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

Project Title: **ENRTF ID: 057-B**

Predicting Hidden Groundwater Connections Between Land and Lakes

Category: B. Water Resources

Total Project Budget: $ 408,455

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

Summary:

Assess baseline groundwater influence on four representative lakes; Develop groundwater models that predict land-use impacts on lake levels and contamination; Assess scenarios of crop-conversions, irrigation, and fertilization.

Name: Gene-Hua Crystal Ng

Sponsoring Organization: U of MN

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Minneapolis MN 55455

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Location

Region: Central, Northwest

County Name: Aitkin, Cass, Crow Wing, Hubbard, Itasca

City / Township:

Alternate Text for Visual:

Top: Side-by-side photos of potato field (with pine tree) and lake, underlain by diagram of groundwater flow and contaminant transport lines that originate under potato field and end at lake. Bottom: State map with the five-county North-Central lakes region highlighted; map shows complex glacial geology and caption: "Complex glacial history: Diverse geology & hydrology in North-Central Lakes Region." Map accompanied by inset photos of representative lakes to be modeled in proposed project; main caption for inset photos: "Four representative groundwater-lake models"; inset photos include the following sub-captions: "Long Lake: Glacial outwash (faster link?), At-risk now!"; "Shingobee Area Research Lakes: Glacial till (slower link?), Shingobee Lake: River-connected; Williams and Crystal Lakes: Closed, Source & Sink."

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

PROJECT TITLE: Predicting Hidden Groundwater Connections between Land and Lakes

I. PROJECT STATEMENT

Through hidden groundwater connections, disturbances from land-use and water appropriations can propagate to our lakes, thus altering their water levels and delivering contaminants such as nitrates. Recent lake-level drops have taught us that groundwater and surface-water are inextricably connected. Statewide estimates by the MPCA/USGS show us that distinct ecosystems allow different amounts of water to infiltrate past roots. These examples sound clear warnings that land-use decisions, such as converting forests to row crops in north-central Minnesota, will affect **aquifers and lakes** through new recharge rates, irrigation pumping, and fertilizer applications. However, "looking" underground at groundwater is not easy, so we urgently need a way to predict how land-use changes and other water appropriations impact our lakes through groundwater.

To uncover the hidden link, we propose to develop a **groundwater model**, applicable to **lakes in north-central Minnesota**, that can **predict**:

- **lake water level changes** due to vegetation water-use and groundwater pumping
- **nitrate loads to lakes through groundwater** from agricultural applications
- **different land-use scenarios** with crop-conversions, irrigation, and fertilization

The proposed work moves us beyond typical monitoring to provide **predictive** capabilities for management decisions; it also looks further than standard water budgets to identify **lake level AND contamination** impacts conveyed through groundwater.

A few research lakes in the Shingobee Headwaters Area indicate *diverse* groundwater inputs of 25-76%, and *complex glacial history* prevents easy extrapolation. Evaluating lake impacts requires in-depth local analysis. We propose four representative groundwater-lake models that cover a range of hydrogeological conditions to demonstrate possible vulnerabilities throughout the north-central lakes region. We will leverage long-term lake data from the relatively undeveloped Shingobee area, as well as initiate a new effort at Long Lake (Hubbard County) to importantly introduce an at-risk lake to the limited groundwater-lake database. With the involvement of UMN's Hydrogeology Field Camp, we will collect groundwater and lake data to build models that can help us manage current threats to our lake water quantity and quality. Backed by concerned citizens and executed with the training of our next generation of hydrogeologists, our project represents a true **community effort** to protect the lakes that lie at the heart of our state's recreational culture and tourism economy.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Collect data on baseline groundwater influence on lake levels and contaminants* **Budget:** $219,390

We will compile decades-long records from three lakes in the Shingobee area (north-central region), including lakes with river inlets/outlets and closed lakes, located in glacial till (potentially less groundwater-connected). To expand the database, we will measure groundwater inputs and water quality at Long Lake, located in glacial out-wash (potentially more groundwater-connected). Long Lake belongs to the Straight River Pilot Groundwater Management Area, identified to be at-risk for groundwater overuse and degraded quality. Our field plan will involve UMN's Hydrogeology Field Camp, an intensive summer college course held near Hackensack.

