Environment and Natural Resources Trust Fund
2017 Request for Proposals (RFP)

Project Title: **ENRTF ID: 046-B**

How Rapidly can Groundwater Quality be Improved?

Category: B. Water Resources

Total Project Budget: $ 672,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2017 - June 2020

Summary:

Aquifers in southeastern Minnesota have continually received excessive doses of anthropomorphic chemicals such as nitrates since WWII. We will estimate how long it will take to make them clean again.

Name: John Nieber

Sponsoring Organization: U of MN

Address: 1390 Eckles Ave

St. Paul MN 55108

Telephone Number: (612) 625-6724

Email nieber@umn.edu

Web Address

Location

Region: Southeast

County Name: Fillmore, Houston, Mower

City / Township:

Alternate Text for Visual:

Illustration shows an inset map of the region of southeastern Minnesota where wells, sprngs and streamflows show high nitrate concentations, and the location of the geological cross-section (designated A-B) showing the major aquifers in the region affected. Also shown is a graph illustrating the rate reduction of nitrate contributed to streamflow by shallow aquifers and the rate of rise of nitrate being contributed to streamflow by deeper aquifers.

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

PROJECT TITLE: How rapidly can groundwater quality be improved?

I. PROJECT STATEMENT

This project will estimate the time required for the major aquifers (Galena, Prairie du Chien, Jordan, Ironton-Galesville) in southeastern Minnesota to be flushed of nitrates that have accumulated in them during the seven decades since WWII. As a result of this accumulation, high nitrate concentrations in the aquifers, and associated springs and streamflow is a pervasive occurrence in the southeast (see inset map representing the southeast region). It is well-known that this accumulation of nitrates has resulted from applications of excessive amounts of nitrogen fertilizers on the regional landscape over many decades.

Current improvements in nitrogen use efficiency in agriculture will lead to reduced leaching of excess nitrate to underlying aquifers. If such improvements occur over large areas of the southeast it will result in significant reductions of nitrate loading of the underlying aquifers. With reduced loading, the nitrate in the aquifers will not be replenished and the recharge and natural flow of water through aquifers will flush subsurface stores of excessive nitrate over time. What is not clear is how long this process will take. The attached figure shows conceptually how aquifer response, or lag time depends on geologic setting. In shallow aquifers, the lag time may be more rapid; in deeper aquifers, increasing nitrate concentrations indicates that lag time can be much longer. The goal of this project is to estimate this lag time quantitatively for different southeastern Minnesota aquifers, using state-of-the-art chemical age-dating and hydrologic modeling methods.

Why do we want to know how long it will take to flush nitrate from these aquifers? It is because with the current and future investments to improve nitrogen use efficiency in agricultural production we want to be able to have a realistic timeframe for improved groundwater and surface water quality to be manifested.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop decadal resolution age-dating of water in the four major aquifers in southeast Minnesota **Budget: $232,000**

Water samples will be collected mostly from wells and a few selected springs within the area represented by the inset map on the illustration. Water samples will be tested for sulfur-hexafluoride, chlorofluorocarbons, tritium and helium-3. The sampling and testing has to be done with extreme expert care due to the low concentrations of these elements and the need to avoid sample contamination. These data will be used to quantify the age of the aquifer water with an accuracy of $\pm$10 years, a much higher resolution than currently available. Additional sampling of streamflows, aquifers and springs will be conducted to measure chloride, nitrate, and the stable isotopes of oxygen and hydrogen. These data will be used to quantify the source of water in the streamflows, and to help quantify travel time of water in the aquifers.

Outcome	Completion Date
1. Maps of the age distribution of the water in the major aquifers in southeastern Minnesota. The time resolution will be $\pm$10 years.	10/31/2018
2. Estimates of the travel time distributions of water in the major aquifers based on the chemical analyses alone.	03/31/2019

Activity 2: Determine travel times for flows within the major aquifers to streams based on hydraulic analyses. **Budget: $190,000**

Springshed boundaries of the four major aquifers will be delineated using geological information derived from the County Geologic Atlases available for the region. An aquifer model will be constructed using the detailed geological information and applied to calculation of travel time within the individual aquifers. The aquifer model will be applied to estimation of the time required for observed nitrate concentrations to be reduced to acceptable levels accounting for the processes of denitrification and flushing by natural flows.

