



Environment and Natural Resources Trust Fund (ENRTF) M.L. 2016 Work Plan

Date of Report: December 4, 2015

Date of Next Status Update Report: January 15, 2017

Date of Work Plan Approval:

Project Completion Date: June 30, 2019

Does this submission include an amendment request? No

PROJECT TITLE: Understanding bedrock fracture flow to improve groundwater quality

Project Manager: Anthony C. Runkel

Organization: Minnesota Geological Survey (University of Minnesota)

Mailing Address: 2609 Territorial Road

City/State/Zip Code: St Paul, MN, 55114

Telephone Number: (612) 626-1822

Email Address: runke001@umn.edu

Web Address: <http://www.mngs.umn.edu/>

Location: Work will take place in Hennepin County. Counties most directly impacted will be Hennepin, Ramsey, Dakota, Washington, and Anoka. Indirect impact to all of southeastern Minnesota.

Total ENRTF Project Budget:

ENRTF Appropriation: \$183,000

Amount Spent: \$0

Balance: \$183,000

Legal Citation: M.L. 2016, Chp. xx, Sec. xx, Subd. xx

Appropriation Language:

I. PROJECT TITLE: Understanding bedrock fracture flow to improve groundwater quality

II. PROJECT STATEMENT:

Using new borehole testing and rock fracture mapping techniques we will gain a better understanding of groundwater flow through fractured bedrock in the Twin Cities that will support better management of water quality and quantity. Groundwater flow in bedrock occurs mostly through fractures (cracks in the rock) in a manner that remains difficult to predict, hampering efforts to protect and remediate groundwater. This problem is particularly acute across southeastern Minnesota, including the Twin Cities, where fractured limestone bedrock is a source of baseflow to streams, and also a source of drinking water. Contaminated water from point (e.g. petroleum products and solvents) and non-point (e.g. nitrate) sources in these limestones is well-known. Point-source contamination plumes are a particular problem in the Twin Cities, with a large number of actively monitored and remediated sites, including Superfund sites in Minneapolis, St. Louis Park, Oakdale, and Edina.

The project will focus on the Platteville Formation in the Twin Cities, a fractured limestone, which is one of the most heavily contaminated bedrock layers in the state. It is also hosts a large number of springs, such as Camp Coldwater spring, that discharge to the Mississippi River, and is the bedrock foundation for infrastructure in the urban core. At a site along the Mississippi River in Minneapolis, we will use recently developed techniques of borehole testing and installation of pressure and temperature sensors in two monitor wells, and detailed mapping of fractures at nearby rock exposures. Pressure and temperature measurements collected from the wells will provide us with information on water flow through fractures, and when evaluated in the context of nearby fracture mapping at the rock exposures, will allow us to link hydraulic (water) properties to rock (fracture) properties to provide a greater understanding of fracture flow.

Application of our results will improve the efficiency and effectiveness of remediation and monitoring at a large number of contamination sites across the Twin Cities. The results will also be applicable to water management at construction (tunneling, building foundation, roadwork) sites, and to modeling groundwater-surface water interaction in areas such as the Minnehaha Creek Watershed. The results will provide a better understanding of fracture controlled flow through limestones regionally across southeastern Minnesota, and therefore link to the mapping of these limestones as part of ongoing County Geologic Atlas mapping program, such as the in-progress Hennepin County Atlas.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 15, 2017:

Project Status as of July 1, 2017:

Project Status as of January 15, 2018:

Project Status as of July 1, 2018:

Project Status as of January 15, 2019:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Monitor well testing and installation of pressure and temperature sensors.

Description: We will use borehole geophysical and video tools to identify and measure fractures, and measure water flow, in two monitor wells on University of Minnesota campus. That information will be used to design and install flexible borehole liners (1 each well) and sensors (15 each well) that will measure pressure and

temperature every five seconds. This work will be conducted by Minnesota Geological Survey scientists, working with the Centre for Applied Groundwater Research, University of Guelph, Ontario, the latter under a Professional/Technical Service contract.

