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

Project Title: **ENRTF ID: 080-B**

Non-Invasive, Cost-Effective Investigation of Groundwater Resources

Category: B. Water Resources

Total Project Budget: $ 93,783

Proposed Project Time Period for the Funding Requested: 2 years, July 2018 to June 2020

Summary:

Management of groundwater resources is hampered by our limited knowledge of the structure of aquifers. This proposal will use a new method to reveal the subsurface distribution of this resource.

Name: Maximiliano Bezada

Sponsoring Organization: U of MN

Address: 310 Pillsbury Drive SE

Minneapolis MN 55455

Telephone Number: (612) 624-5215

Email bezada@umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The Problem - Groundwater is a hard resource to manage because we dont know what the underground sediments or bedrock look like unless we drill. The Solution – Use the small seismic waves that are created by trees rustling in the wind or passing vehicles to learn what the structure of the subsurface looks like without having to drill. This method works much the same way as an ultrasound or x-ray scan.

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

PROJECT TITLE: Non-invasive, cost-effective investigation of groundwater resources

I. PROJECT STATEMENT

Clean groundwater is a vital natural resource in Minnesota. Effective management of this resource requires knowledge of the location and extent of the aquifers (water-bearing geological deposits). Since these are underground, we need a clear picture of what the subsurface looks like. Producing such a picture is a challenging task. Drilling provides direct observations but the associated costs and labor are very high. The technology that is currently used for exploration gives an idea of what the subsurface looks like, but is not always sufficient. We propose to implement a method to improve knowledge of the subsurface and apply the method to areas in the state that have been especially challenging. To do this, we will carry out work in three phases:

- **Collection and analysis of seismic data for subsurface imaging**
- **Development and calibration of seismic imaging software for efficient use in the field**
- **Application of imaging methods to groundwater systems in Minnesota**

Details of the Earth's subsurface can be imaged by passing seismic waves in the ground, just as x-rays and ultrasound can image in the inside of the human body. Seismic imaging has traditionally been an expensive and complex endeavor. Specialized equipment and personnel are necessary to generate and record the signals capable of probing the Earth's subsurface. However, recently developed methods are now able to harness background 'noise', small seismic waves created by wind, cars, or weather, to achieve the same ends. The method works by reproducing characteristics of the recorded waves using models of subsurface properties.

We will achieve this proposal's goals by developing a software package for seismic imaging with background noise specifically tailored to Minnesota's geology. The methods that will be implemented are capable of imaging the subsurface in regions that are complex enough that they may currently require more expensive approaches. In particular, regions with multiple types of sediment above the bedrock have traditionally proved hard to image, but are necessary to understand for managing groundwater resources. Once the method and its capabilities are tuned to Minnesota's geology, we will prepare the method for field application and investigate the most efficient ways to apply the approach.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Collection and analysis of seismic data for subsurface imaging* **Budget: $** 43,555

The first phase of this project will be to translate academic ideas developed to image the entire Earth to groundwater-scale studies (depths of ~300 ft). Observations will be made from two datasets. First, the federally funded EarthScope program deployed seismic instruments across Minnesota every 45 miles between 2010 to 2013. This data is freely available online (http://ds.iris.edu/gmap/_US-TA) and will be used in the initial stages of implementation. Second, seismic noise will be collected at well-characterized sites in Minnesota, where inferences about the subsurface can be ground-truthed against pre-existing results. Some data has been collected by the PIs prior to this proposal from 16 sites in the Twin Cities area on private property. The budget for this activity includes one half of one year's salary for the post-doctoral scholar J. Byrnes, summer salary for PI Maximiliano Bezada, and travel to one site to be determined in collaboration with the MGS.

Outcomes	Completion Date
1. Implementation of imaging techniques with available data	*December 2018*
2. Ground-truthing results and analysis at well-characterized sites	*July 2019*

Activity 2: *Development and calibration of seismic imaging software for efficient use in the field* **Budget: $ 21,578**

The second stage will prepare the results for use in the field. The two aspects of this phase will be software development and cost-benefit analysis. Once we understand how useful different observations are for our imaging targets, software to efficiently infer geological structures with seismic data will be developed.

Emphasis on an intuitive, interactive user interface will streamline the release and maximize the usefulness of the software. Cost-benefit analysis will include a comparison between our noise-based imaging with drilling and traditional seismic results to evaluate the extent to which more invasive or expensive methods can be supplemented or even replaced. Different aspects of the process will be investigated to learn the most efficient and effective application of our approach. For example, for how long must seismic data must be collected at a site, what are the best conditions for recording noise, and how can the computation time needed to get results be minimized? The budget for this activity includes one fourth of one year's salary for post-doctoral scholar J. Byrnes.