Outcome	Completion Date
1. Maps illustrating calculated travel time distributions of water within the four studied aquifers.	12/31/2018

2. Estimates of the time required for nitrate levels to drop to acceptable levels within the four major aquifers.	03/31/2019

Activity 3: Simulate chemical travel times in a laboratory scale model. **Budget: $104,000**

A laboratory scale model representative of the layered aquifer system will be constructed and used to provide data for validating the travel time models developed in Activity 2. The laboratory experiments will facilitate testing of various types of aquifer situations known to exist in the region. This experimental apparatus will provide direct visible evidence to demonstrate chemical flushing from aquifer systems and will also be useful in demonstrating groundwater flow and chemical transport processes to stakeholders, students, and educators.

Outcome	Completion Date
1. A report providing details of the laboratory experiments and results of the validation testing of the travel time distribution models. The laboratory scale model will be available to others wishing to use it for experiments and for educational/training activities.	6/30/2019

Activity 4: Develop a simple tool for estimating lag-time for nitrate flushing. **Budget: $146,000**

A mathematical modeling tool will be developed for use in applying an aquifer travel time distribution in the determination of the lag-time required for chemicals to flush out of an aquifer system.

Outcome	Completion Date
1. Report outlining the features of the modeling tool and results of testing the model for the major aquifers in southeastern Minnesota. The report will provide details on how to apply it to lag-time estimation. This model will be provided to state agencies and available on-line for use by consultants and educators.	03/31/2020

III. PROJECT STRATEGY

A. Project Team/Partners

No ENRTF funding required:

Dr. John L. Nieber, Professor, Dept. of Bioprod. and Biosyst Eng. (**BBE**) Serve as project principal investigator. **Mr. Kevin Keuhner**, Minn. Dept. of Agr. Assist with data acquisition from field sites, and work with landowners associated with established BMPs.

ENRTF funding required:

Dr. Robert Tipping, Minn. Geol. Survey (**MGS**). Lead effort on water chemical sampling, and historical chemical data compilation and analysis. **Dr. Anthony Runkel**, MGS. Lead the effort on aquifer identification, characterization, and hydrogeological assessments. **Dr. Joseph Magner**, BBE. Assist with interpretation of chemical tracer data. **Mr. Brad Hansen**, BBE. Manage field sampling and construction and operation of laboratory scale model. **Graduate Research Assistants**, Univ. of Minn. Assist with all aspects of the project including field sampling, laboratory experiments, and modeling. **Undergraduate Research Assistants**, Univ. of Minn. Assist with all aspects of the project including field sampling, laboratory experiments, and modeling.

B. Project Impact and Long-Term Strategy

When landuse is improved the improvement in water quality will not be immediate. Setting realistic planning horizons for the time to meet water quality standards in aquifers and streams should take into account the lag time that occurs between landuse improvement and the water quality response. This project will provide environmental managers in southeastern Minnesota with estimates of the time required to flush nitrate from the region's four major aquifers. The estimates will also provide insight into the rate at which other contaminants such as pesticides can be flushed. The results of the project will provide detailed groundwater flow information also useful to other environmental management activities such as well-head protection mapping. This project should be viewed as being a piece of a larger effort that should be initiated to map the lag-time for aquifers around the entire state of Minnesota. The project will also provide support for the training of two graduate students and a several of undergraduate students.

C. Timeline Requirements

The proposed project duration will be 3.0 years.

2017 Detailed Project Budget

Project Title: How rapidly can groundwater quality be improved?

