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

Project Title: **ENRTF ID: 061-B**

Snowpack-Driven Groundwater Recharge across Minnesota

Category: B. Water Resources

Total Project Budget: $ 453,386

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

Summary:

Snowmelt provides up to 80% of Minnesotas groundwater recharge. We will measure this statewide, build spring recharge forecasts, and find solutions where climate and land-use change impact snowmelt water resources.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Measuring snowmelt infiltration to recharge groundwater; up to 80% of groundwater recharge is from snowmelt

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

PROJECT TITLE: Snowpack-driven groundwater recharge across Minnesota

I. PROJECT STATEMENT

Minnesota's winter snowpack provides up to 80% of the state's annual groundwater recharge that sustains our abundant lakes, wetlands, and groundwater resources. Changes in **pumping, land-use, and climate** cause water shortages, **even in Minnesota**. Minnesota's snow remains **critically understudied** because, unlike snowmelt in the arid West that flows from the mountains to the valleys, it seeps through the subsurface, invisible but essential.

Here we propose to **measure statewide snowpack and soil moisture**, investigate changes in response to **climate and land-use change**, and **propose solutions to maintain Minnesota's groundwater.** We will:

1. **Generate a complete record of snow depth and near-surface soil moisture from the mid-2000's to present, and continue this record into the future**, using state-of-the-art algorithms with data from 40 of MnDOT's GPS survey stations to develop a new snow-based water resources monitoring network
2. Install deeper soil moisture and temperature probes to measure **snowmelt infiltration** and **spring thaw** at these sites, allowing us to **estimate past groundwater recharge and measure it into the future.**
3. **Identify key areas of concern** in which groundwater recharge is changing due to **climate, land-use, and/or water use**. **A single warm and/or dry winter can cause spring lake levels to be low; multiple such winters in a row cause low water to be the "new normal".**
4. **Develop groundwater recharge forecasts** to guide responsible and sustainable groundwater use.
5. Propose solutions to preserve Minnesota's snowpack and promote infiltration into thawing spring soils, such as **planting cover crops, building effective riparian buffers, and restoring local ponds.**

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Generate a statewide 10-year history of snow depth and soil moisture, with continued real-time monitoring into the future **Budget: $84,326**

Use MnDOT GPS stations to compute snow depth and soil moisture over the past decade and into the future. Project partner Larson has already completed a successful pilot study on a subset of Minnesota stations.

Outcome	Completion Date
1. Add those MnDOT GPS stations whose data are currently discarded to the long-term data archive: enables this work, helps MnDOT land surveying	12/1/2017
2. Produce a continuous snow depth and soil moisture record for each GPS station	12/31/2018

Activity 2: Add sensors to trace snowmelt through the subsurface and to the aquifers **Budget: $298,206**

Add deep soil moisture probes and subsurface temperature sensors to each of the GPS sites used for this work, with the help of technology developed by PI Wickert. Build a GPS station in the Arrowhead Region (Isabella, MN), which currently is the only part of Minnesota to not have one that can be used to measure water.

Outcome	Completion Date
1. 1 new GPS station built to measure snowpack and soil moisture in the currently-unmonitored Arrowhead Region	8/31/2018
1. Subsurface probes added to measure groundwater recharge at each GPS station	9/30/2018

Activity 3: Develop forecasts of springtime groundwater recharge and recommendations for actions to enhance infiltration of Minnesota's snowmelt **Budget: $75,853**

The suite of GPS-derived snow depth and shallow soil moisture measurements, together with soil temperature and deeper soil moisture from newly installed probes, will be analyzed to determine the contribution of snow to annual groundwater budgets. We will then apply these results to calibrate a snow and soil moisture hydrology model that can **"hindcast" the historical record of snow-groundwater interactions and predict seasonal recharge based on snowpack**. We will **run model experiments to estimate how Minnesotans can change land cover to enhance groundwater recharge**. We will distribute reports documenting past trends of snow inputs to

groundwater to state agencies to establish an understanding of baseline conditions, as well as our recommendations for future action. A project website will provide real-time data streams of snow depth and soil moisture, as well as forecasts of snow-driven recharge at the GPS snow hydrology stations.

