field Camp courses at the U. She is seeking ways to engage students and expose them to important hydrogeological applications and techniques.

Ng was a Mendenhall postdoctoral fellow at the USGS (2010-2011) after working as a postdoctoral research associate at MIT (2009). She received her PhD in Environmental Engineering from the MIT (2009) and her BA in Applied Mathematics from Harvard University (2003).

Department of Earth Sciences, University of Minnesota - Twin Cities

The Department is part of the Newton Horace Winchell School of Earth Sciences and belongs to the College of Science and Engineering at the University of Minnesota. It includes about 25 full faculty members and it awards bachelors, masters, and doctorate level degrees in Earth Sciences and various sub-disciplines, including hydrogeology. A number of on-going research projects in the department focus on Minnesota water resources issues, including in the karst region of southeast Minnesota and in watersheds and surface waters with high sulfate and mercury.