Outcomes	Completion Date
1. Software development for the methods studied during Activity 1	*November 2019*
2. Cost-benefit analysis for best-use practices	*January 2020*

Activity 3: *Application of imaging methods to groundwater systems in Minnesota* **Budget: $ 28,650**

Once the software is developed, it will be made available for use free of charge. We will then begin the application of the imaging method to challenging sites in Minnesota. Sites with multiple types of sediment or that are above weak bedrock have traditionally been challenging to image. These sorts of sites are abundant in Minnesota and are the types of sites where our method will produce significant gains. Three locations for application will be chosen in collaboration with the MGS. The budget for this activity includes one fourth of one year's salary for post-doctoral scholar J. Byrnes, one and one-half month's summer salary for Asst. Profs. M. Bazada and A. Wickert, as well as travel to three sites.

Outcomes	Completion Date
1. Release of a software package for subsurface imaging	*March 2020*
2. Characterization of three challenging sites in Minnesota	*July 2020*

III. PROJECT STRATEGY

A. Project Team/Partners

The project team will consist of Principal Investigator (PI) Assistant Professor Maximiliano Bezada (University of Minnesota), co-PIs Assistant Professor Andrew Wickert (University of Minnesota) and Dr. Joseph Byrnes, a post-doctoral scholar (University of Minnesota), and project partner Val Chandler of the MGS. **M. Bezada and J. Byrnes** will collect and manage the acquired data, implement the imaging methods, and develop the software package that will be produced by this proposal. **J. Byrnes** will be primarily responsible for the travel and data management portion of this project. **A. Wickert** will provide guidance in choosing the sites for Activity #3 and make available his expertise in Minnesota geology. **V. Chandler** will be responsible for providing guidance to the other team members to ensure that the development and application of the new methodology is tailored to the needs of the MGS and to address subsurface imaging challenges encountered in the County Atlas project.

B. Project Impact and Long-Term Strategy

Investment in this project will enable future assessment of groundwater resources in Minnesota. These resources cannot be managed effectively if the subsurface geology is not sufficiently understood. By performing cost-benefit analysis with our method, the use of more invasive and costly approaches can be minimized. The software developed, along with manuals and documentation, will be made freely available to end-users in Minnesota, including the MGS and DNR, for imaging projects.

A primary goal of this proposal is to increase the resolution of the subsurface mapping done by the MGS as part of the County Atlas project without a significant increase in costs. The MGS is enthusiastic about adopting this methodology, provided that it be proven successful in the field.

C. Timeline Requirements

This project will be completed within two years.

2018 Detailed Project Budget

Project Title: *Non-invasive, cost-effective investigation of groundwater resources*

