



# Environment and Natural Resources Trust Fund

2021 Request for Proposal

## General Information

**Proposal ID:** 2021-184

**Proposal Title:** Algal Toxicity Detection and Mitigation in Minnesota Waters

## Project Manager Information

**Name:** Miki Hondzo

**Organization:** U of MN - St. Anthony Falls Laboratory

**Office Telephone:** (612) 644-1850

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## Project Basic Information

**Project Summary:** Our major objective is to integrate existing commercially available drone and multiple spectral camera array technologies to quantify algal biomass, toxin concentrations, and temperature conditions in twelve Minnesota lakes.

**Funds Requested:** \$199,000

**Proposed Project Completion:** 2023-06-30

**LCCMR Funding Category:** Small Projects (H)

**Secondary Category:** Water Resources (B)

## Project Location

**What is the best scale for describing where your work will take place?**

Statewide

**What is the best scale to describe the area impacted by your work?**

Statewide

**When will the work impact occur?**

In the Future

## Narrative

### **Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.**

Cyanobacteria (blue-green algae) are photosynthetic organisms that have been populating a growing number of nutrient-rich freshwater ecosystems including lakes, rivers, wetlands, and stormwater ponds in Minnesota. The rapid growth of cyanobacteria often leads to blooms that cannot only degrade water quality but also produce cyanotoxins. The cyanotoxins (Microcystin) can bio-accumulate in fish, concentrate in air through lake aerosol, and affect the liver and reproductive system of living organisms. The amount of intracellular toxin concentration and toxin release rapidly change and are highly correlated with the water temperature, wind conditions, and cyanobacterial growth rates. High resolution, short-term, and rapid detection of cyanobacteria biomass, water temperature, and toxin concentrations are vital prerequisites for the sustainable prevention, control, and mitigation of aquatic ecosystems. We propose to test, verify, and document the application of drone technology to quantify the onset, growth, and dissipation of cyanobacterial blooms and toxins in twelve Sentinel lakes in Minnesota. The current use of remote sensing satellite technologies, up to one image per day and spatial resolution of about 1 km, are too coarse and are not existent for the prediction of cyanobacterial toxicity in Minnesota lakes whereas the median surface area of the 10,000 lakes is about 1km<sup>2</sup>.

### **What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.**

Monitoring of water quality is difficult and could be misleading because of the patchy and transient distribution of its variables. The quantification of toxins and algal biomass usually take several days after the collection of samples. The proposed drone-based quantification of algal biomass, temperature, cyanotoxin and potentially nutrients can transform the current monitoring techniques and practices used to detect and manage water quality in aquatic ecosystems. The effectiveness algal mitigation strategies including the use of various chemicals or clays in flocculating and removing the algal cells, or in situ aeration are contingent upon the rapid detection of water quality variables. The proposed drone-based monitoring technology will provide rapid (e.g. 2 hours data collection and 1 hour data processing) and spatially extensive (1 km<sup>2</sup> with 10x10 cm resolution) data of the algal biomass, cyanotoxin, temperature, and potentially nutrient distributions over the lake surface. The data will reveal the hot spots of algal biomass and toxin concentrations around the lake perimeter and over the lake surface, and consequently guide the placement of best management practices to improve water quality in the lake, and inform the public how safe the lake is for recreational purposes.

### **What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?**

We will 1) Document technical requirements, accuracy, and uncertainty of drone sensing technology to quantify algal biomass, water temperature, and cyanotoxin concentrations; 2) Post publicly available web-based prediction models that can readily import the spatially-distributed drone images and convert them to engineering units and predict cyanotoxin bloom events with a 1-3 day lead-time; and 3) Specify implementation steps of drone-based technology to mitigate (physical/chemical) excessive cyanobacterial blooms and toxin concentrations. The project will benefit the economy of Minnesota's recreation industry, water treatment plants, and fisheries by ensuring the public can use lakes safely, free from exposure to cyanotoxins.

## Activities and Milestones

### Activity 1: Quantify cyanobacterial biomass, cyanotoxins, and water temperature using the buoy and drone technologies to develop detection protocols and prediction models

**Activity Budget:** \$100,000

#### Activity Description:

In collaboration with MPCA, one lake will be selected for high-resolution algal, water quality, and cyanotoxin monitoring by a buoy with water quality sensors. Water samples will be collected and analyzed for algal biomass, chlorophyll, cyanotoxin, phosphate, and nitrate concentrations under laboratory conditions. Simultaneously, drone (DJI Matrix; available at SAFL) and miniature field spectroradiometer (e.g. Ocean Optics, weight 65 g, 40x40x20 mm) will be deployed to measure the light intensity per wavelength of solar irradiance and water surface reflectance at the different growth stage of cyanobacteria. The analysis of water samples under laboratory conditions and the drone-spectroradiometer data of the light intensity spectral wavelength bands will reveal the most sensitive wavelengths for the detection of cyanobacteria and toxin concentrations. The quantification of specified wavelengths is crucial for the development of prediction models and accurate detection of algal biomass and toxin concentrations. The prediction models will generate aerial images (e.g. 1x1 km<sup>2</sup> lake surface with 10x10 cm resolution) of cyanobacteria and toxin concentrations. The models will be formulated through simple Excel spreadsheet predictors. The drone will be designed to land and take off on the water. A commercially drone-flotation system will be tested, and if necessary redesigned at SAFL.

