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

Project Title: **ENRTF ID: 090-B**

Determining which Iron Minerals Remove Phosphorous from Stormwater

Category: B. Water Resources

Total Project Budget: $ 384,591

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

Summary:

Iron-enhanced sand filters installed throughout Minnesota are exhibiting mixed effectiveness. We hypothesize that only certain iron minerals will remove phosphorous from water; we propose to determine which minerals work.

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Location

Region: Statewide

County Name: Carver, Dakota, Hennepin, Scott

City / Township:

Alternate Text for Visual:

This project will determine which iron minerals (e.g., goethite, magnetite, └ferrihydrite, etc.) are most effective at removing excess phosphorous from └water, thereby improving water quality in urban and rural environments.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: Determining which iron minerals remove phosphorous from stormwater

I. PROJECT STATEMENT

Excess phosphorous is a water quality problem affecting storm runoff, rivers, and lakes in urban and agricultural settings throughout Minnesota, causing algal blooms, making lakes green, and negatively affect fish and wildlife. More than 50 iron-enhanced sand filter basins have been installed throughout Minnesota since 2009 to remove phosphorous from water, and many more are scheduled for installation with costs ranging from $30k-$300k each. The physical and hydrological properties of enhanced iron-sand filters are well known, but their chemical properties are not (Table 1). The iron-enhanced sand filter systems that are currently installed are not all working effectively. **We hypothesize that only certain iron minerals will remove phosphorous from water, and our proposed work is to determine which iron minerals make iron-sand filters work efficiently.**

Table 1. Iron-enhanced sand filters: research and development status	**Known**	**Unknown**
Hydraulic conductivity range	X	
Speed of water flow through filter	X	
Filter longevity: Physical sediment clogging	X	
Filter longevity: Chemical capacity to hold phosphorous		X
Quantity of total iron for long-term effectiveness in filtering		X
Specific iron minerals that effectively bind with phosphorous		X

The favored iron source for iron-enhanced sand filter systems is an iron-rich powder recycled from industrial waste. We expect that the iron within this product will be a mixture of at least six separate forms of iron minerals, tabulated below (Table 2), and each mineral will have a different ability to remove phosphorous from water. The current design criteria adopted by the Minnesota Pollution Control Agency specifies that after combining iron powder with sand, filter systems must have 5-8% iron. We believe that future design criteria need to specify a percent of each iron mineral to avoid wasting money on filter systems that use ineffective iron products.

Table 2. Iron minerals expected in recycled industrial waste	**Estimated capacity to bind phosphorous**	**Detectable & quantifiable by magnetic methods < 100 ppm**	**Detectable by X-ray diffraction < 100 ppm**
Ferrihydrite, disordered	High affinity for P binding	yes	no
Goethite, FeO•OH	Common in environment, binding w/P unknown	yes	no
Magnetite, Fe_3O_4	Correlates w/heavy metals, binding w/P unknown	yes	no
Metallic Iron, Fe	Unstable in environment, binding w/P unknown	yes	no
Hematite, Fe_2O_3	Low P adsorbability	yes	no
Siderite, $FeCO_3$	Low P adsorbability	yes	no

Our overall goal is to determine which specific minerals are most effective at removing phosphorus in iron-enhanced sand filters. The proposed work will examine four enhanced iron-sand filter systems and a series of lake cores where the same sources of iron are being applied to remove phosphorous from lakes. Our characterization process involves two project activities, iron mineral characterization and chemical monitoring of filter systems, outlined below.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Determine which iron minerals bond with phosphorous Budget: $301,416

Using samples from enhanced iron-sand filters at multiple time stages and from filters exhibiting a range of effectiveness, we will discover which iron minerals actively bind phosphorous and remove it from stormwater. We will use an electron microprobe on select samples to identify the sites where phosphorous is bonding with iron to refine understanding of the bonding efficiency of these two elements.