Outcome	Completion Date
1. Evaluate long-term groundwater-lake data for trends at three Shingobee area lakes	9/30/19
2. Measure groundwater inputs and nitrate loading at the at-risk Long Lake	9/30/19
3. Train 30 UMN college students a year on groundwater-surface water field methods	7/31/19

Activity 2: *Develop groundwater model that predicts land-use impacts on lake water quantity and quality* **Budget:** $96,970

Our predictive model will represent: recharge under different vegetation, groundwater flow to lakes, and nitrate loading to lakes through groundwater. The groundwater computer code MODFLOW will serve as the model

core, with additional components for nitrate and recharge that leverage results from PI Ng's 2016 LCCMR project 011-A ("Assessment Tool for Understanding Vegetation Growth Impacts on Groundwater Recharge"). Activity 1 results will serve as calibration data to build the four representative groundwater-lake models.

Outcome	Completion Date
1. Develop model of recharge for different land-use (forest, crops)	10/31/19
2. Develop model of groundwater flow to lakes	11/30/19
3. Develop model of nitrate transport and reaction	12/31/19
4. Implement model for representative lakes: Long Lake and three Shingobee Area Lakes	12/31/19

Activity 3: *Evaluate the impact of different land-use management scenarios on lakes* **Budget:** $92,095

To evaluate lake impacts of current and planned land-use and related water-use scenarios, we will apply different cropland conversions, pumping/irrigation plans, and nitrate applications to the four baseline models. Results will cover various conditions found throughout the north-central lakes region. UMN Extension will communicate possible lake-level and contamination impacts to stakeholders and managers through reports and presentations. Model details will be disseminated to facilitate future, detailed implementations at other lakes.

Outcome	Completion Date
1. Compile current and potential land-use management scenarios in north-central MN	12/31/19
2. Apply scenarios to models to predict possible changes in lake levels and contaminants	6/30/20
3. Report to citizens and managers: possible impacts related to >3,000 north-central lakes	6/30/20

III. PROJECT STRATEGY

A. Project Team/Partners

Requesting funds:

Lead-PI **Prof. Crystal Ng** (UMN-TC): Advise graduate students, incorporate field work into UMN's Hydrogeology Field Camp, lead model development and scenario tests.

Co-PI **Prof. Joe Magner** (UMN-TC): Advise graduate students, lead field work.

Co-PI **Molly Zins** (UMN-Extension): Coordinate with land-owners and managers, present results.

Co-PI **Scott Alexander** (UMN-TC): Manage field work, including with UMN's Hydrogeology Field Camp.

UMN graduate students: Carry out all aspects of project

NOT requesting funds: Project partner **Brian Neff** (USGS): Process and transfer Shingobee Area data.

Contributing funds: Project partner **Long Lake Area Association (Hubbard County) Inc**: Provide $8000 for water isotope analyses and one monitoring well, facilitate property access at Long Lake for monitoring wells.

B. Project Impact and Long-Term Strategy

This project expands currently limited understanding about groundwater-lake interactions by providing a predictive tool for managers and stakeholders to make informed decisions regarding land-use. Incorporating results from PI Ng's 2016 LCCMR project will add value to an LCCMR-funded product. The four representative models will benefit lakes throughout the region by demonstrating possible vulnerabilities. Reports and presentations will communicate model results, as well as model details to facilitate ready implementation with other specific lakes. New monitoring wells will be installed in an under-instrumented, critical region; the DNR will potentially accept up to four wells into their long-term observation well network. Coordination by UMN Extension will build long-lasting community involvement. Participation of the UMN Hydrogeology Field Camp will introduce students to critical problems in the state and equip them with specialized field skills as they enter Minnesota's environmental professions.

C. Timeline Requirements

Three years to collect sufficient data (two full summers) and develop and apply the model.