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 115,672
Amount Spent: \$ 0
Balance: \$ 115,672

Outcome	Completion Date
1. Depiction of fracture patterns in the two monitor wells, that can be compared with fracture patterns that we characterize from outcrops (Activity 3)	February 15, 2017
2. Measurements of groundwater flow through fractures in the two monitor wells	February 15, 2017
3. Borehole liners and sensors installed in the two wells will provide temperature and pressure data for a period of two years (Activity 2)	February 15, 2017

Activity Status as of January 15, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 15, 2018:

Activity Status as of July 1, 2018:

Activity Status as of January 15, 2019:

Final Report Summary:

ACTIVITY 2: Collect groundwater pressure and temperature data from monitor wells for 2 years

Description: Scientists from the Minnesota Geological Survey will extract sensors from wells at approximately 6 month intervals to download temperature and pressure data, followed by re-insertion of sensors for additional data collection.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 18,572
Amount Spent: \$ 0
Balance: \$ 18,572

Outcome	Completion Date
1. Acquisition of two years of continuous (five second intervals) data showing temperature and pressure variability that provide an understanding of groundwater flow conditions	November 1, 2018

Activity Status as of January 15, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 15, 2018:

Activity Status as of July 1, 2018:

Activity Status as of January 15, 2019:

Final Report Summary:

ACTIVITY 3: Map fractures in bedrock along Mississippi River near the tested monitor wells

Description: Fractures (cracks) in the limestone of the Platteville Formation will be mapped by photo-based trace mapping of exposures along east bank of Mississippi River, about 500 yards from monitor wells tested as part of Activity 1. This process includes high-resolution, seamless photograph collected by a camera mounted on a drone, near Washington Avenue bridge. Fractures shown on the photograph will be traced on the photograph electronically in the office, and then adjusted and measured in the field, on the outcropping. The final product will be a depiction of the natural fractures system in the Platteville Formation.

Summary Budget Information for Activity 3:

ENRTF Budget: \$ 18,450

Amount Spent: \$ 0

Balance: \$ 18,450

Outcome	Completion Date
1. Documentation of the fracture patterns that control groundwater flow	November 1, 2018

Activity Status as of January 15, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 15, 2018:

Activity Status as of July 1, 2018:

Activity Status as of January 15, 2019:

Final Report Summary:

ACTIVITY 4: Synthesize information, disseminate results to groundwater managers.

Description: Compile and interpret pressure and temperature data collected from the two monitor wells, to understand how water flows through fractures. Compare and evaluate these results to fracture patterns mapped at nearby rock exposure to link together fracture patterns with water flow. Produce reports and presentations summarizing the results, which will be disseminated to organizations that have a role in managing groundwater quality and quantity, such as MPCA, DNR, County environmental managers, and environmental consulting industry.

Summary Budget Information for Activity 4:

ENRTF Budget: \$ 30,306

Amount Spent: \$ 0

Balance: \$ 30,306

Outcome	Completion Date
1. Peer reviewed report(s) and public presentations of results that explain how fractures control groundwater flow, which will lead to more effective remediation of contamination sites, and improve management strategies to better protect fractured rock aquifers from further degradation	July 1, 2019

Activity Status as of January 15, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 15, 2018:

Activity Status as of July 1, 2018:

Activity Status as of January 15, 2019:

Final Report Summary:

V. DISSEMINATION:

Description: We will disseminate results to organizations that have a role in managing groundwater quality and quantity, such as MPCA, MNDNR, County environmental managers, and environmental consulting industry. Dissemination will include presentations at meetings such as the Minnesota Ground Water Association, and begin before the project ends, as we progressively acquire data. At the conclusion of the project, the results will appear in published, peer-reviewed report(s), that are routinely disseminated widely by the Minnesota Geological Survey (MGS), including through our website at <http://www.mngs.umn.edu/>. MGS reports also include links to all raw data that support the conclusions of the report. Results are also likely to be of sufficient interest and applicability to be published in one or more national or international journals.