Outcome	Completion Date
1. Identity of the most effective iron minerals for phosphorous trapping	December 1, 2019
2. Determination if iron minerals within filters get used up or remain active over time	May 31, 2019+
3. Best practice recommendation for iron sources, according to which minerals bond phosphorous the best and for the longest	July 1, 2020
4. Easy method to rapidly assess recycled iron quality prior to acquisition	July 1, 2021

Activity 2: Assess water and filter chemistry for effective iron-phosphorous bonding Budget: $ 83,175

Because a variety of chemical conditions in the water and within an enhanced iron-sand filter can hinder the ability of iron to hold phosphorous within a filter, we will monitor the chemistry of four filter systems using:

1. Laboratory chemistry of water samples (pH, elements)
2. Monitoring of water chemistry before and after filtration (conductivity, dissolved oxygen, turbidity)
3. Monitoring within the filters (redox, dissolved oxygen)

This task will allow us to recommend chemical buffers to maximize efficiency of future systems and identify the chemical conditions when effectiveness wanes or terminates.

Outcome	Completion Date
1. Table of real-time effectiveness of different iron-sand filters, by type, from monitoring water chemistry pre- and post-filtration	July 1, 2018- May 31, 2021
2. Best practice recommendation for iron-sand filter installation maintenance, for long term effectiveness and to prevent biological oxygen demand to cause chemical failure of filter systems	July 1, 2019- July 1, 2020

III. PROJECT STRATEGY

A. Project Team/Partners

Joshua Feinberg, University of Minnesota Department of Earth Sciences, Institute for Rock Magnetism
Beth Fisher, University of Minnesota Department of Earth Science, Institute for Rock Magnetism
John Gulliver, University of Minnesota Department of Civil Engineering, St. Anthony Falls Laboratory
Poornima Natarajan, University of Minnesota Department of Civil Engineering, St. Anthony Falls Laboratory
Chris Meehan, Wenck Associates, access to iron-enhanced sand filter installations, no money requested

B. Project Impact and Long-Term Strategy

We will determine which iron minerals are most effective at removing phosphorus in iron-enhanced sand filter basins and lake sediments for cost-efficient use of clean water funds available to the State of Minnesota.

C. Timeline Requirements

Three years to complete all proposed outcomes, starting on July 1, 2018. Two years to characterize the chemistry and mineralogy for the most effective iron-enhanced sand filters. An additional year to complete field methods to rapidly assess iron quality prior to acquisition and to define best practices for new iron filter systems.

2018 Detailed Project Budget

Project Title: *Determining which iron minerals remove phosphorous from stormwater*