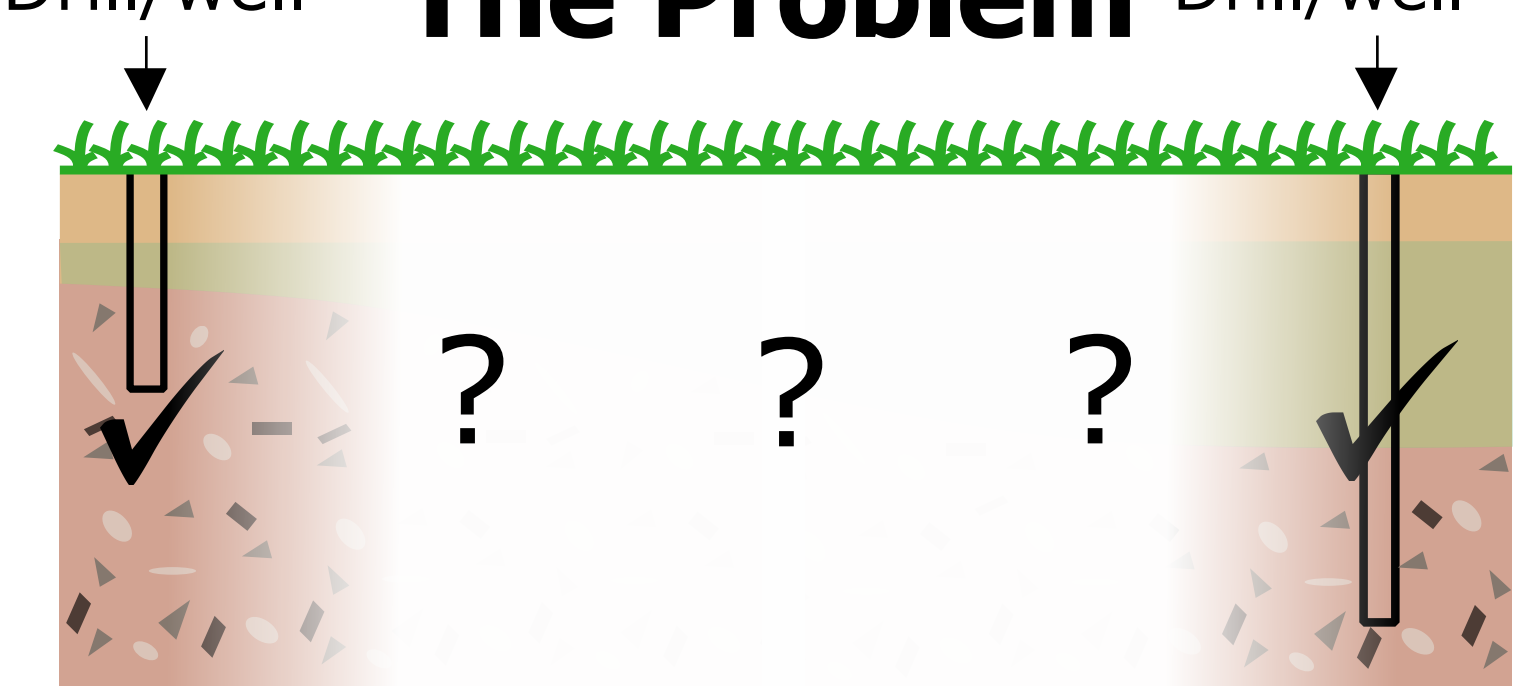
IV. TOTAL ENRTF REQUEST BUDGET 2 **years**

BUDGET ITEM	AMOUNT
Personnel: *PI Max Bezada 1 month of summer salary for each of the two years. Fringe rate 33.7%*	$ 23,262
Personnel: co-*PI Joseph Byrnes 100% salary, 0.5 time. Fringe rate 22.4%. Two years*	$ 63,048
Personnel: Andrew Wickert, 0.5 months of summer salary for Year 2. Fringe rate 33.7%	$ 5,873
Travel: *Travel by J. Byrnes to sites in Minneasota determined in collaboration with the MGS for Activities #1 and #3, per the Universities of Minneasota's reimbursement plan.*	$ 1,600
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 93,783