Status as of January 15, 2017:

Status as of July 1, 2017:

Status as of January 15, 2018:

Status as of July 1, 2018:

Status as of January 15, 2019:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	\$ Amount	Overview Explanation
Personnel:	\$ 81,723	1 MGS senior scientist for project management, borehole equipment installation, fracture characterization, and synthesis of results; 16.6% time per year for 3 years, 74% salary, 26% benefits (\$45,438); 3 MGS staff for assistance with borehole equipment installation, fracture characterization, and synthesis of results, as follows: 1 MGS senior scientist 8.3% time per year for 3 years, 74% salary, 26% benefits (\$21,403); 1 scientist MGS 4.2% time per year for 3 years, 74% salary, 26% benefits (\$8,202); 1 assistant scientist MGS 4.2% time per year for 3 years, 74% salary, 26% benefits (\$6,680)
Professional/Technical/Service Contracts:	\$40,800	1 contract with Centre for Applied Groundwater Research (CAGR) , University of Guelph, Ontario: Acquisition of borehole data from two

		monitor wells that will provide recognition of rock fractures in the wells, and where and in what direction natural groundwater flow occurs. Includes directional temperature logs (CAGR is sole source provider), acoustic and optical televiewer logs, and full waveform sonic logs. Design and installation of a borehole liner and 15 sensors (a technique developed and deployed only by CAGR) in each of two monitor wells (total 2 borehole liners and 30 sensor arrays designed and installed) (\$40,000); 1 contract for drone-based photography to image fractured rock along Mississippi River at University of Minnesota, provider TBD (\$800)
Equipment/Tools/Supplies:	\$4082	Borehole liners to be installed in two monitor wells. FLUTE brand flexible liners, Total of 2 liners @ \$1541 ea (\$3082). Shipping of equipment ("Green Machine") necessary to extract and reinsert borehole liner (\$1000)
Capital Expenditures over \$5,000:	\$55,050	Data logger sensors that measure pressure and temperature (to be installed in two boreholes): Total 30 sensors @ \$1827.50 ea , plus shipping @ \$225 (\$55,050)
Fee Title Acquisition:	\$	
Easement Acquisition:	\$	
Professional Services for Acquisition:	\$	
Printing:	\$	
Travel Expenses in MN:	\$1345	Truck rental for monitor well liner installation, retrieval, re-installation (to retrieve data 4 times during course of project) (rental, 5 weeks @ \$269/week) (\$1345)
Other:	\$	
TOTAL ENRTF BUDGET:		\$183,000

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than \$5,000: Thirty data logger sensors that measure pressure and temperature to be installed in two boreholes will be purchased and will be continue to be used by the Minnesota Geological Survey for the life of these sensors for similar projects and purposes. If the instrument is sold prior to its useful life, proceeds from the sale will be paid back to the Environment and Natural Resources Trust Fund.

Number of Full-time Equivalent (FTE) Directly Funded with this ENRTF Appropriation: 1.0 FTE

Number of Full-time Equivalent (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0.2 FTE

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			

	\$	\$	
State			
University of Minnesota	\$95,486	\$	In-kind Services To Be Applied To Project During Project Period: The University of Minnesota's Facilities and Administrative rate is 52% 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 would have been allowed on this project, would be \$95,486
TOTAL OTHER FUNDS:	\$95486	\$	

VII. PROJECT STRATEGY:

A. Project Partners:

Project Partners Receiving Funds:

- **Centre for Applied Groundwater Research** , University of Guelph, Ontario, led by Dr. Beth Parker. \$40,000 for geophysical testing and installation of pressure and temperature sensors as a contracted collaboration. This Centre is uniquely capable of acquiring temperature profiles that measure flow direction through fractures in monitor wells, and in installation of the nested pressure and temperature sensors, a procedure developed by their group. The information acquired from these procedures is key to understanding flow through fractures in the two monitor wells we are testing on the University of Minnesota campus. Contribution to interpretation of final results and publication during final year of project will be an unpaid contribution.

Project Partners Not Receiving Funds:

- **Braun Intertec**, Bloomington, Minnesota. Kelton Barr, Principal Hydrogeologist, providing unpaid consultation at all stages of the investigation. Mr. Barr has over 40 years of experience remediating fractured limestone contamination sites in the Twin Cities.