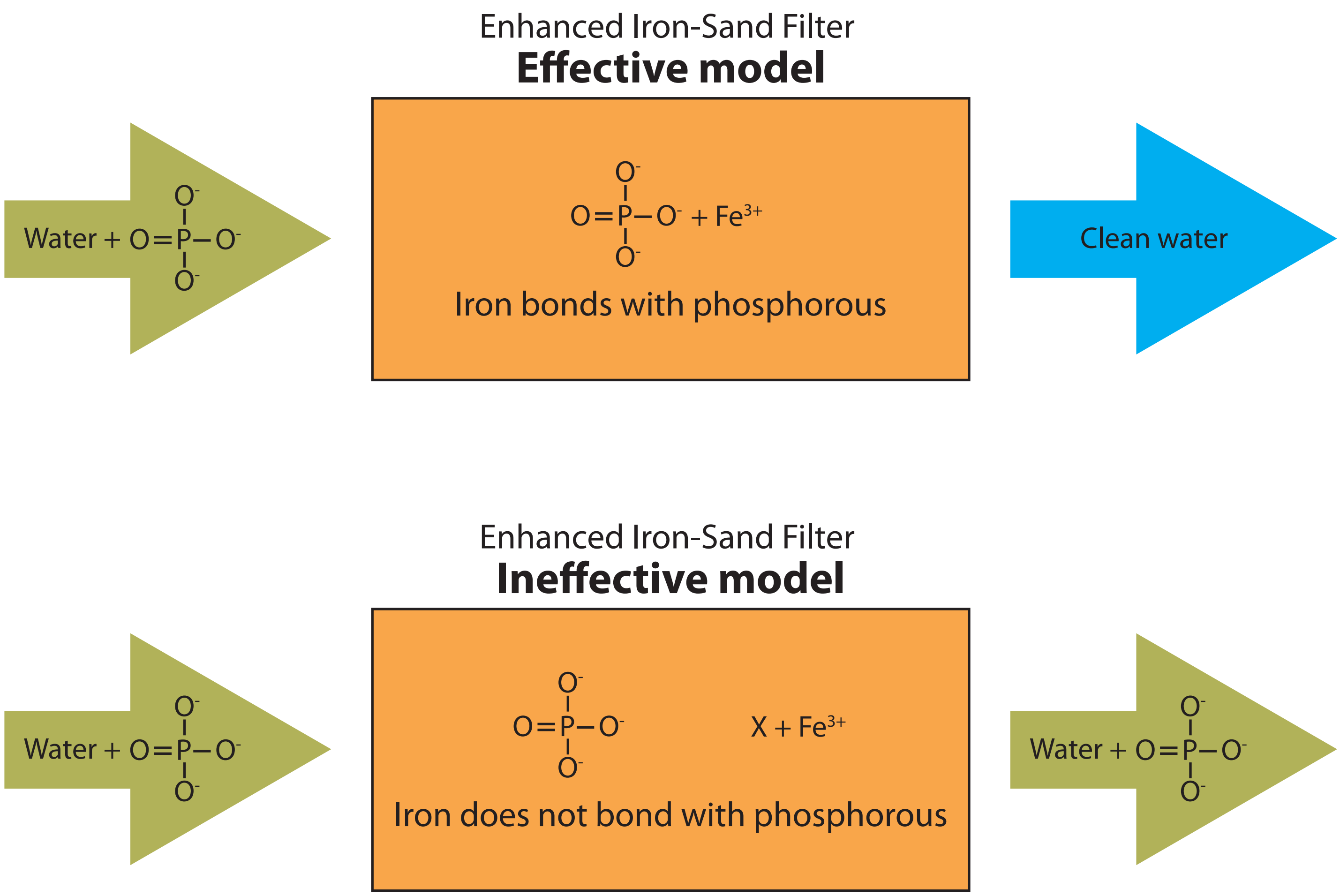
IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel: Research Associate (B. Fisher), Field sample collection, laboratory experiments, data collection and analysis, 100% salary, 25% benefits, 75% time for 2 years, 50% time for third year.	$ 188,461
Personnel: Associate Professor (J. Feinberg), Supervisory and Analysis, 8% time, 75% salary, 32% benefits, 3 years. Partial summer salary.	$ 30,716
Personnel: Professor (J. Gulliver), Supervisory and Analysis, 4% time, 75% salary, 25% benefits, 3 years. Partial summer salary.	$ 35,669
Personnel: Research Associate (P. Natarajan), Field sample collection, laboratory experiments, data collection and analysis, 16% time, 75% salary, 25% benefits, 3 years.	$ 38,225
Personnel: Engineers and staff for fabrication and construction of equipment for lab and field installations, 16% time, 75% salary, 25% benefits, 3 years.	$ 39,564
Equipment/Tools/Supplies: 4 sensor stations for chemical monitoring	$ 12,329
Equipment/Tools/Supplies: Reagents for laboratory chemical analyses	$ 674
Equipment/Tools/Supplies: Microsroscopy for element assicoations, 100 hours @ $50-100/hr	$ 7,500
Equipment/Tools/Supplies: 3 years of expirementation cost and consumables for iron mineral characterization (liquid helium, customized sample holders, environmentally controlled sample storage, database management, instrument maintenance and user fees)	$ 29,292
Travel: To sites in MN to collect samples. 2000 miles first year, 1000 miles second and third year @	$ 2,160
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 384,591