Outcome	Completion Date
1. Determine current snow contributions to groundwater budget using the fully-instrumented GPS snow hydrology network	08/31/2019
2. Develop snow hydrology model to assess historical trends of snow inputs to groundwater	08/31/2019
3. Produce seasonal snow-driven recharge forecasts based on snowpack	03/31/2020
4. Recommend actions to enhance groundwater recharge	06/30/2020
5. Communicate results through reports and real-time data streams	06/30/2020

III. PROJECT STRATEGY

A. Project Team/Partners

Lead PI Prof. Dr. Andrew Wickert (UMN) requests funding to lead the field component, advise a master's and an undergraduate student, and support two technical specialists. His team will build and install all instrumentation.

Co-PI Prof. Dr. Crystal Ng (UMN) requests funding to support a master's student and lead the hydrologic modeling component.

Project partner Nathan Anderson (MnDOT) will provide GPS expertise, knowledge of local projects and agencies, and field assistance with equipment installations. **(No ENRTF funds requested.)**

Project Partner Prof. Dr. Kristine Larson (U. Colorado) developed the GPS methods for hydrology and will provide technical expertise and support. **(No ENRTF funds requested.)**

B. Project Impact and Long-Term Strategy

Infiltration of gradually-melting snow into thawing ground provides up to 80% of Minnesota's groundwater recharge even though it accounts for only 20% of precipitation because snow is minimally lost to evaporation, plant transpiration, and/or flow through rivers**.** Our proposed project will provide a **continuous stream of snow and soil moisture information** that will serve the state far beyond the funded duration of this project with **minimal effort or cost**. Our **action recommendations** to enhance snowmelt-driven groundwater recharge will guide state agencies and citizens, and their effectiveness will be monitored when action is taken at GPS monitoring station sites. By archiving currently-discarded GPS data, Minnesota will be poised to exploit the up-and-coming algorithms that Project Partner Larson is developing that use **GPS to measure vegetation growth and long-term groundwater storage and release**. **Historical and continuously-streaming snow and water data, groundwater forecasts, and action recommendations will be made available through our project website**, hosted at the University of Minnesota and linked from MnDOT's website and national GPS networks. This work complements co-PI Ng's 2016 LCCMR project 011-A (recommended for funding) to improve its statewide recharge estimates, increasing the impact of both projects at no added cost; it can similarly benefit other efforts to evaluate the state's water budget. Importantly, this will be one of the first major efforts to track and quantify the disproportionately important role of snow hydrology on Minnesota's water resources.

C. Timeline Requirements

The project will span three years. Hardware and algorithm development during the first academic year will precede a summer field season for instrument deployment. The project will require two full years after deployment to analyze a representative set of trends in snowfall and soil moisture. Subsequent soil sensor and GPS data processing and analysis will lead to Wickert's master's student's thesis. The second year will also include preliminary results and algorithm refinement that will culminate in Ng's student's master's thesis. In the third year, we will reduce costs to a minimum in order to continue to monitor the network and analyze the data without any major field component.

