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

Project Title: **ENRTF ID: 060-B**

Improving Water Quality by Capturing Sulfate in Wetlands

Category: B. Water Resources

Total Project Budget: $ 578,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

The overall goal of this project is to provide effective strategies for removing excess sulfate, a priority pollutant, from mining discharge waters in northeastern Minnesota and improving water quality.

Name: Cara Santelli

Sponsoring Organization: U of MN

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Web Address

Location

Region: Northeast

County Name: Itasca, Lake, St. Louis

City / Township:

Alternate Text for Visual:

Top: Map of northern Minnesota shows elevated sulfate concentrations in northeastern Minnesota due to industrial activities. Bottom: Conceptual diagram demonstrating the myriad of hydrogeological, microbial, and geochemical factors affecting sulfate capture in wetlands and streams.

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

PROJECT TITLE: Improving water quality by capturing sulfate in wetlands

I. PROJECT STATEMENT

Elevated sulfate in watersheds is of immediate environmental concern in Minnesota. Wetlands provide a way of naturally capturing excess sulfate to **improve water quality** and **environmental health**. Many factors contribute to the effectiveness of wetlands for capturing sulfate. These factors must be clearly identified in order to develop better sulfate-water discharge practices and sulfate remediation technologies -- strategies that will allow **continued industry success** while achieving **cleaner water.** The overall goal of this project is to provide **effective strategies for removing excess sulfate from mining discharge waters in northeastern Minnesota and improving water quality**.

This primary goal will be accomplished by:

- Determining the primary factors that control sulfate capture in natural wetlands
- Developing a predictive tool for maximizing sulfate capture in wetlands
- Providing guidance for sulfate-water mining discharge practices to promote wetland capture
- Providing design targets for constructed wetlands to enhance sulfate remediation

Building off previous sulfate studies by the MPCA, DNR, and other state researchers, we will examine three wetlands on the Iron Range with sulfate-rich surface waters from permitted mining operation discharges. These sites represent the range of sulfate concentrations that occur throughout northern Minnesota. We will assess the geochemistry, microbiology, and hydrogeology of these natural wetlands throughout several years to determine how these interconnected factors drive the removal of sulfate from mining discharge waters throughout different seasons. Although the proposed work is centered on mining discharges, sulfate-rich discharges are also a concern from other industries, such as ***mineral processing facilities,*** as well as ***municipal water and wastewater facilities***. Our work could further provide guidance to **Minnesota-wide industries and townships** for managing sulfate discharges that adhere to, or even surpass, water quality regulations. This project will help Minnesota continue to lead as a steward of its natural resources and environment.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Evaluate the extent of sulfate capture in natural wetlands **Budget: $ 249,000**

As sulfate-rich waters migrate through wetlands and downward into the subsurface, sulfate is captured by undergoing transformations to other sulfur forms (such as iron sulfide or elemental sulfur) that are retained in wetland sediments. Not all transformed sulfur forms, however, are retained for longer-term (e.g., more than one season) storage of sulfur; thus, it is imperative to characterize and quantify all the different sulfur forms in wetland porewaters and sediments. We will collect and analyze the sulfur geochemistry of surface waters, porewaters, and sediment cores from 3 different wetlands in the Iron Range. Samples will be taken throughout each site over two consecutive years in order to evaluate increases or decreases in sulfate capture during different seasons and in varying sediment properties. Multiple techniques are required to measure the different sulfur forms and environmental geochemistry involved in sulfate capture. We will use ion chromatography, colorimetric techniques, X-ray absorption spectroscopy and ICP-MS to analyze our samples.

