

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

Project Title:

ENRTF ID: 081-B

Web-GIS for Satellite Monitoring of all Minnesota Lakes

Category: B. Water Resources

Total Project Budget: \$ 393,506

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

This proposal aims to develop a modern publically accessible Web-based Geographic Information System (Web-GIS) for low-cost and super-resolution water quality monitoring of almost all Minnesota lakes from space.

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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:

Problem statement and flowchart of the idea

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



PROJECT TITLE: Web-GIS for Satellite Monitoring of all Minnesota Lakes

I. PROJECT STATEMENT

This proposal aims to develop a modern publically accessible Web-based Geographic Information System (Web-GIS) for low-cost and super-resolution water quality monitoring of almost all Minnesota lakes from space.

• **Why such a system is needed?**

Urban and agricultural developments are increasing the pollutant loads and thus degrading the water quality of Minnesota lakes. Increased frequency of Harmful Algal Blooms (HABs) and related death of pets and aquatic animals have been reported in numerous incidents in past few years. **To track water quality hazards for public protection, a low-cost and easy access monitoring system is essential that covers almost all lakes in Minnesota.** Satellites monitoring is a promising technology; however, **the existing predictive tools are inadequate. Because these tools (1) are only applicable over large lakes with minimum dimension of greater than 1000 m; (2) can only capture water quality parameters at the lake surface; (3) are not sufficiently accurate for complex topography of Minnesota lakes with high turbidity; and (4) not often easily accessible to improve daily life of all Minnesotans.**

• **How do we develop the Web-GIS? What are the objectives?**

This project will use modern developments in information sciences and physical simulations of lakes for

- 1- **Developing a state-of-the-art database and a predictive software tool** that enable to optimally integrate multi-satellite imageries for high-resolution monitoring of all Minnesota lakes with unprecedented accuracy—using the data from the recently launched Multispectral Imager (MSI, 2015-present) and the Ocean and Land Colour Instrument (OLCI, 2016-present) on board the European Space Agency’s Sentinel 2 & 3 satellites. The MSI has a spatial resolution of 10–60 meters while OLCI provides more accurate observations related to water quality parameters but with lower resolution of 300 meters.
- 2- **Applying and validating the tool** over a few important lakes in Minnesota using intensive field measurements.
- 3- **Delivering and maintaining a modern publically accessible Web-GIS** that uses the database and the predictive software tool for almost real-time monitoring of areal extent and key water quality parameters of almost all Minnesota lakes.

• **What are the innovations?**

The project outcomes will go beyond our existing capabilities because

- 1- The tool will rely on the physical laws of lake modeling and can detect changes in numerous key water quality variables (i.e., temperature, harmful algal blooms, water toxicity) throughout the “water depth” under all feasible boundary conditions of Minnesota Lakes even with high turbidity.
- 2- The system will enable to optimally integrate multi-satellite data and provide monitoring capabilities at unprecedented resolution from space—~100 m grid with a revisiting time of 1 to 2 days.
- 3- The technology will be portable across different satellites and can be easily adapted to future U.S. satellites.
- 4- The Web-GIS will provide a user friendly and easily accessible platform that all Minnesotans with internet access can use to monitor the conditions of their neighboring lakes.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Development of a Predictive Software Tool

Budget: \$135,000

We will use a set of meteorological, lake, and radiative transfer models to produce a database and an open source predictive software tool to fulfill the project objectives.

Outcome	Completion Date
1. A comprehensive database that relates key water quality parameters of Minnesota lakes to satellite imageries based on historical observations and knowledge of meteorological and lake models.	Jan 2019
2. An open source predictive software tool that enables almost daily monitoring of the area and key water quality parameters of Minnesota lakes from multi-satellite imageries.	Aug 2019



Activity 2: Apply and Validate the Software Tool over a few Lakes in Minnesota

Budget:\$135,500

The performance and accuracy of the software tool will be validated during the late spring and early summer in the second and third year of the project through intensive field measurements primarily over the South Central and Madison Lakes. Weather data and water samples will be collected throughout the depth of the lake utilizing the SAFL water quality buoy and ongoing field campaign efforts.

Outcome	Completion Date
1. A high-resolution field-portable Spectroradiometer will be added to SAFL water quality buoy to measure the light energy emanating from the lakes during satellite overpasses for validation purposes. This device will be a new asset for research community in SAFL and U of M to advance our capabilities in remote sensing of Minnesota aquatic environments.	Aug 2020
2. A unique dataset that will contain seasonal changes in water quality parameters, their corresponding radiative signals, and coincident satellite imageries. This dataset will be publically shared to help research community to better understand the relationships between lake water quality conditions and satellite imageries.	Sep 2020

Activity 3: Implementation of the Web-GIS

Budget: \$123,000

To make the output of the software tool publically available, we will build a project specific server that will automatically download the satellite data, extract the required information over Minnesota, utilize the software tool, visualize the results, and make them available through a user-friendly web-based GIS application. The system will be coupled with the Google Earth software package to facilitate information accessibility by the public.