#### Activity Milestones:

Description	Completion Date
Specification of safe operational conditions for the drone-spectroradiometer-flotation system.	2021-11-30
Specification of most sensitive wavelength bands for the prediction of cyanobacteria, cyanotoxin, and water temperatures.	2022-10-31
Accuracy/uncertainty of the drone-spectroradiometer system for detection of cyanobacteria and toxins in selected lake	2022-11-30

### Activity 2: Apply and verify drone-spectroradiometer water quality prediction in 12 Sentinel lakes and explore mitigation strategies

**Activity Budget:** \$99,000

#### Activity Description:

The proposed outcomes of Activity 1 will be verified in 12 Sentinel lakes in collaboration with the MPCA. We will augment the existing sampling protocol of MPCA by simultaneously collecting the water samples and flying the drone with spectroradiometer over the specified lakes. The proposed field monitoring over the range of lakes and ecoregions will provide a unique opportunity to verify the proposed drone technology and models and assess the reliability of using the drone technologies to detect real-time toxin and algal concentrations. In the outdoor bioreactors at SAFL (10x10x1 m), we will explore feasible mitigation strategies including the effectiveness of clays in flocculating and removing the cyanobacterial cells with corresponding toxins, and dispersing the cyanobacterial cells by in situ aeration. In addition to water sample collection and evaluation under laboratory conditions, the drone-spectroradiometer technology will be implemented for the detection of spectral signatures of cyanobacteria before and after the release of toxins. We propose to produce a series of tutorial videos on exiting website, to educate potential users on how to a) conduct spectroradiometer and drone measurements, b) upload files, c) visualize the data, d) interpret the cyanobacterial biomass and toxin concentrations, and e) apply feasible mitigation strategies.

**Activity Milestones:**

Description	Completion Date
Implementation steps of drone-based technology to mitigate (physical/chemical) excessive cyanobacterial blooms and toxin concentrations.	2023-06-30
Web-based prediction models with online instruction protocols for sensing water quality by drone technology.	2023-06-30
Accuracy/uncertainty of drone technology to predict algal biomass, toxin, and water temperature concentrations	2023-06-30

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Shahram Missaghi	Minneapolis Public Works - Surface Water & Sewers Division	Dr. Missaghi, Water Resources Regulatory Coordinator, will facilitate the outreach of the project. In the available website ( <a href="http://hab.umn.edu">http://hab.umn.edu</a> ), we will design an online education module tentatively entitled “Environmental Factors and Drone Sensing of Cyanotoxins and Water Quality in Minnesota Lakes.”	No
Dr. Matt Lindon	Minnesota Pollution Control Agency (MPCA)	Dr. Lindon, research scientist, will coordinate the selection of 12 Sentinel lakes for field data collection and the integration of proposed prediction models (water temperature, chlorophyll biomass, and toxin concentrations) within the state lake database.	No

## Long-Term Implementation and Funding

**Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?**

We will share the results and the technical specification of the drone sensing technology with the broader community through our existing website (<http://hab.umn.edu>) with focus on cyanobacteria and harmful algal blooms. We will design an online education module tentatively entitled “Environmental Factors and Drone Sensing of Cyanotoxins.” The MPCA supports the project through scientific and field-scale collaborations. At least four meetings will be organized with MPCA’s research scientist Dr. Matt Lindon for knowledge exchange. The second year of the project will include working with MPCA to validate the drone sensing technology in 12 Sentinel lakes, MN.

## Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Assessing the Increasing Harmful Algal Blooms in Minnesota Lakes	M.L. 2016, Chp. 186, Sec. 2, Subd. 04b	\$270,000

## Project Manager and Organization Qualifications

**Project Manager Name:** Miki Hondzo

**Job Title:** James L. Record Professor

**Provide description of the project manager’s qualifications to manage the proposed project.**

Miki Hondzo (PI), James L. Record Professor

Department of Civil, Environmental, and Geo- Engineering, University of Minnesota

Dr. Hondzo will be responsible for the development and guidance of the detection of cyanotoxins under field and laboratory conditions using the proposed drone and spectral camera technologies. He will guide the development of Excel spreadsheet-type models for the early detection and prediction of cyanotoxins in Minnesota waters. Dr. Hondzo has 20 years of experience in physical limnology and water quality monitoring and modeling in lakes. Furthermore, he will be responsible for exploring and documenting the proposed mitigation strategies of harmful algal blooms and cyanotoxins. A physical/chemical mitigation strategy will be investigated in the field and outdoor bioreactors at SAFL by adding clay particles for the aggregation and dispersal of cyanobacteria and associated toxins. A mechanical mitigation strategy will be investigated at SAFL and in the field by injecting air bubbles for the dispersal of cyanobacteria and cyanotoxins. Dr. Hondzo will be responsible for the submission of yearly progress reports. Dr. Hondzo is an Associate

Editor of the Environmental Fluid Mechanics journal.