IV. TOTAL ENRTF REQUEST BUDGET 3 years

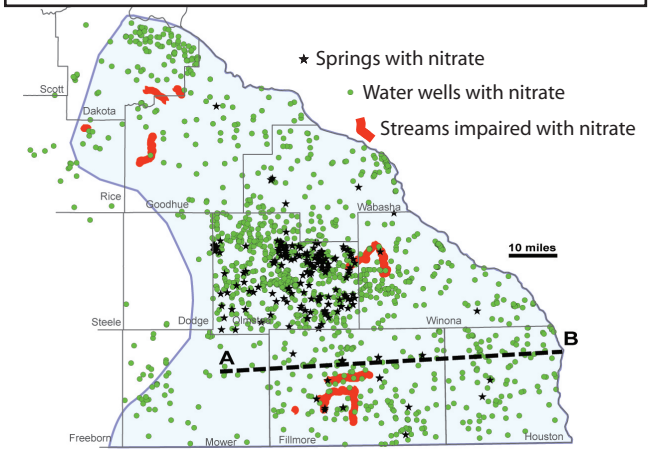
BUDGET ITEM	AMOUNT
Personnel:	
Robert Tipping; Hydrogeologist/hydrogeochemist, Minnesota Geological Survey. Lead effort on water chemical sampling, and historical chemical data compilation and analysis. 66% salary, 34% fringe. 13% of full time, soft money, 7/1/17-6/30/20.	$ 39,000
Anthony Runkel; Hydrogeologist, Minnesota Geological Survey. Lead the effort on aquifer identification, characterization, and hydrogeological assessments. 66% salary, 34% fringe. 13% of full time, soft money,7/1/17-6/30/20.	$ 41,000
Joseph Magner; Hydrogeologist, University of Minnesota, Department of Bioproducts and Biosystems Engineering. Assist with effort on travel time estimation and analysis of geochemistry. 66% salary, 34% fringe. 8% of full time, soft money, 7/1/17-6/30/19.	$ 28,000
Bradley Hansen; Senior Scientist, University of Minnesota, Department of Bioproducts and Biosystems Engineering. Manage field sampling activities and manage the construction and maintenance of the laboratory scale groundwater model. 66% salary, 34% fringe. 8% of full time, soft money, 7/1/17-6/30/19.	$ 67,000
Graduate Research Assistants; Two, one M.S. and one Ph.D. Assist with all aspects of the project. 62% salary, 38% fringe. 50% of full time, 7/1/17-6/30/20.	$ 253,000
Undergraduate Research Assistants; Number to be determined. Assist with all aspects of the project. 100% salary, 0% fringe. 100% of full time in summer, 25% full time in school year, 7/1/17-	$ 25,000
Professional/Technical/Service Contracts: Age-dating of water samples. Subcontract with the USGS, Minnesota Water Science Center Office. The water samples will be tested for elements that are extremely difficult to analyze, and the sampling itself requires a very specific skill possessed by a very limited group of scientists. Water sample analysis cost, for 25 samples and 5 replicates, four chemical constituents (sulfur-hexafloride, chloroflorocarbon, tritrium and helium-3) each is $54,000 ($1,800 per sample). Cost for sample collection and analysis of sample analytical results for age-dating of water, $114,000; this includes travel costs, salary for USGS researchers, and equipments for water sampling.	$ 168,000
Equipment/Tools/Supplies: Chemical analysis of water samples; includes nitrates, specific conductivity, chloride, oxygen-18 and deuterium; $11,000. Supplies and building of model groundwater system for experimental analysis of travel time in aquifers; $35,000	$ 46,000
Travel: Travel will be limited to visiting field sites to collect water samples and monitor streamflows, and to participate in meetings with agency staff and stakeholders to present results of the project activities.	$ 5,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 672,000

V. OTHER FUNDS

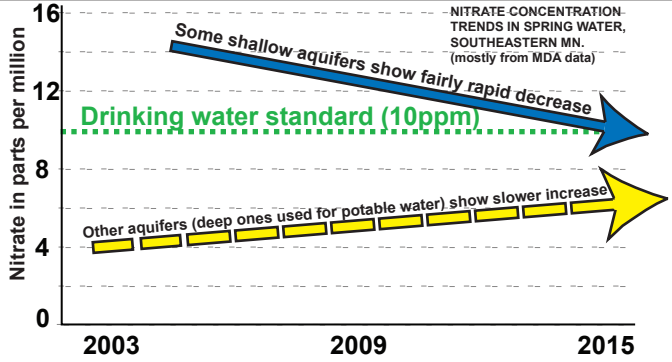
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period	N/A	
Other State $ To Be Applied To Project During Project Period	N/A	
In-kind Services To Be Applied To Project During Project Period	N/A	
Indirect costs/facilities administration (53%)	$220,200	*secured*
Match, USGS, Water Science Center, Mounds View, Minnesota.	$11,900	*to be secured*
Funding History: Proposed project builds on County Atlas mapping in southeastern Minnesota, funded through ENRTF going back to the early 1980's, with additional funding coming from Clean Water Fund for Winona and Houston County mapping. The project also builds on a recently completed investigation of bedrock controls on nitrate distribution in southeastern Minnesota streams, paid for by the Minnesota Pollution Control Agency through funds acquired from The Minnesota Clean Water Fund.		completed
Remaining $ From Current ENRTF Appropriation	N/A	

HOW RAPIDLY CAN GROUNDWATER QUALITY BE IMPROVED?