2017 Detailed Project Budget

Project Title: Predicting Hidden Groundwater Connections between Land and Lakes

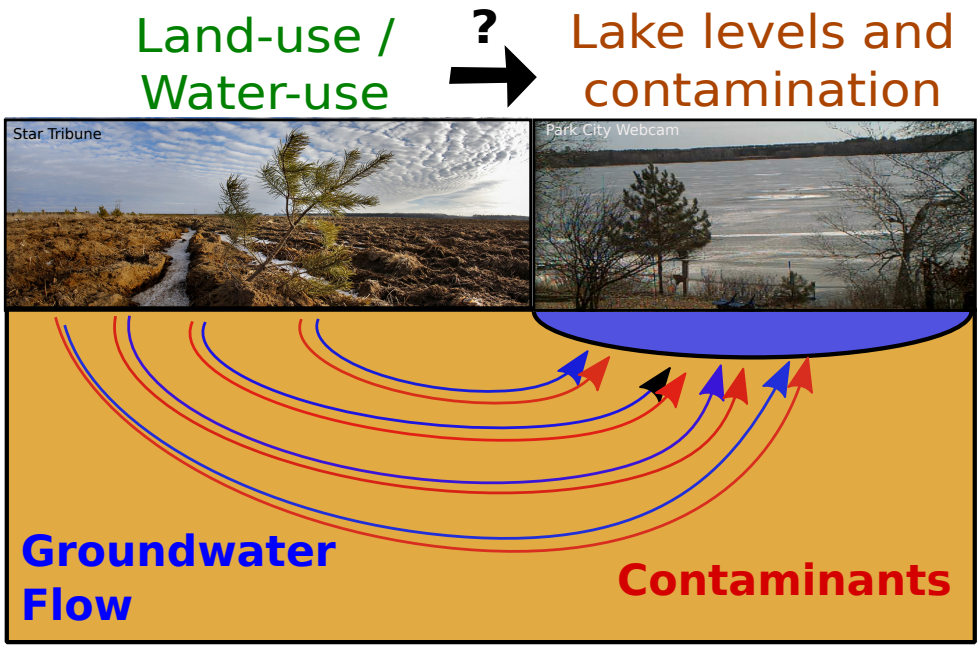
IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel: Dr. Gene-Hua Crystal Ng (lead PI) (professor, UMN-TC, Dept of Earth Sciences), 7% FTE (2.75 summer months total), 75% salary, 25% benefits. Will lead Activities 2 (model development) and 3 (scenario testing) and will advise graduate students. Will help involve U of M Hydrogeology Field Camp in Activity 1 (Field data collection).	$ 29,233
Personnel: Dr. Joe Magner (professor, UMN-TC, Dept of Bioproducts and Biosystems Engineering), 8% FTE (3 summer months total), 75% salary, 25% benefits. Will lead Activity 1 (field data collection) and advise graduate students	$ 48,172
Personnel: Molly Zins (Executive Director, UMN Extension), 9% FTE (3.5 months total), 75% salary, 25% benefits. Will coordinate field data collection with landowners, lead community outreach, and help communicate research results	$ 23,928
Personnel: Scott Alexander (research scientist, UMN-TC, Dept of Earth Sciences), 25% FTE (9 months total), 79% salary, 21% benefits. Will carry out Activity 1 (field data collection) and lead work with U of M's Hydrogeology Field Camp	$ 51,427
Personnel: 2 graduate students, 50% FTE (Student #1: Yr 1-2, Student #2: Yr 2-3), 42% salary, 58% benefits (includes tuition). Student #1 will primarily carry out Activity 1 (field data collection) and Student #2 will primarily carry out Activity 2 (model development). Both will contribute to Activity 3 (scenario tests).	$ 172,055
Professional/Technical/Service Contracts: Water chemistry (cations and anions) analyses on water samples. UMN Water Chemistry Lab (Dept of Earth Sciences): $70/sample. Monthly samples at 7 lake and groundwater locations.	$ 17,640
Equipment/Tools/Supplies: Groundwater monitoring wells (~10 units), DNR agrees to potentially add up to 4 units to state's long-term observation well network at conclusion of project.	$ 45,000
Equipment/Tools/Supplies: Construction supplies to build seepage meters, temperature probes, and piezometers for measuring groundwater-surface water exchanges. In-house fabrication more cost-effective than purchasing pre-made instruments.	$ 11,000
Travel: Travel from Twin Cities to north-central lakes region to carry out field work and present results to community, approx monthly visits. GSA lodging rate: $89, GSA per diem: $51, UMN mileage rate: $0.56/mi for 400 mi round-trip	$ 10,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 408,455

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: Contribution from Long Lake Area Association (Hubbard County) Inc ("LLAA") for: water isotope lab analyses (UMN isotope lab, $15/sample, monthly precipitation, lake, and groundwater samples), and for installation of 1 monitoring well ($4500).	$ 8,000	Approved for funding by LLAA
Other State $ To Be Applied To Project During Project Period: N/A	$ -	
In-kind Services To Be Applied To Project During Project Period: Commitment by USGS scientist to process and contribute data on Shingobee area lakes to project. (approx 80	$ -	Secured
In-kind Services To Be Applied To Project During Project Period: The U of M's Facilities and Administrative rate is 52% of modified total direct costs (modified to exclude certain fringe and capital equipment costs). The amount, if F&A expenses would have been allowed on the project, is indicated here. The University will provide office space, IT services, and administrative / financial services in support of the project.	$ 190,417	Secured
Funding History: N/A	$ -	
Remaining $ From Current ENRTF Appropriation: 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 vegetation water-use and recharge estimates that facilitate the assessment of land-use impacts on lakes in this project.	$ -	Rec'd for funding