Ardeshir Ebtehaj (Co-PI), Assistant Professor

Department of Civil, Environmental, and Geo- Engineering, University of Minnesota

Dr. Ebtehaj will be responsible for the development of the analytical models that relate the cyanotoxin concentrations and the measurements of the spectroradiometer. He will guide the detection of cyanobacteria and cyanotoxins by remote sensing using the drone and hyperspectral camera technologies. He has been studying remote sensing of environment and water systems for ten years. Dr. Ebtehaj is an associate editor of the Journal of Hydrometeorology. He was a NASA's Earth and Space Science Fellow in 2014 and won a NASA's new investigator (Early Career) award in 2018 for his contribution in remote sensing sciences.

**Organization:** U of MN - St. Anthony Falls Laboratory

**Organization Description:**

The St. Anthony Falls Laboratory (SAFL), University of Minnesota, is a unique laboratory located on an island just downstream of the only major waterfall on the Mississippi River – St. Anthony Falls. SAFL comprises 4460 m<sup>2</sup> of flumes, basin, tanks and offices. SAFL houses several smaller labs, including wet chemistry, sediment analysis, and a biological laboratory with phytoplankton-growth chambers, and incubators. The EcoFluids Laboratory, developed by PI Hondzo, allows SAFL researchers to study the interactions among fundamental fluid mechanics, microbiological processes, and chemical reactions that are mediated by biological organisms. In situ micro-profiling sensors with robotic computer-controlled traversing system for dissolved oxygen, nitrate, pH, temperature, conductivity, fluid flow velocity, and fluorescence have been developed and tested under laboratory and field conditions. Five water quality data sondes with SDI12 communication protocols are available for continuous, adaptive, and in situ field sensing of temperature, dissolved oxygen, nitrate, pH, turbidity, PAR, and chlorophyll-a concentrations. The SAFL staff is particularly experienced in conducting and analyzing field measurements of water quality in lakes, rivers, and reservoirs. Automated data collection, sampling protocols, wireless data transfer and display over the Internet have been developed for several state and federal funding agencies at SAFL.

## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
<b>Personnel</b>								
Miki Hondzo		PI			27%	0.16		\$45,882
Ardeshir Ebtehaj		Co PI			27%	0.08		\$15,296
Graduate Student		Graduate Student			46%	1		\$104,223
Chris Ellis		Engineer			8%	0.04		\$5,262
Ben Erickson		Research Scientist			23%	0.08		\$6,680
Undergraduate Student		assist with research			0%	0.3		\$7,795
							<b>Sub Total</b>	<b>\$185,138</b>
<b>Contracts and Services</b>								
							<b>Sub Total</b>	-
<b>Equipment, Tools, and Supplies</b>								
	Tools and Supplies	Laboratory supplies, toxicity (ELISA), chlorophyll standards, drone spectroradiometer	Quantification of algal biomass, toxin concentration, nutrient concentration					\$10,000
							<b>Sub Total</b>	<b>\$10,000</b>
<b>Capital Expenditures</b>								
							<b>Sub Total</b>	-
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
	Miles/ Meals/ Lodging	Training, field data collection, and outreach	Training, field data collection, and outreach					\$2,000

5/18/2020

							<b>Sub Total</b>	<b>\$2,000</b>
<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	<b>-</b>
<b>Printing and Publication</b>								
	Publication	Open access publication fees to allow papers to be available immediately	the results will be published in the peer reviewed research journals and books					\$1,000
							<b>Sub Total</b>	<b>\$1,000</b>
<b>Other Expenses</b>								
		Wireless data transfer fees	The field data transfer will be available through a wireless communication service					\$362
		GIS software license	The integration of drone images is required through a specialized GIS software					\$500
							<b>Sub Total</b>	<b>\$862</b>
							<b>Grand Total</b>	<b>\$199,000</b>



Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
<b>State</b>				
			<b>State Sub Total</b>	-
<b>Non-State</b>				
In-Kind	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	\$91,110
			<b>Non State Sub Total</b>	<b>\$91,110</b>
			<b>Funds Total</b>	<b>\$91,110</b>

## Attachments

### Required Attachments

#### *Visual Component*

File: [fbddcb0b-5b6.pdf](#)

#### *Alternate Text for Visual Component*

Excessive nutrient export from the watersheds of MN and a warming climate trigger cyanobacterial blooms and elevated cyanotoxin concentrations in lakes and surrounding air (lake spray aerosols). Cyanotoxins are harmful to human and animal health. We propose a drone-based technology with spectral cameras (spectroradiometer) to quantify the areal distribution (e.g. 1x1 km with spatial resolution 10x10 cm) of cyanobacterial biomass, toxin concentrations and water temperatures over the lake surface. The major outcomes (1-5) of research are outlined above.

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Does your project have patent, royalties, or revenue potential?**

No

**Does your project include research?**

Yes

**Does the organization have a fiscal agent for this project?**

Yes, Sponsored Projects Administration

