Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 240-F**

Precursors of Failure in Mine Tailings Dams

Category: F. Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Sub-Category:

Total Project Budget: $ 298,000

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

We aim to obtain data for design of an early warning system for predicting conditions that result in failure of mine tailings dams.

Name: Joseph Labuz

Sponsoring Organization: U of MN

Job Title: Professor

Department: Civil, Environmental, and Geo- Engineering

Address: 500 Pillsbury Dr SE, Civil Engineering Building

Minneapolis MN 55455

Telephone Number: (612) 625-2466

Email jlabuz@umn.edu

Web Address:

Location:

Region: Northeast

County Name: St. Louis

City / Township: Babbitt

Alternate Text for Visual:

The visual shows a diagram of the mining process that produces tailings and the approach used to develop data for design of an early warning system.

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

PROJECT TITLE: PRECURSORS OF FAILURE IN MINE TAILINGS DAMS

I. PROJECT STATEMENT

The aim of the project is to obtain data for design of an early warning system to predict the conditions that could result in the onset of failure in a mine tailings storage facility called a tailings dam. This will be accomplished by

- quantifying, with laboratory-scale strength tests and geophysical methods such as seismic probing, mechanical indices of mine-tailings material before and after failure;
- correlating the seismic measurements to traditional indicators of performance such as soil strength affected by earth and water pressures; and
- validating *in situ* the utility of seismic and conventional monitoring of mine tailings.

The iron range area in northern Minnesota is home to numerous basins of mine tailings, which are essentially the remains of finely crushed rock after iron ore extraction. Currently there are six operating tailings storage facilities managed by their owners and under review by their engineering teams, while numerous (historical) tailings basins have been reclaimed or abandoned after use. The performance of tailings dams from a geoengineering perspective has been excellent, as no catastrophic events or failures have been recorded in the State of Minnesota. Unfortunately, this has not been the case in other locations. Although rare in the US, failure of containment systems for mine tailings can be deadly. A recent example is the January 25, 2019 collapse of Vale's Brumadinho iron ore tailings dam in Brazil.

The mining and processing of low-grade metallic ores result in large quantities of material (finely crushed rock) in the form of a slurry – a mixture of water and clay-to-sand size particles. The slurry is retained in tailing storage facilities, where the solids settle with time, and the water is recycled to the processing plant or treated prior to discharge. Mining operations of 50,000 tons or more per day are common, with greater than 95% or more of the mined rock being non-ore material, which must be stored in tailings dams. Thus, the main function of a tailings dam is to store solids permanently and to manage process water temporarily. The length of time that water must be retained ranges from a few days to months, depending on gradation and mineralogy of the tailings. According to a 2006 joint report by the International Commission on Large Dams (ICOLD) and the United Nations Environment Program (UNEP), "… dams are prestigious structures used to … store water, whereas tailings dams are required for the storage of unwanted waste, desirably at minimum cost."

A tailings dam is a "work in progress" since its size is dependent on how long a mine operates and at what rate the ore is processed. Continuous dam management is critical and conventional monitoring systems are often used. However, an early warning system for predicting the conditions that could result in the onset of failure in mine tailings has not been developed. To date, very little research has been performed on mine tailings specifically in regards to seismic and strength characteristics. Much of the published research contain only a few tailings-type materials in their database. This research aims to expand this body of knowledge.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: Laboratory testing of mine tailings combined with strength testing and seismic probing
Description: A literature review of the current tailings dams within the State, active and non-active, will be completed. Triaxial compression tests with seismic probing on 12 specimens of reconstituted tailings material from one site, which is representative of the some of the materials found in northern Minnesota, will be performed. Specimens will be saturated and checked prior to testing. Consolidation under four different hydrostatic pressures will simulate field conditions. In essence, each compression test will involve seismic probing throughout the testing process and stress path, with 50 measurements of travel time recorded. The 12 specimens, each with 50 seismic records and corresponding displacement and loading conditions, will result in a wealth of data for a "machine learning" approach.