Outcome	Completion Date
1. Determine sulfur forms and concentrations through time and space within wetlands	Oct. 31, 2020
2. Identify where and when the most sulfur is retained within wetland sediments	Oct. 31, 2020

Activity 2: Identify factors controlling sulfate capture in wetlands **Budget: $ 157,000**

Environmental factors (pH, temperature), the overall geochemistry of the system, the hydrogeologic flow conditions, and the quantity and types of microorganisms present all result in sulfur transformations and, importantly, sulfate capture within wetland sediments. Some factors improve long-term sulfate capture (e.g.,

higher infiltration rates into sediments, where sulfate can be transformed), while other factors inhibit or reverse sulfate capture (e.g., cold temperatures that hinder the activity of microorganisms that transform sulfate). Using samples and data collected in Activity 1, we will assess the geochemical, microbiological and hydrogeologic flow conditions that impact the sulfur geochemistry. Microbial communities naturally occurring within wetland sediments will be assessed by high throughput DNA sequencing, and key organisms that promote sulfur transformations will be identified and quantified. Hydrogeologic flow will also be assessed through space and time by installing monitoring wells throughout the streams and wetlands. These parameters will be used to develop and implement the predictive model in Activity 3.

Outcome	Completion Date
1. Identification of hydrogeologic flow parameters that promote sulfate capture	Nov. 31, 2020
2. Identification of microorganisms that promote sulfur transformation within wetlands	Dec. 31, 2020

Activity 3: Guide regional sulfate discharge and remediation practices with modeling Budget: $ 172,000

Measurements from Activities 1 and 2 will be used to develop a hydrogeochemical model that can simulate the sulfate capture capacity of a wetland under different environmental conditions. The model will allow us to extrapolate beyond the measurements from the intensive monitoring study sites and evaluate current and future water quality throughout region. Specifically, we will implement the model to assess different scenarios of sulfate-water flow (e.g., seasonal timing, flow rate, and concentration levels) and wetland properties (e.g., sediment properties, temperature, and vegetation cover). Simulated results will be used to generate guidance for townships and industries to implement discharge practices and design constructed wetlands that generate the highest water quality in our watersheds. Recommendations will be published in reports to be circulated to municipalities and private companies through our partnership with the DNR.

III. PROJECT STRATEGY

A. Project Team/Partners

Project partners receiving ENRTF funds (all at University of Minnesota, Department of Earth Sciences):

- Dr. Cara Santelli: Expertise in biogeochemistry of natural and polluted environments
- Dr. Crystal Ng: Expertise in hydrologic models, has established work on sulfate and groundwater on the Iron Range
- Dr. Amy Myrbo (LacCore facility): Will assist with coring and sampling activities.

Project partners not receiving funds:

- Dr. Megan Kelly (MNDNR): Will provide field and geochemical data from the DNR to supplement the current project data and will assist with accessing field locations and sampling.

B. Project Impact and Long-Term Strategy

Quantifying sulfate capture in wetlands and the factors facilitating it will guide major stakeholders in implementing water discharge practices that can **enhance sulfate removal** and **generate cleaner water** in our watersheds. Although mining discharge areas are the focus of the current study, results can be expanded to inform discharge practices from wastewater municipalities and other industries throughout the state. Furthermore, assessing sulfate capture by natural wetlands will provide strategic information for developing constructed wetland bioremediation systems for removing sulfate prior to entering the environment. The hydrogeologic model developed in this project will serve as a ready tool for future assessments of sulfate capture in northeast Minnesota and beyond. Information generated from this work will be disseminated through scientific publications, a publicly available report, and discussions with our project partners at the DNR and interested stakeholders.

C. Timeline Requirements

The proposed project will be completed within three years.