Predicting the hidden link: GROUNDWATER



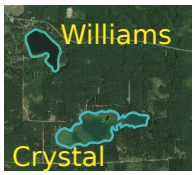
Complex glacial history →
Diverse geology & hydrology in North-Central Lakes Region

Four Representative Groundwater-Lake Models

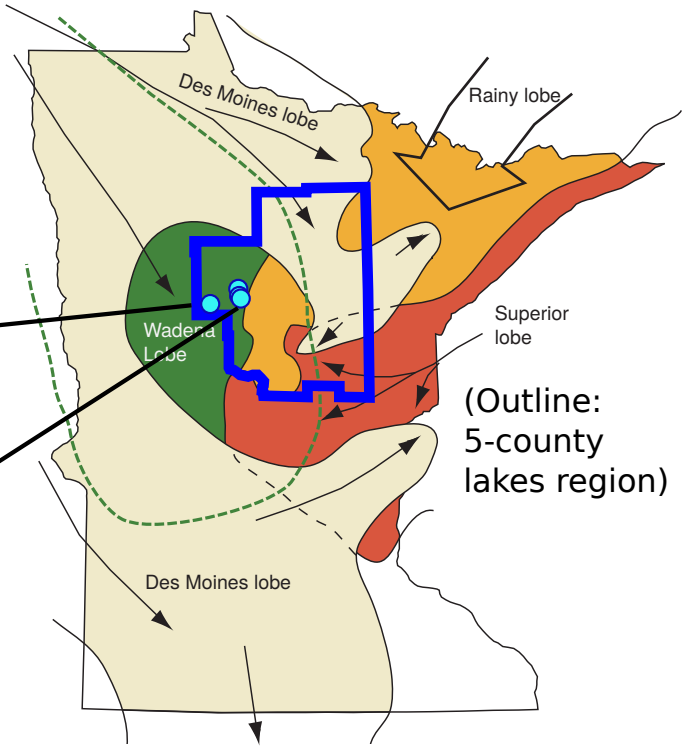
<u>Long Lake:</u>
Glacial outwash (faster link?)
At-risk now!

<u>Shingobee Area Research Lakes:</u>
Glacial till (slower link?)

River-connected



Closed, Source & Sink



(Outline: 5-county lakes region)

Project Manager Qualifications & Organizational Description

Gene-Hua (Crystal) Ng
Assistant Professor of Hydrogeology
Department of Earth Sciences
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Professor Ng joined the Department of Earth Sciences at the University of Minnesota in April 2014 following a position as a Research Hydrologist at the US Geological Survey (USGS) in Menlo Park, CA. She is also a graduate advisor in the Water Resources Sciences program at the University of Minnesota. Her research focuses on integrating computational models and field data to understand interactions among climate, vegetation, biogeochemical processes, groundwater, and surface water systems.

In past work, she evaluated groundwater recharge impacts due to grassland conversion to crops in the Southern High Plains. She also modeled recharge changes in that region under different climate scenarios. In the Mojave Desert, she implemented a model to identify hydrogeological feedbacks relating shrub growth and rainfall patterns. Her work has also included groundwater contamination studies, including one examining impacts of the 1979 oil spill near Bemidji, MN.

Since arriving at the U, Professor Ng has been involved in a couple of Minnesota-focused projects. She is investigating the role of groundwater-surface water interactions in how sulfate impacts wild rice in northeastern Minnesota. This project includes field measurements of water flow and chemistry, in both groundwater and stream water, along with a coupled groundwater / water chemistry model of the streambed. She is also developing a groundwater / water chemistry model to predict sulfate levels leaving a taconite mining basin on the Iron Range. Her newest project, approved for funding by the LCCMR, will produce in a model that estimates state-wide recharge under changing vegetation. Her previous and on-going work in ecohydrology, groundwater-surface water interactions, water quality, and hydrogeological modeling provide the qualifications needed for the proposed project on the groundwater connection between land-use and lakes.

In addition to her commitment to research, Ng is passionate about her General Hydrogeology and Hydrogeology Field Camp courses at the U. She is seeking ways to engage students and expose them to important hydrogeological applications and techniques. Involving the U's Hydrogeology course in the proposed work will benefit both the project and students.

Ng was a Mendenhall postdoctoral fellow at the USGS (2010-2011) after working as a postdoctoral research associate at MIT (2009). She received her PhD in Environmental Engineering from the MIT (2009) and her BA in Applied Mathematics from Harvard University (2003).

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 hydrogeology. A number of on-going research projects in the department focus on Minnesota water resources issues, including in the karst region of southeast Minnesota and in watersheds and surface waters with high sulfate and mercury.