Outcome	Completion Date
1. A project specific server that will be integrated with the existing SAFL computational facility to provide the required hardware capacity for satellite data storage, processing, visualization, and sharing.	Nov 2020
2. A modern Web-GIS with analytical and visualization tools.	Mar 2021
3. An early warning system for detection of critical trends in key water quality variables.	July 2021

III. PROJECT STRATEGY

A. Project Team/Partners

Ardeshir Ebtehaj: Assistant Professor at SAFL and Department of Civil Environmental and Geo-Engineering, UMN—expert in hydrologic sciences and remote sensing.

Miki Hondzo: Professor at SAFL and Department of Civil Environmental and Geo-Engineering, UMN—expert in ecological fluid dynamics, and water quality modeling in lakes.

Shahram Missaghi: Associate Extension Professor, UMN—expert in surface water management and outreach.

Len Kne: U-Spatial Associate Director, Research Computing—expert in GIS, web development, spatial databases.

B. Project Impact and Long-Term Strategy

The scientific outcomes will advance knowledge in remote sensing of water quality, can leverage future out of state collaborations, and foster federally funded research projects.

From societal perspectives, the outcomes will provide a modern publically accessible low-cost monitoring system that can track changes in water quality of almost all lakes in Minnesota with unprecedented accuracy and resolution. The web-based GIS will provide timely information to Minnesotans, even in remote and rural areas, which will help them to protect their lives and properties against water quality related hazards (e.g., toxic algal blooms). The early warning system can inform decision makers and water treatment plants for timely mitigation actions to avert large-scale water quality crises.

Long-term Strategy is to maintain and support the Web-GIS system at SAFL computational facility beyond the lifetime of the project and gradually deliver the tool to the Minnesota Pollution Control Agency for long-term operation and public benefit.

C. Timeline Requirements

The project will require efforts of one PhD students for 3 years under the supervision of the project’s Co-PIs.

2018 Detailed Project Budget

Project Title: Web-GIS for Satellite Monitoring of all Minnesota Lakes

IV. TOTAL ENRTF REQUEST BUDGET 3 Years: \$393,506

BUDGET ITEM	AMOUNT
Personnel:	\$ 316,053
Ardeshir Ebtehaj, PI (75% salary, 25% benefits): 23.31% FTE, 2.1 months in 3 years. Ardeshir will provide expertise in modeling of meteorological conditions, remote sensing software tool development, and supervision for the GIS web-based design. (\$27,875)	
Miki Hondzo, Co-PI (75% salary, 25% benefits): 23.31% FTE, 2.1 months in 3 years. Hondzo will provide scientific knowledge in physical limnology, lake water quality modeling, detection of harmful algal blooms, and field validation experiments. (\$44,410)	
Shahram Missaghi, Co-PI (75% salary, 25% benefits): 16.65% FTE, 1.5 months in 3 years. Missaghi will provide scientific expertise in lake 3D modeling. (\$12,579)	
Len Kne, Co-PI (78% salary, 22% benefits): 5% FTE, 0.45 month per year for 1 year. Kne provide expertise in GIS, web development and spatial databases. (\$8,681)	
IT support (78% salary, 22% fringe): 20% FTE, 1.8 month. The IT staff at SAFL will provide support for design of the required hardware cyberinfrastructures, project specific servers and databases, computational resources, and maintenance of the web services (\$32,758). A Web-GIS programmer with 20% FTE from the U-SPATIAL team will be in charge for developing the web-based GIS tool (\$22,896) in the last year of the project	
One graduate student (59% salary, 41% fringe): The graduate student will be in charge of data collection, tool developments, and field validation experiments under the supervision of the project PIs. (\$166,854)	
Professional/Technical/Service Contracts:	
Equipment/Tools/Supplies: A FieldSpec 4 Hi-Res Spectroradiometer (\$61,255.8) and its accessories (\$13697.2) with installation cost (\$1,000). This instrument will be used for field and laboratory validation of the proposed predictive tool. This instrument is not currently available in SAFL and will advance scientific capabilities of the U of M community in remote sensing of Minnesota's aquatic systems.	\$ 75,953
Travel: In state travel costs to set up field experiments in the Central and Madison Lakes. This cost covers a few travels to the lakes for field experimentation and validation of the developed tools.	\$ 1,500
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND \$ REQUEST =	\$ 393,506