2018 Detailed Project Budget

Project Title: *Improving water quality by capturing sulfate in wetlands*

IV. TOTAL ENRTF REQUEST BUDGET *3* years

BUDGET ITEM	AMOUNT
Personnel:	$ 432,000
Dr. Cara Santelli, lead PI (professor, UMN-TC, Dept of Earth Sciences), 7.7% FTE (4 summer weeks each year), 75% salary, 25% benefits. Will lead Activity 1 and 2 and particpate in Activity 3 and will advise graduate students. (Total = $38,053)	
Dr. Gene-Hua (Crystal) Ng, co-PI (professor, UMN-TC, Dept of Earth Sciences), 7.7% FTE (12 summer weeks total), 75% salary, 25% benefits. Will lead Activity 3 and participate in Activities 1 and 2, and will advise graduate student. (Total = $34,932)	
2 PhD students in each year, 1 MS for years 1 and 2: 50% FTE, 42% salary, 58% benefits (includes tuition). PhD Student #1: geochemistry and field work, PhD Student #2: mechanistic model. MS Student: Microbiology and field work (Total = $359,255)	
Professional/Technical/Service Contracts	$ 77,000
DNA sequencing and quantification at the UMN Genomics Center for microbiological community analysis: DNA Sequencing for entire project ($17850) and qPCR analysis ($1584) . (Total=$19,434)	
Groundwater wells: shallow installation ($4500/well/new site; 8 new wells total; based on quote from Traut companies plus cost for finishing / securing well and removal at project end) (Total=$36,000)	
Sediment Coring assistance with LacCore at UMN: full quote includes technician assistance with coring equipment, technician travel, coring equipment, core sampling, sampling tools, boat rental for river access; $1,292/trip for 12 trips. (Total=$15,504)	
Trace metal and gas geochemistry analysis at UMN Earth Sciences Analytical Facility ($32/ sample; 180 samples total of sediment extracts, pore waters and surface waters) (Total=$5,760)	
Equipment/Tools/Supplies:	$ 45,000
Geochemistry and analytical supplies for ion chromatography and specrophotometry analysis: Ion-chromatography columns, guards and replacement supplies ($14,600), reagents ($3,200), plasticware ($1,500), gas tanks($200) Total=($19,500)	
Field and lab supplies: Sampling equipment (1300), sample storage ($3000), filtering supplies ($1500), consumable sampling and lab supplies ($5000). Total=$(10,800)	
Supplies for microbial community and activity measurements: DNA extraction kits ($2000), DNA amplification supplies ($3000), cDNA reagents ($2000). (Total=$7000)	
Miscellaneous Computer Supplies: hard drives ($500), replacement parts ($500). (Total=$1000)	
Pressure transducers for hydrology: transducers ($800 each; 4 total). (Total=$3200)	
Supplies for groundwater sampler and piezometer construction: PVC pipes, screens, plastic drums, tubing, stakes, wiring, data loggers. (Total=$3000)	
Travel:	$ 24,000
Argonne National Lab for geochemistry analytical facilities REQUIRED to quantify specific sulfur forms using instrumentation NOT AVAILABE IN MN. These instruments are ONLY available at national labs. Instrument time is FREE, but travel funds needed. 2 people needed to staff instrument over 6 days. Travel for two people/trip ($1950): round trip airfare to Chicago ($500), car rental ($200), lodging ($850), M&IE ($400); 4 trips. (Total=$7800)	
Iron Range field sites for sampling: 12 trips (3 days; 2 nights; 4 people); cost per trip $1067. Per trip costs: Fleet vehicle ($183), mileage ($0.23/mile; 800 miles); hotel ($340); meals ($360)	
Field sites for groundwater peeper installation: 12 trips (1 day each) for 2 people; $245 per trip. Costs include UMN fleet rental ($61) and mileage ($0.23/mile; 800 miles)	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 578,000