B. Project Impact and Long-term Strategy:

Application of our results will improve the efficiency and effectiveness of remediation and monitoring at a large number of contamination sites across the Twin Cities. The results will also be applicable to water management at construction (tunneling, building foundation, roadwork) sites, and to modeling groundwater-surface water interaction in areas such as the Minnehaha Creek Watershed. The results will provide a better understanding of fracture controlled flow through limestones regionally across southeastern Minnesota, and therefore link to the mapping of these limestones as part of ongoing County Geologic Atlas mapping program, such as the in-progress Hennepin County Atlas. The borehole equipment purchased for this project, and the investigative methods, can be subsequently deployed in both wells and springs at other sites in southeastern Minnesota.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	\$ Amount
Proposed project builds on over 5 years of research by MGS staff on fractured rock groundwater flow in the Platteville Formation, funded through Minnesota Geological Survey base funding, and a 2010 Metropolitan Council grant.	~July 1, 2010-July 1, 2015	\$60,000
ENTRF funded a 2010 project "Investigation of the hydrologic properties of the St. Lawrence Formation" (M.L. 2010, Chp. 362,	July 1, 2010-June 30, 2013	\$307,000

Sec. 2, Subd. 3a). The results of that investigation have led to the development of techniques and concepts that we will apply to this proposed project.		
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VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A

IX. VISUAL COMPONENT or MAP(S): See attached visual component

X. RESEARCH ADDENDUM: N/A

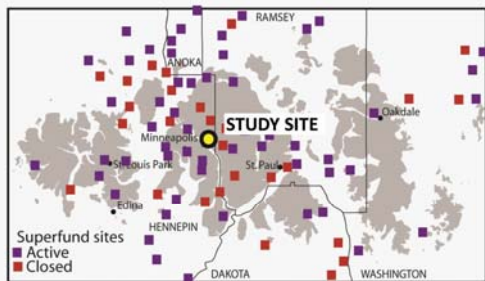
XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 15, 2017, July 1, 2017, January 15, 2018, July 1, 2018, January 15, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

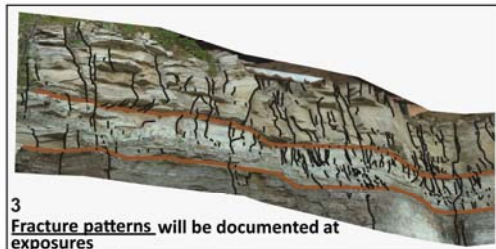
Understanding Bedrock Fracture Flow to Improve Groundwater Quality

Environment and Natural Resources Trust Fund (ENTRF) (Proposal ID:049-B)

Anthony Runkel, Minnesota Geological Survey

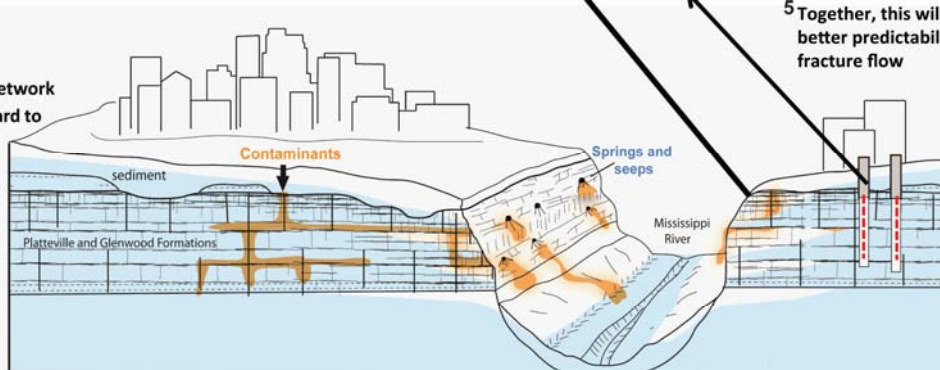


1 The Platteville limestone (gray) is one of the most heavily polluted formations in the state



3 Fracture patterns will be documented at exposures

2 Contaminants move through a complex network of fractures, downward to deeper aquifers and laterally to rivers in a manner difficult to predict



4 Pressure and temperature in wells will record water flow through fractures

5 Together, this will lead to better predictability of fracture flow



Depiction of the fractured limestone and contamination plumes beneath the Twin Cities