Project Title:Snowpack-driven groundwater recharge across Minnesota

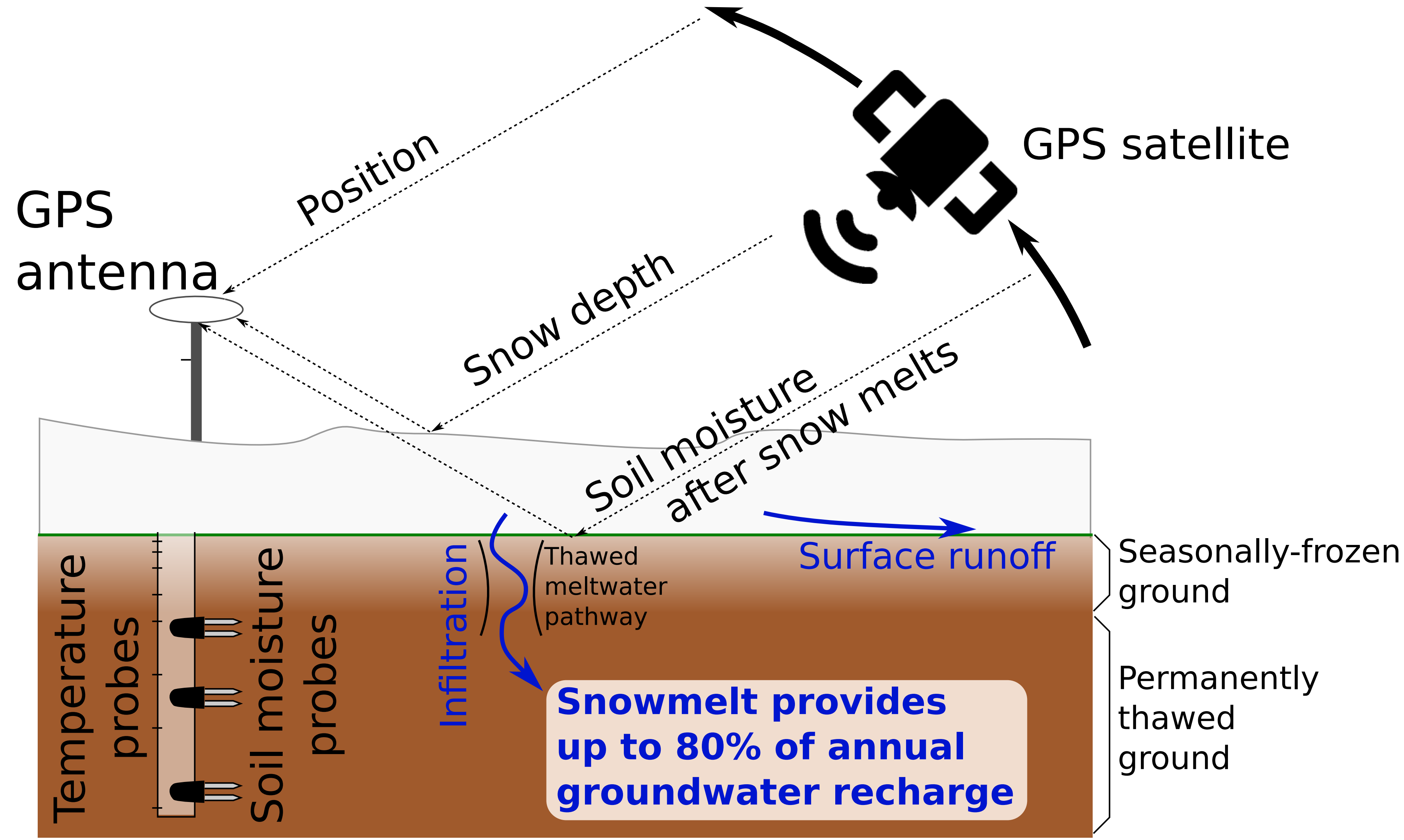
IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel	**$ 323,002**
PI Wickert: 74.8% salary, 25.2% benefits, 3 summer months total, equaling 8% FTE for each year ($32,742)	
co-PI Ng: 74.8% salary, 25.2% benefits, 2.5 summer months total, equaling 6% FTE for years 1 and 2 and 8% FTE for year 3 ($28,461)	
2 graduate students: 56.3% salary, 43.7% benefits, 2 years, 50% time position, equaling 50% FTE for years 1 and 2 ($170,349)	
3 undergraduate researchers, 100% salary, $10/hr for 1,440 hours total ($14,400)	
Research professional for subsurface temperature measurements, 78.5% salary, 21.5% benefits, 3 months total, equaling 17% FTE in year 1 and 8% FTE in year 2 ($16,898).	
Research professional to build and manage sensor network, 78.5% salary, 21.5% benefits, 8 months total, equaling 33% FTE for years 1 and 2 ($60,151).	
Professional/Technical/Service Contracts	**$ 15,000**
Installation of one research- and survey-grade GPS antenna and receiver over a natural ground surface in the Arrowhead Region; contractor to be chosen by competitive bid with the assistance of MnDOT/MnCORS, represented by project partner Nathan Anderson. 50% costs will be covered by MnDOT ($15,000)	
Equipment/Tools/Supplies	**$ 63,294**
42 data loggers equipped with continuous power supply systems and cell phone modems for telemetry: 41 for the field + 1 for the lab at $500/each ($21,000)	
126 Decagon Devices soil moisture probes: 3/site at 41 sites, plus one benchtop set of 3 probes for the lab at $269/probe ($33,894)	
42 temperature probes (41 for the field + 1 for the lab) at $200/probe ($8800)	
Travel:	**$ 8,040**
Mileage to travel across the state to install and maintain equipment: 11,000 miles at $0.54/mile ($3240)	
Lodging for 40 nights at $120 total/night ($4800)	
Additional Budget Items	**$ 44,050**
Telemetry for 41 data loggers for 3 years, based on Verizon research communications pricing ($150/unit/year) ($19,350)	
Field Maintenance: cleaning and repairing solar panels, wires, and data loggers ($4000)	
Data archiving: receiving and processing snowpack, temperature, soil moisture, and GPS data in an archive housed at the Saint Anthony Falls Laboratory at UMN ($6000)	
Project publication and dissemination: two scientific journal articles at $2500; information distiled in a booklet for state agencies and citizens at $1,000; travel for students and 1 PI to American Geophysical Union conference to showcase Minnesota's groundwater recharge network and present each component of our work plan at $3600 ($1200/ea); website to present and disseminate realtime and historic data, groundwater forecasts, and project recommendations at $6000 ($15,600)	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 453,386**