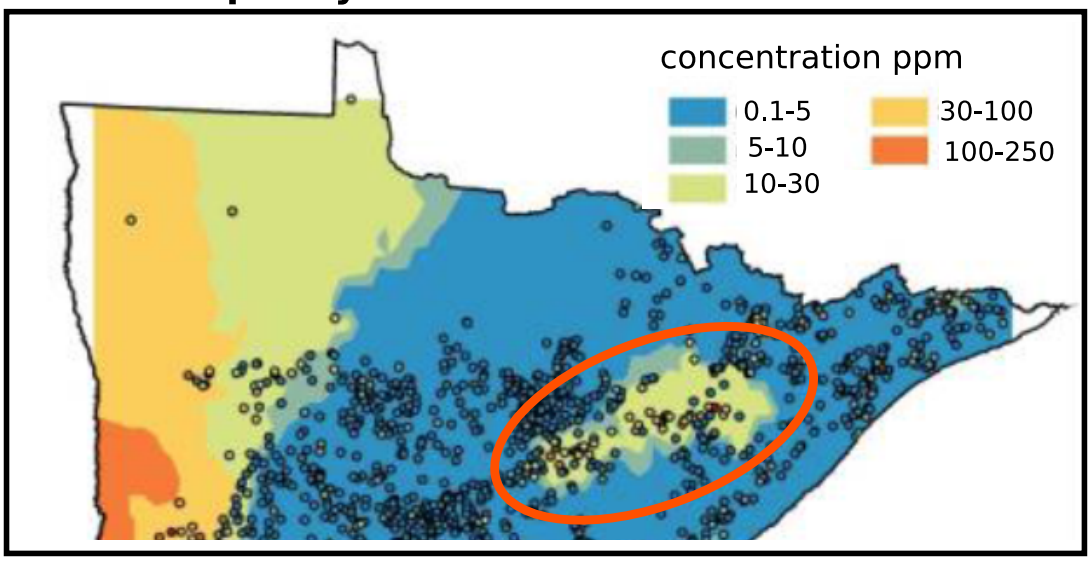
V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	NA	
Other State $ To Be Applied To Project During Project Period:	NA	
In-kind Services To Be Applied To Project During Project Period: Dr. Megan Kelly (MN DNR) will provide in kind assistance by providing supplemental DNR-collected data on water discharge and chemistry, field sampling, and working with interested mining companies. Additionally, In kind F&A costs (54%) are not allowed on the proposal at an estimated $312,000.	$ 312,000	*Pending*
Past and Current ENRTF Appropriation:	NA	
Other Funding History:	NA	