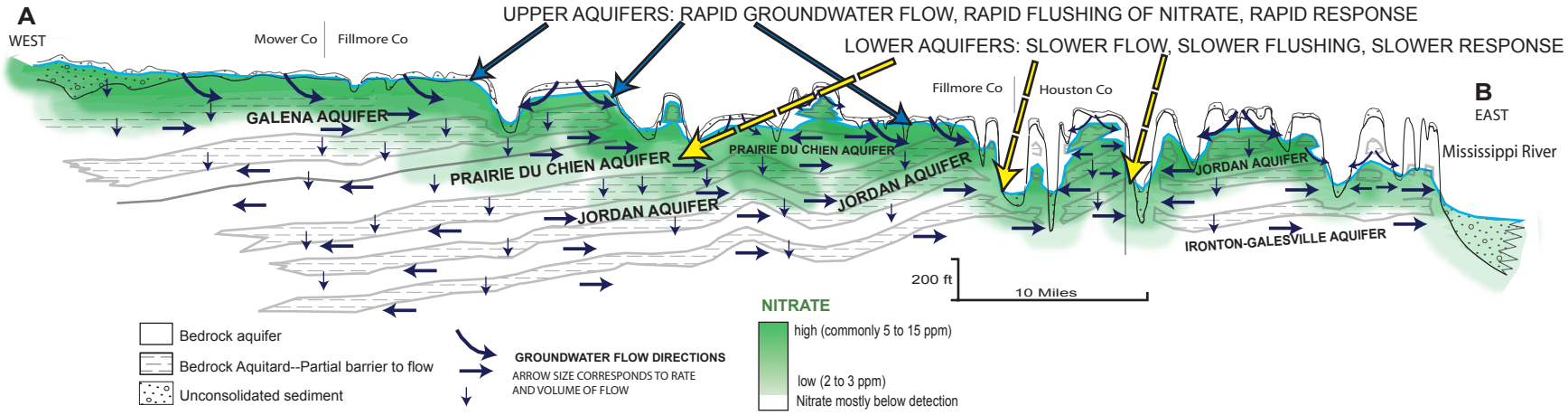
NITRATE AND OTHER CONTAMINANTS ARE COMMMON IN GROUNDWATER OF SOUTHEASTERN MINNESOTA



TRENDS IN NITRATE LEVELS DIFFER FROM AQUIFER TO AQUIFER



THE NITRATE TRENDS IN SPRINGS AND STREAMS VARY BECAUSE OF VARIABLE RESPONSE TIME TO LAND SURFACE CHANGES SUCH AS AGRICULTURAL PRACTICES



OUR PROJECT WILL ESTIMATE THE TIME REQUIRED FOR FLUSHING NITRATE FROM SE MINNESOTA AQUIFERS, PROVIDING A TOOL FOR WATER MANAGERS TO SET REALISTIC BEST MANAGEMENT PRACTICE GOALS

All illustrations are modified from Runkel and others, (2014): Minnesota Geological Survey Open File Report 14-02

Project Manager Qualifications & Organization Description

PI:

Name: John L. Nieber
Title: Professor
Degrees: 1972, B.S., Forest Engineering, Syracuse University
1974, M.S., Civil and Environmental Engineering, Cornell University
1979, Ph.D., Agricultural Engineering, Cornell University
Licensed Professional Engineer: Minnesota
Certified Professional Hydrologist: American Institute of Hydrology
Affiliation: Department of Bioproducts and Biosystems Engineering, University of Minnesota
Address: 1390 Eckles Ave., St. Paul, MN 55108
Phone: 612-625-6724
Email: nieber@umn.edu

John Nieber has over 35 years of experience working as a professional hydrologist in conducting teaching and research activities related to hydrology and water quality. In the 1980's he collaborated on research involving remote sensing of soil moisture and is currently advising a graduate student on a self-funded project using GRACE satellite data, and meteorological and hydrologic data to characterize changes in water storage within the Minnesota River Basin. He managed a LCCMR project on freshwater sustainability from 2007-2009, from which maps of groundwater recharge were derived. The work resulting in three publications in the scientific literature and has influenced freshwater sustainability planning activities within Minnesota. One student, Dr. Heidi Peterson received her Ph.D. degree as a result of support from this project. In 2014 Dr. Nieber took a 5-month sabbatical leave to the University of Padova in Italy to study the topic of travel time distributions for water in watersheds. The purpose was to learn techniques that could be used to estimate the lag time required for contaminants to be flushed out of watershed surface waters, soils and groundwater. John Nieber has managed numerous other projects as well, including being the manager of a five-year contract with the MPCA for the Impaired Waters Program. He is the author of over 60 refereed articles in the scientific literature.

Organization:

The University of Minnesota Twin Cities campus is one of the Big Ten universities. It ranks very highly in many of its programs including its College of Food, Agriculture and Natural Sciences, and it College of Sciences and Engineering. It has excellent library resources and its resources for supercomputing are exceptional. In addition to all of the high quality features at the University of Minnesota, faculty at the University of Minnesota have developed excellent working collaborative relationships with scientists and engineers at the state and federal agencies within Minnesota.