ENRTF BUDGET: $108,000

Outcome	Completion Date
1. Literature review of tailings dams within the State of Minnesota	*Mar 31, 2021*
2. Triaxial compression tests with seismic probing of reconstituted tailings from one site	*Jun 30, 2021*
3. Database of displacement, stresses, pore pressures, and velocities	*Jun 30, 2022*

Activity 2 Title: Correlation between seismic and traditional indicators
Description: Artificial intelligence and machine learning algorithms will be customized and applied to the obtained data sets. Despite its tremendous potential, this approach has not been applied to the mine tailings problem. The available measurements will be split into a training data set and a validation data set, designed to test the effectiveness of the proposed data interpretation methodology. The featured deformation, pore pressure, confining and axial stresses, and seismic velocities data will be interpreted both by the data learning approach and the construction of nomograms using traditional regression techniques.
ENRTF BUDGET: $92,000

Outcome	Completion Date
1. Artificial intelligence and machine learning algorithms	*Dec 31, 2021*
2. Charts using traditional regression techniques	*Mar 31, 2022*

Activity 3 Title: Field testing of mine tailings cross-hole seismics and surface wave analysis
Description: The most suitable form of a seismic survey such as the cross-hole testing or the spectral analysis of surface waves will be used to probe significant volumes of *in situ* mine tailings for seismic wave speeds at several frequencies of excitation. The obtained seismic measurements and their interpretation resulting from the analysis in activity 2 will be applied and correlated with the conclusions on stability using existing methods.
ENRTF BUDGET: $98,000

Outcome	Completion Date
1. Cross-hole seismics at one site	*Sep 30, 2022*
2. Spectral analysis of surface waves	*Mar 31, 2023*

III. PROJECT PARTNERS AND COLLABORATORS: The UMN team will be led by Professors Joseph Labuz and Bojan Guzina, Department of Civil, Environmental, and Geo- Engineering. It will include one graduate and one undergraduate student. Labuz is an expert in lab testing and behavior of fluid-saturated materials; Guzina has extensive experience in seismic imaging and machine learning. Barr Engineering, industry leaders in mine tailings design and monitoring, will assist in specimen preparation and field testing at an available site.

IV. LONG-TERM IMPLEMENTATION AND FUNDING: The ultimate, long term goal of the project is to develop an early warning detection system for identifying failure of mine tailings. Stakeholders will have a tool to quantitatively assess a site-specific tailings dam. Further, this will be the first study in the State of Minnesota to investigate how seismic imaging and machine learning can provide relevant information on *in situ* behavior of mine tailings. Once the data are obtained from this study, the next step will be to design and implement the early warning detection system.

V. SEE ADDITIONAL PROPOSAL COMPONENTS:
A. Proposal Budget Spreadsheet B. Visual Component or Map
F. Project Manager Qualifications and Organization Description