Improving Water Quality by Capturing Sulfate in Wetlands

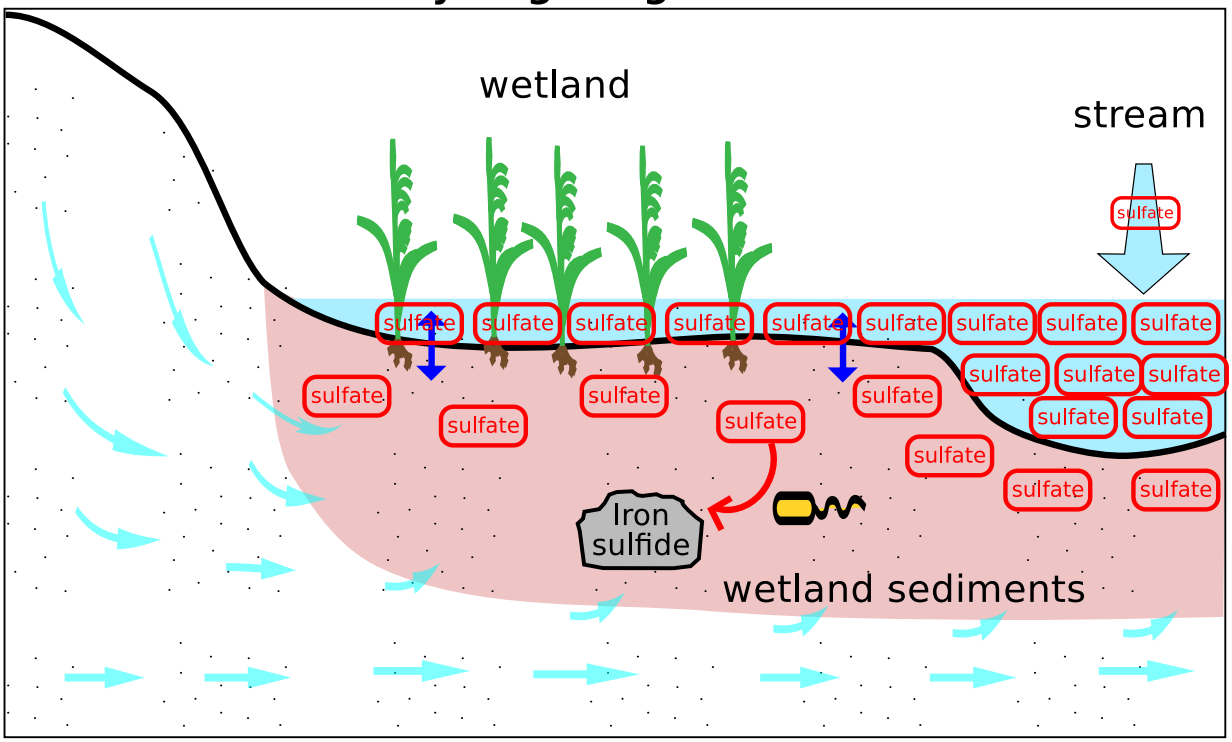
Threat to Our Watersheds

Elevated sulfate concentrations - a water quality concern in northeast Minnesota



Our Proposed Solution

Wetlands soils can capture sulfate - depending on geochemical, microbial, and hydrogeologic factors



Project Manager Qualifications & Organization Description

Cara M. Santelli, PhD
Assistant Professor
Department of Earth Sciences, BioTechnology Institute, MnDRIVE
University of Minnesota

B.S. Geology and Geophysics, 2000, University of Wisconsin, Madison
Ph.D. Geomicrobiology, 2007, Massachusetts Institute of Technology, MIT/WHOI Joint Program in Oceanography, Cambridge, MA

Dr. Cara Santelli is an interdisciplinarily trained scientist whose research examines the impact of microbial activity on geological and environmental processes such as mineral formation, mineral alteration and weathering, metal and metalloid redox transformations, nutrient biogeochemical cycling, and the remediation of polluted environments. Dr. Santelli's specific research objectives are driven by conducting fundamental scientific research on environmentally relevant biogeochemical processes and key elements in nature that are further influenced by anthropogenic activities, such as mining and agriculture. Research in her lab utilizes diverse techniques, ranging from metagenomics, genomics, and transcriptomics to understand microbial communities and molecular mechanisms associated with specific biogeochemical activities to mineralogical X-ray and spectroscopic techniques to identify and characterize biomineralization products and stability of these products in a changing environment. In addition to answering key questions on the mechanisms, metabolic pathways, and geochemical impact of mineral-microbe interactions, research in the Santelli lab seeks to inform and improve strategies for remediating inorganic pollutants to improve the quality and health of water and soil environments. Dr. Santelli is currently a co-PI on an unrelated ENRTF-funded project "Reducing Salt and Metal Removal Costs with Microbes", 2016-2019. She is also currently funded by the National Science Foundation to improve bioremediation technologies for the remediation of coal mine drainage. Dr. Santelli has published numerous scientific studies related to the transformation of metals and pollutants by microorganisms in impacted environments and in engineered remediation systems. Dr. Santelli is also developing new collaborations with Minnesota engineering firms for the development of novel bioremediation technologies for metal and metalloid pollutants.

Dr. Santelli will lead the project in collaboration with co-PI Dr. Crystal Ng and collaborators Dr. Amy Myrbo and Dr. Megan Kelly. Dr. Santelli will oversee the project timeline and ensure timely and successful implementation of the project activities. Dr. Santelli and Dr. Ng are currently working together on a project in Northern Minnesota to collect preliminary data for selecting the best field locations and for initiating development of the mechanistic model by building on a much simpler model (developed by Dr. Ng) that does not yet incorporate complex sulfur chemistry and microbiological data.

Organization Description
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). Dr. Santelli, Dr. Ng, and Dr. Myrbo all reside in the Department of Earth Sciences in the College of Science and Engineering. Dr. Santelli is also a member of the BioTechnology Institute (BTI), A number of on-going research projects in the Earth Sciences department and BTI focus on Minnesota water resources and bioremediation issues, including in the mining region of northeast Minnesota and in watersheds and surface waters with high sulfate and mercury. The laboratories and offices of the PI and co-PI contain the necessary fixed and moveable equipment and facilities needed for the proposed studies.