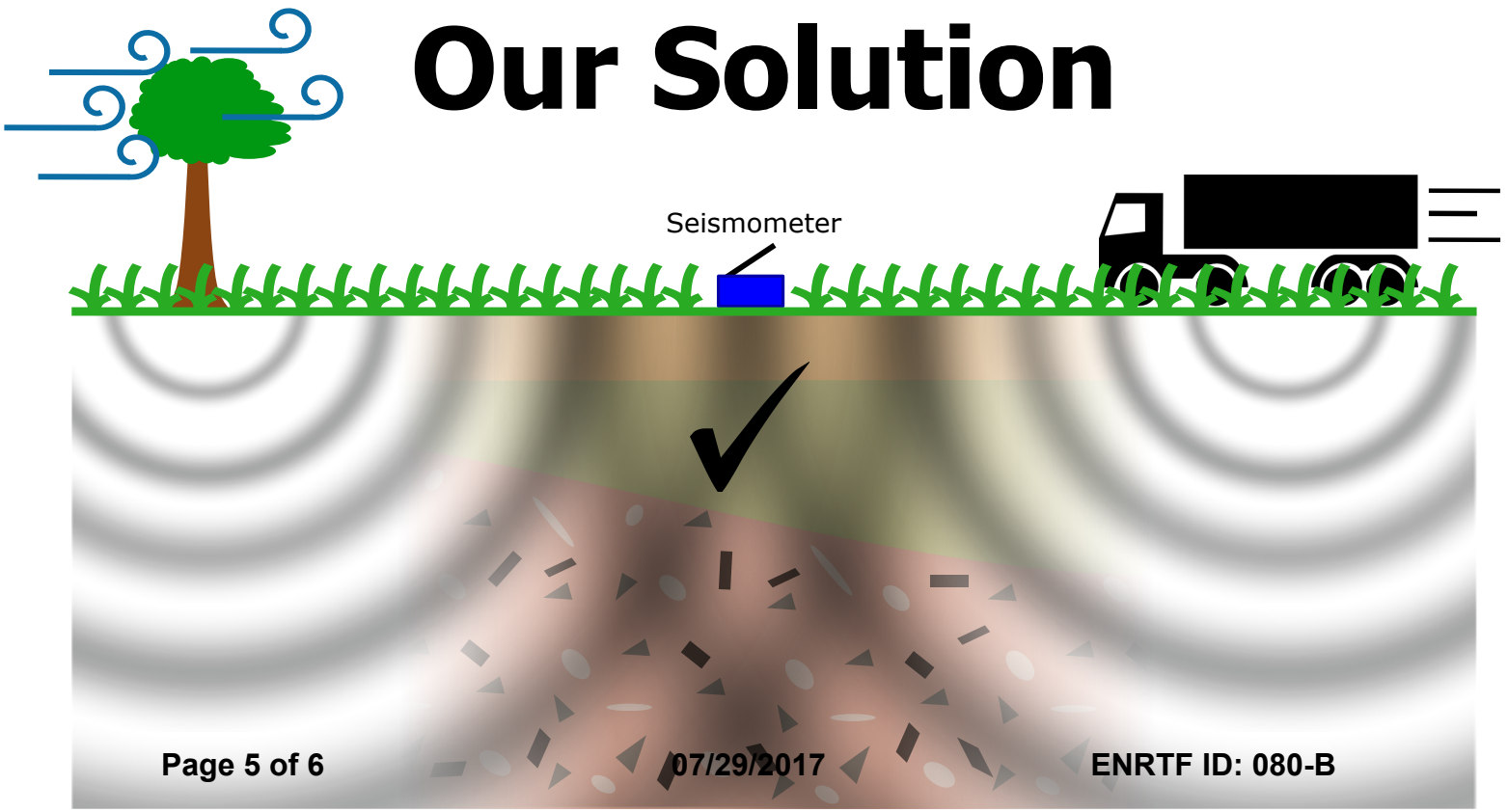
V. OTHER FUNDS

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: Bezada, Byrnes, and Wickert have access to resources at the Minnesota Supercomputing Institute (MSI). These computing resources will be used to process data during the implementation stages. The University of Minnesota's Facilities and Administrative rate is 54% of modified total direct costs (total direct less graduate student fringe, capital equipment, subawards over $25,000 and on-site facilities rental). The amount, if F&A expenses had been allowed on the project, they would mount to $51,939. The University will provide office space, IT services, and administrative / financial services in support of the project.	$ 51,939	*secured*
Past and Current ENRTF Appropriation: 2017: Landslide hazards and impacts on Minnesota's natural environment (awaiting MN legislative vote)	$ 500,000	*pending*
Other Funding History: None to date. This is a new initiative by the project team.	$ -	-

The Problem



Our Solution



Project Manager Qualifications & Organizational Description

Project Title: Non-invasive, cost-effective investigation of groundwater resources

Maximiliano Bezada

Assistant Professor of Geophysics
University of Minnesota – Twin Cities
612-624-5215
mbezada@umn.edu

Professor Bezada joined the Department of Earth Sciences at the University of Minnesota in September 2014 following a position as a postdoctoral researcher at the University of Oregon. His research focuses on using geophysical, mainly seismological data to image subsurface structure, primarily at the crustal and upper mantle scales (depths of 40-400 miles). In prior work, Professor Bezada has developed, modified, or adapted seismic and other geophysical techniques to be applied to specific circumstances and to incorporate various technical innovations. This work has often resulted in significantly improved understanding of the subsurface and consequent advances in our understanding of geological processes.

Bezada received his BS in Geophysical Engineering from Simón Bolívar University in Venezuela (his country of origin) in 2005. After a brief period working for the Venezuelan Seismic Research Foundation, he moved to the United States to pursue a PhD in Geophysics, which he obtained from Rice University in Texas, in 2010. He then spent four years as a postdoctoral researcher at the University of Oregon before joining the Faculty of the Earth Sciences Department at the University of Minnesota.

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 geophysics. The department has a strong hydrogeology program with several ongoing projects focusing on Minnesota water resources. This project would help consolidate collaborations between the hydrogeology and geophysics groups in the department.