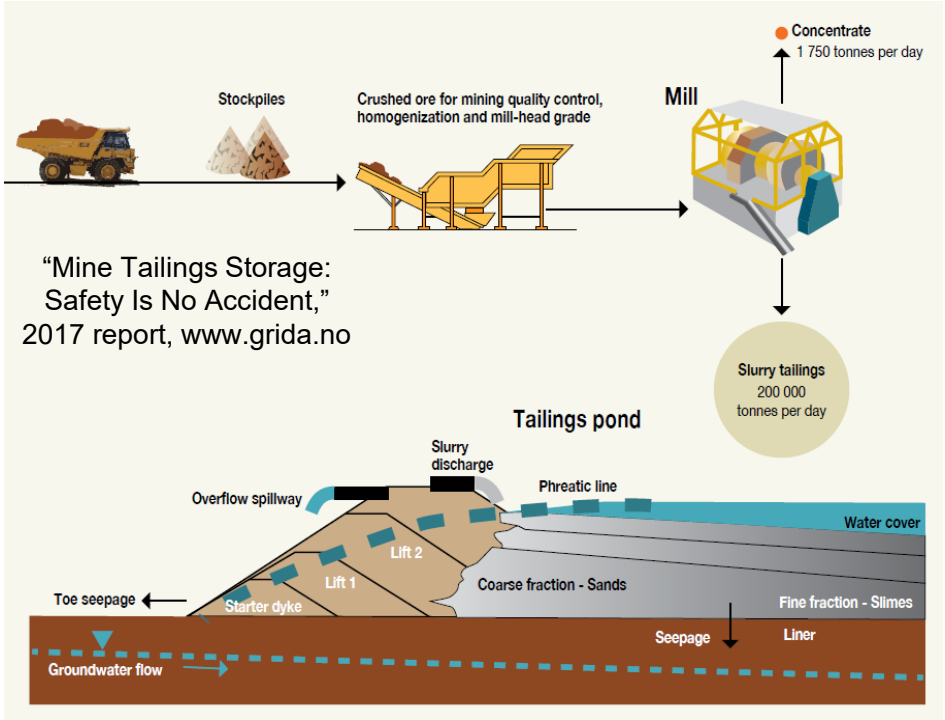
Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Joseph Labuz
Project Title: Precursors of Failure in Mine Tailings Dams
Organization: University of Minnesota, Twin Cities
Project Budget: $298,000
Project Length and Completion Date: 3 years, June 30, 2023
Today's Date: April 9, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 233,000	$ -	$ 233,000
Personnel: Labuz PI; 2.42 weeks of effort per year for three years, salary 73.5% of cost, fringe benefits 26.5% of cost. Laboratory supervision, provide guidance on strength and seismic measurements for the project, including specimen preparation, stress conditions, and development of seismic monitoring.			$ -
Personnel: Guzina PI; 2.74 weeks of effort per year for three years, salary 73.5% of cost, fringe benefits 26.5% of cost. Project supervision, provide guidance on seismic imaging and machine learning for the project, including transducer selection, transducer calibration, and data interpretation.			$ -
Personnel: Graduate student; 50% time per year for 2.75 years, 58.8% salary, 31.7% tuition, 9.5% fringe benefits. Conduct laboratory experiments and data analyses.			$ -
Personnel: Undergraduate student; Approximately 150 hours per year, 100% salary. Assist with specimen preparation and experimental setup.			$ -
Professional/Technical/Service Contracts			
Professional/Technical/Service Contracts: Barr Engineering will perform specimen preparation and field testing at a selected site; they will review the testing results and analysis. Barr Engineering is selected as the single-source contractor because of expertise in tailings dams, including both design and monitoring. Barr Engineering is providing a competitive price for the contracted work at a rate of $125/hr, a standard rate for a professional engineer. Effort certification will be tracked. It is estimated that the work will involve 120 hours per year for years 1 and 2, and 156 hours for year 3, for a total of 396 hours.	$ 49,500	$ -	$ 49,500
Equipment/Tools/Supplies			
Laboratory supplies, including membranes, LVDTs ($2,000). Machining of platens to house ultrasonic transducers ($1,000).	$ 3,000	$ -	$ 3,000
Capital Expenditures Over $5,000			
Bender element conditioner and data acquisition system	$ 12,000	$ -	$ 12,000
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
	$ 500	$ -	$ 500
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 298,000	$ -	$ 298,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Guzina and Labuz will provide unpaid time to the project, including 1% academic year cost-share each.		$ 14,148	$ -	$ 14,148
In-kind: Because the project has no indirect costs, laboratory space, electricity, and other overhead expenses are provided at no charge to the project. The University of Minnesota indirect cost recovery rate is 54% of MTDC.		$ 130,695	$ -	$ 130,695

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

PROJECT TITLE: PRECURSORS OF FAILURE IN MINE TAILINGS DAMS



"Mine Tailings Storage: Safety Is No Accident," 2017 report, www.grida.no

We aim to obtain data for design of an early warning system for predicting conditions that result in failure of mine tailings dams. This will be accomplished by:

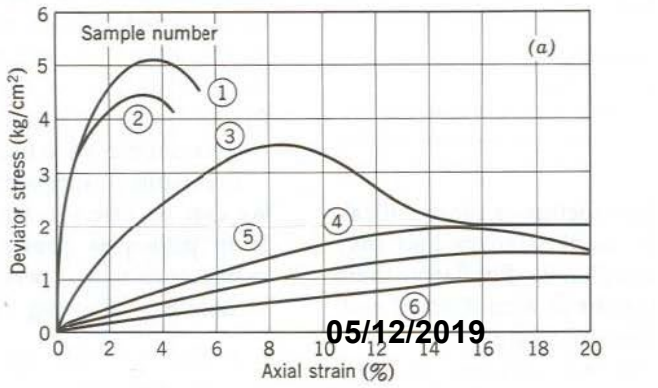
1. quantifying, with lab-scale tests, mechanical indices of mine tailings before and after failure;

2. correlating the seismic measurements to traditional indicators of performance such as earth and water pressures; and

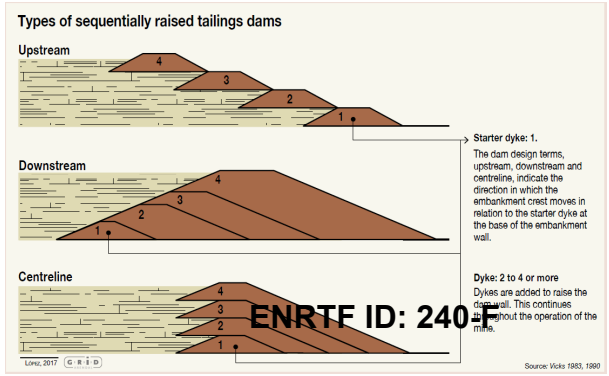
3. validating *in situ* the utility of seismic and conventional monitoring of mine tailings.

1. **Lab testing with seismic probing**

2. **Data analysis using machine learning**



3. **Field testing with seismic surveys**



Project Manager Qualifications and Organization Description

Project Title: Precursors of Failure in Mine Tailings Dams

Project Manager Qualifications

Joseph F. Labuz
MSES/Miles Kersten Professor, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota (UMN), Minneapolis, MN. Labuz has been at Minnesota since 1987, and he is a world leader in experimental investigation of strength and deformation of fluid-saturated materials.
1985 Ph.D. Civil Engineering, Northwestern University, Evanston, IL
1981 M.S. Civil Engineering, Northwestern University, Evanston, IL
1979 B.S. Civil Engineering (with honors), Illinois Institute of Technology, Chicago, IL

Bojan G. Guzina
Shimizu Professor, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota, Minneapolis, MN. Guzina has been at Minnesota since 1998, and he is leading expert in seismic imaging and machine learning.
1996 Ph.D. Geotechnical Engineering, University of Colorado, Boulder, CO
1992 M.S. Geotechnical Engineering, University of Colorado, Boulder, CO
1989 Dipl. Inz., Civil Engineering, University of Belgrade, Yugoslavia

Organization Description

The University of Minnesota (UMN) has world-class programs in civil, environmental, and geo-engineering, with over 50 years of initiating and promoting research and applications in characterizing material behavior. Several significant contributions to the geoengineering field were devised or refined at UMN. These include the displacement discontinuity method for predicting the stability of underground excavations, the distinct element method for modeling the behavior of blocky rock masses, and the constitutive response of fluid-saturated materials for determining solid-fluid coupling and flow characteristics.

The geomechanics laboratories at UMN are well equipped for determining strength and seismic properties of tailings, including triaxial compression testing. Basic instrumentation associated with an experimental mechanics laboratory is also available. Maintenance of hydraulic systems is performed annually by a certified technician. Supporting equipment to monitor seismic velocities include a high speed data acquisition system.

Barr Engineering is a national leader in tailings dams design and monitoring. They have performed annual dam safety inspections on large embankment tailings dams and modeling for dam seepage, stability, and deformation analysis. They have installed a variety of geotechnical instrumentation that includes vibrating wire piezometers, open-pipe piezometers, inclinometers, Shape Accel Array (SAA) inclinometers, and relief wells.