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: N/A	$ -	
Other State $ To Be Applied To Project During Project Period: N/A	$ -	
Joshua M. Feinberg, In-kind time for supervision of project, 12% of appointment	$ 46,075	*Secured*
John S. Gulliver, In-kind time for supervision of project, 12% of appointment	$ 78,000	*Secured*
Past and Current ENRTF Appropriation: N/A	$ -	
Other Funding History: N/A	$ -	

Which forms of iron minerals efficiently remove phosphorous from water?



This project will determine which iron minerals (e.g., goethite, magnetite, ferrihydrite, etc.) are most effective at removing excess phosphorous from water, thereby improving water quality in urban and rural environments.

Project manager qualifications and organizational description

Beth Fisher will **perform most tasks** in the proposed work, including the mineral characterization, water and filter media chemical analysis, and the installation and monitoring of environmental sensors. Fisher is a biogeochemist with a background in geology and soil science. Her most recent work applies these fields with a comprehensive, watershed-scale study of soil chemistry, mineralogy, and soil organic carbon. Her work identified iron minerals as key players in environmental chemistry and she recognized that the different personalities of iron minerals were the reason for mixed results in enhanced iron-sand filtration systems. Fisher initiated, designed, and wrote this proposed project, bringing together the collaboration between Gulliver, Feinberg, and Wenck Associates.

Prof. Joshua Feinberg will serve as **Project Manager**, with attention to guiding laboratory analyses. He has over 19 years of experience working as a geoscience professional for state and federal natural resource agencies, for private environmental consulting corporations, and as a university professor overseeing federally funded scientific research. Feinberg is currently a tenured Associate Professor in the Department of Earth Sciences at the University of Minnesota and the Associate Director of the Institute for Rock Magnetism (IRM), which is a National Multi-User Facility funded primarily by the National Science Foundation. Feinberg's research uses a combination of geophysical approaches (e.g., rock magnetism, paleomagnetism, gravity) and material characterization techniques (e.g., scanning and transmission electron microscopy, scanning force microscopy, X-ray diffraction and fluorescence) to characterize natural and synthetic iron-bearing minerals. Feinberg teaches the University's "Mineralogy" course and served as an editor of the journal "American Mineralogist" for 8 years.

Prof. John Gulliver will serve as Project Advisor, providing expert knowledge of iron-sand filtration and access to sites where filters and iron lake amendments are installed. Gulliver is a Professor in the Department of Civil, Environmental and Geo- Engineering at University of Minnesota. Much of his research, in conjunction with other faculty, involves the development of new technology for stormwater treatment and assessment of field performance of stormwater treatment practices, including the SAFL Baffle, which converts any sump into an effective sediment settling device, the Iron-Enhanced Sand Filter, which removes dissolved, as well as particulate phosphorus, and the MPD Infiltrometer, which can measure infiltration into soil accurately and effectively with minimal volume of water. He has investigated the retention of metals by bioretention media, the infiltration rates of various stormwater treatment practices, the impact of various types of impervious areas on runoff, and the impact of climate change on stormwater infrastructure. He is a co-author of the book, Optimizing Stormwater Treatment Practices: A Handbook of Assessment and Maintenance, published by Springer. Gulliver has expanding his interdisciplinary research activities related to managing and treating urban runoff and publication of the practitioner-oriented newsletter, Stormwater Updates.

Organization Description. The University of Minnesota is a prestigious public university and the state of Minnesota's land-grant university. In addition to the laboratory facilities available to the PIs, the university includes multiple core facilities (including the Characterization Facility, the Saint Anthony's Falls Laboratory, and the Minnesota Supercomputing Institute) that have the equipment and instruments necessary for the proposed studies.