V. OTHER FUNDS (This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)

SOURCE OF FUNDS	AMOUNT	Status
In-kind Funds To Be Applied To Project During Project Period: Unrecovered UMN overhead (54% MTDC)	\$131,331	Secured
Other Non-State \$ To Be Applied To Project During Project Period: Indicate any additional non-state cash dollars secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.	N/A	Indicate: Secured or Pending
Other State \$ To Be Applied To Project During Project Period: Indicate any additional state cash dollars (e.g., bonding, other grants) secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.	N/A	Indicate: Secured or Pending
In-kind Services To Be Applied To Project During Project Period: Indicate any additional in-kind service(s) secured or applied for to be spent on the project during the funding period. For each type of service, list type of service(s), estimated value, and indicate whether it is secured or pending. In-kind services listed must be specific to the project.	N/A	Indicate: Secured or Pending
Past and Current ENRTF Appropriation: Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.	N/A	Indicate: Unspent? Legally Obligated? Other?
Other Funding History: Indicate funding secured but to be expended prior to July 1, 2018, for activities directly relevant to this specific funding request. State specific source(s) of funds and dollar amount.	N/A	

Tools that enable to use satellite data for low-cost and high-resolution monitoring of lakes are critical to improve water quality management in the land of 10,000 lakes.

Fact: Lakes are one of the most important elements of Minnesota's water resources and ecological systems.

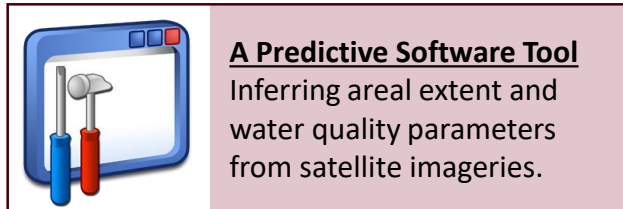


Concern: Nutrient and pollutants from agriculture and urban sources are increasing the biomass of toxic algal blooms (HABs) and degrading lakes' water quality.

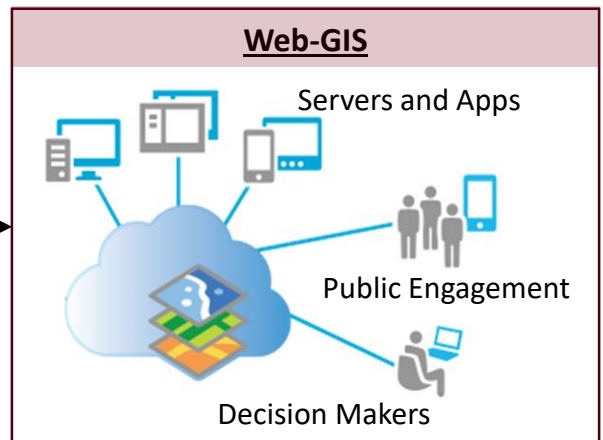


Solution: Satellite data can provide a low-cost and accurate water quality monitoring system for all lakes in Minnesota.

Project Flowchart



Validation Efforts:
A high-resolution spectroradiometer (left) will be added to SAFL water quality buoy (right) for field validation efforts.



Project Manager Qualifications & Organization Description

Project Manager Qualifications

Ardeshir Ebtehaj is an Assistant Professor in the Department of Civil, Environmental, and Geo- Engineering (CEGE) at the University of Minnesota and has a joint appointment with the Saint Anthony Falls Laboratory. Ardeshir received his PhD in Civil and Water Resources Engineering and his MS degree in Mathematics, both from the University of Minnesota in 2013. Prior to joining the department, he worked for two years as a postdoctoral researcher at the Georgia Institute of Technology and he served for one year as an Assistant Professor in Utah State University. He was a NASA Earth and Space Science Fellow during the last year of his PhD training and he was a recipient of both Interdisciplinary and Doctoral Dissertation Fellowships of the University of Minnesota. He is currently an associate editor of the *Journal of Hydrometeorology*, is a member of precipitation technical committee of the American Geophysical Union (AGU), and is a past recipient of an AGU best student paper award.

Organization description

The University of Minnesota, Twin Cities is a public research university in Minneapolis and Saint Paul, Minnesota. The University of Minnesota mission is threefold:

- **Research Discovery** – to generate knowledge, understanding and creativity by conducting high-quality research.
- **Teaching and Learning**—to share knowledge and prepare graduate, professional, and undergraduate students to take leadership roles in the state, the nation, and the world.
- **Outreach and Public Service** – to exchange knowledge between university and society by applying scholarly expertise to community problems.