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:N/A	$ -	N/A
Other State $ To Be Applied To Project During Project Period:N/A	$ -	N/A
In-kind Services To Be Applied To Project During Project Period	**$ 196,108**	**Secured**
The Minnesota Department of Transportation has offered to pay for 50% of the proposed GPS station at Isabella, MN	$ 15,000	Secured
The University of Minnesota's Facilities and Administrative rate is 52% of modified total direct costs. The University will provide office space, IT services, and administrative / financial services in support of the project.	$ 181,108	Secured
Funding History:N/A	$ -	N/A
Remaining $ From Current ENRTF Appropriation: While not tightly linked to this proposal's work plan, co-PI Ng's 2016 project, 011-A "Assessment Tool for Understanding Vegetation Growth Impacts on Groundwater Recharge" (7/1/16-6/30/19), will provide state-wide recharge results that will facilitate groundwater budget assessments in this project.	**$ 212,000**	**Recco-mended for funding**

Measuring the health of Minnesota's snowpack: a healthy snowpack means good groundwater recharge



MnDOT's existing GPS monuments are easily extended to be snowpack and groundwater recharge monitoring stations.

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Professor Wickert joined the Department of Earth Sciences and the Saint Anthony Falls Laboratory at the University of Minnesota in August 2015, following a postdoctoral research position in the Institute for Earth and Environmental Science at the Universität Potsdam in Germany. He is also a graduate advisor in the Water Resources Sciences program at the University of Minnesota. His water resources research focuses on the development of innovative instrumentation to improve measurements and reduce costs and build observational networks. As a native of Minnesota who cares passionately for its lands, waters, and people, he is committed to understanding and improving the natural environment in his homeland and our interactions with it.

Wickert integrates the **effects of climate and land-use change on the Earth's surface**, and recently co-authored a review of the state of the science at this critical intersection. In his past work, he **developed inexpensive open-source data loggers** that have been used to understand denitrification in the Mississippi River delta and the Gulf of Mexico dead zone, measure the effects of frost on hillslope shape and soil development across Colorado, monitor glacier melt in Alaska, and gauge streams in Argentina. He also builds instruments to photograph and measure how hillslopes erode and change following wildfire. All of these designs are open-source and available for professional and citizen science. He has also worked with GPS stations across the Midwest to understand how the load of the continental glaciers from the last ice age warped Earth's crust and have affected the Mississippi River is ways that continue to be seen today. On a broader scale, he continues work towards **continental-scale water balances** to understand how changing climate and melting ice sheets can affect global ocean circulation.

In his teaching, Wickert has **taught future state scientists about the glacial geology of Minnesota**, supported the University of Minnesota's geology club, and helped to plan the University of Minnesota geology field camps. He is currently planning new courses on geomorphology – the science of how landscapes form and change – and computational methods in Earth sciences; both of these are tied tightly to hydrology.

Prior to his postdoctoral position in Potsdam, Germany, Wickert received his Ph.D. in geology from the University of Colorado Boulder (2014), his S.B. in Earth, Atmospheric, and Planetary Science from MIT (2008), and his high school diploma from Harding Senior High School on Saint Paul's east side (2004).

Saint Anthony Falls Laboratory, University of Minnesota (Twin Cities)

Research at the historic Saint Anthony Falls Laboratory (SAFL), part of the College of Science and Engineering at the University of Minnesota, is focused at the intersection of fluid dynamics with major societal challenges in energy, environment and health. SAFL scientists and engineers integrate experiments in the laboratory and field with advanced computational tools and theory to obtain innovative, science-based solutions to real-world fluid-flow problems.