Environment and Natural Resources Trust Fund
M.L. 2016 Project Budget

Project Title: Understanding bedrock fracture flow to improve groundwater quality
Legal Citation: M.L. 2016, Chp. xx, Sec. xx, Subd. xx
Project Manager: Anthony C. Runkel
Organization: Minnesota Geological Survey (University of Minnesota)
M.L. 2016 ENRTF Appropriation: \$ 183,000
Project Length and Completion Date: 3 years, June 30, 2019
Date of Report: 12/4/15



ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	Activity 4 Budget	Amount Spent	Activity 4 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	Monitor well testing and installation of pressure and temperature sensors.			Collect groundwater pressure and temperature data from monitor wells for 2 years			Map fractures in bedrock along Mississippi River near the tested monitor wells			Synthesize information, disseminate results to groundwater managers.				
Personnel (Wages and Benefits)	\$17,002	\$0	\$17,002	\$16,765	\$0	\$16,765	\$17,650	\$0	\$17,650	\$30,306	\$0	\$30,306	\$81,723	\$81,723
1 senior scientist, Project Manager, MGS: \$45,438 (16.6% time per year for 3 years, 74% salary, 26% benefits)														
1 senior scientist, MGS: \$21,403 (8.3% time per year for 3 years, 74% salary, 26% benefits)														
1 scientist MGS: \$8202 (4.2% time per year for 3 years, 74% salary, 26% benefits)														
1 assistant scientist MGS: \$6680 (4.2% time per year for 3 years, 74% salary, 26% benefits)														
Professional/Technical/Service Contracts														
Photography of fractured bedrock along east bank of Mississippi river at U of Minnesota campus, using camera mounted on drone.							\$800	\$0	\$800				\$800	\$800
Centre for Applied Groundwater Research (CAGR) , University of Guelph, Ontario: Acquisition of borehole data from two monitor wells that will provide recognition of rock fractures in the wells, and where and in what direction natural groundwater flow occurs. Includes directional temperature logs (CAGR is sole source provider), acoustic and optical televiwer logs, and full waveform sonic logs. Design and installation of a borehole liner and 15 sensors (a technique developed and deployed only by CAGR) in each of two monitor wells (total 2 borehole liners and 30 sensor arrays designed and installed)	\$40,000	\$0	\$40,000										\$40,000	\$40,000
Equipment/Tools/Supplies														
Borehole liners to be installed in two monitor wells. FLUTE brand flexible liners, Total of 2 liners @ \$1541 ea	\$3,082	\$0	\$3,082										\$3,082	\$3,082
Shipping of equipment ("Green Machine") necessary to extract and reinsert borehole liner (\$1000)				\$1,000	\$0	\$1,000							\$1,000	\$1,000
Capital Expenditures Over \$5,000														
Data logger sensors that measure pressure and temperature (to be installed in two boreholes): Total 30 sensors @ \$1827.50 ea, plus \$225 shipping (\$55,050)	\$55,050	\$0	\$55,050										\$55,050	\$55,050
Fee Title Acquisition														
<i>Specify an estimated number of parcels and acreage and who will hold the title to the land(s) acquired.</i>														
Easement Acquisition														
<i>Specify an estimated number of parcels and acreage and who will hold the easement for the land(s) acquired.</i>														
Professional Services for Acquisition														
<i>List costs associated with fee title and easement acquisition transactions. Indicate expected number of transactions and average costs per transaction.</i>														
Printing														
<i>List types of printing costs anticipated.</i>														
Travel expenses in Minnesota														
Equipment rental (truck) for monitor well liner installation, retrieval, re-installation (to retrieve data 4 times during course of project) (truck rental, 5 weeks @ \$269/week ; total \$1345)	\$538	\$0	\$538	\$807	\$0	\$807							\$1,345	\$1,345
Other														
<i>Describe the expense—one row per type/category. Add rows as needed. Be specific.</i>														
COLUMN TOTAL	\$115,672	\$0	\$115,672	\$18,572	\$0	\$18,572	\$18,450	\$0	\$18,450	\$30,306	\$0	\$30,306	\$183,000	\$183,000