Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-221

Proposal Title: Aerial Multispectral Imaging for Minnesota Lake Ecosystem Monitoring

Project Manager Information

Name: Sayan Biswas

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: The MNI-WANA ("Water-Now" in Lakota language) Project, employing aerial drone-mounted multispectral cameras, aims to assess phosphorus, chloride, and nitrogen concentrations in eight heavily polluted lakes in central and southern Minnesota.

ENRTF Funds Requested: $425,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Water Resources (B)

Project Location

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

Region(s): Central, SE, SW, Metro,

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

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

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

Controlling Minnesota lake water quality is important to preserve ecosystem health, support recreational activities, and ensure safe drinking water for communities. The Minnesota Pollution Control Agency (MPCA) and its partners have surveyed lakes across all 80 major watersheds in the state. Their analysis reveals that 75% of lakes meet water quality standards, while 25% fail due to elevated phosphorus and nitrogen levels causing algal growth. Phosphorus and excessive nitrogen are primary concerns in Minnesota lakes, while chloride from road salt in urban and roadside areas poses an escalating threat to water quality. Excessive nitrogen exacerbates eutrophication, leading to harmful algal blooms and oxygen depletion, endangering aquatic life. Moreover, lakes in southern and western Minnesota are more contaminated compared to those in the north and center. For example, Madison Lake in Blue Earth County is popular for fishing and swimming, but it faces high phosphorus levels and algae blooms. Similarly, Medicine Lake in Plymouth deals with excessive phosphorus and chloride, stressing fish, and hosts invasive Eurasian milfoil. However, MPCA's sporadic sampling, limited to peak seasons and localized areas, hinders comprehensive understanding. More frequent monitoring, including airborne technology for mapping water contaminants, is essential for better water quality management.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

Drones equipped with multispectral cameras will monitor the water quality of Minnesota lakes, estimating phosphorus, chloride, and nitrogen levels from measured turbidity, chlorophyll-a pigments, and dissolved organic matter concentrations. Multispectral imaging, capturing images across various wavelengths (ultraviolet to deep Infrared), provides detailed environmental data, with custom filters tailored to detect different contaminants. This remote sensing technique can also assess additional water quality parameters like temperature, transparency, and algal growth. While satellite imaging has been used for remote sensing, drone-based aerial sensing offers advantages over satellites due to its ability to mitigate atmospheric effects like cloud cover and particles, allowing for more accurate quantitative measurements. Additionally, drones provide higher spatial resolution, enabling detailed localized contaminant quantification.

Our project, called the Minnesota Initiative for Water Aerial Navigator for Assessment (MNI-WANA), embraces the Lakota language. "MNI" symbolizes water, while "WANA" represents now, embodying the essence of "Water-Now." Eight lakes in southern and central Minnesota will undergo quantitative aerial measurements, supplemented by water sampling for comparison with lab-based measurements. The resulting two-year survey from May to October, conducted at least monthly, will provide comprehensive 2D imaging of seasonal contaminant variations and inform remediation efforts and water quality management strategies.

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?

Minnesota's vast network of lakes and rivers, totaling over 11,000 lakes, 104,000 miles of rivers and streams, and 13 million acres of surface water, holds immense ecological and cultural significance. They shape the land's history, support livelihoods, and provide enjoyment for millions through activities like fishing and swimming. However, these water bodies are vulnerable to pollution and disruptions, leading to ecological imbalances and invasive species. Our project offers a straightforward solution: using aerial drone-based multispectral imaging for year-round water quality monitoring. This approach is user-friendly and informative, aiding in the protection and management of water resources for future

Activities and Milestones

Activity 1: Development, instrumentation, and integration of drone-mounted multispectral camera system

Activity Budget: $190,000

Activity Description:
In this activity, we will calibrate, test, and prepare the multispectral camera, drones, mounts, data collection tools, and remote sensors for field testing. Two more multispectral camera systems (Vendors: Hyspex or Spectral Devices – camera info attached) will be purchased with a spatial detection capability of less than 1 cm. Note that phosphorus and chloride lack distinct absorption peaks within the electromagnetic spectrum typically targeted by multispectral imaging. Instead, multispectral imaging will indirectly assess their levels in water by examining Chlorophyll-a, turbidity, and organic matter. To capture these parameters simultaneously, two cameras will be employed:
Camera 1:
Chlorophyll-a: 440-460 nm (blue) and 660-680 nm (red)
Turbidity: 500-550 nm (blue-green region) and near-infrared wavelengths
Camera 2:
Dissolved organic matter: 250-400 nm (UV)
Both cameras will undergo calibration in a lab setting to accurately quantify phosphorus and chloride concentrations in water. Subsequently, we will perform field measurements in the following eight lakes.
Southern Minnesota

- Madison Lake - Blue Earth County
- Lake Winona - Winona County
- Prior Lake - Scott County

Central Minnesota

- Medicine Lake - Hennepin County
- Lake Minnetonka - Hennepin County
- Lake Phalen - Ramsey County
- Bde Maka Ska - Hennepin County
- White Bear Lake - Ramsey County

Activity Milestones:

Description	Approximate Completion Date
Set up and synchronize multispectral cameras and remote-control data acquisition	December 31, 2025
Complete testing of the camera system in a laboratory setting	February 28, 2026
Multispectral camera systems capable of detecting phosphorous and chloride with 5% accuracy	April 30, 2026
Activity 1 summary report	May 31, 2026

Activity 2: Comprehensive field testing of water contaminant measurement in eight Minnesota lakes using multispectral imaging

Activity Budget: $90,000

Activity Description:
Throughout the active season in Minnesota, spanning from May to October (6 months), when algal blooms and recreational water activities peak, field testing efforts will be concentrated on the eight lakes identified in activity 1. A team consisting of three scientists—PI Biswas, a postdoctoral researcher, and a PhD graduate student—will visit these lakes at various times each month for the entire season, measuring phosphorus, chloride, and nitrogen levels at least

once per month. Additionally, other significant water contaminants such as algae, dissolved organic matter, water temperature, and color will be assessed. These measurements will generate a 2D map of the lake surface over the 6-month period, aiding in understanding the seasonal variation in the growth of different water contaminants. The collected data will be correlated with weather events such as rainfall, atmospheric temperature, humidity, and specific human activities. This task aims to conduct a comprehensive investigation using multispectral imaging to estimate water contaminants accurately.

Activity Milestones:

Description	Approximate Completion Date
Deploy multispectral imaging system for field testing	April 30, 2026
Complete the first field testing campaign	October 31, 2026
Calibrate and optimize the multispectral imaging results with lab-scale water sample tests	November 30, 2026
Complete analysis of water contaminant data from eight lakes over a period of six months	December 31, 2026
Activity 2 summary report	December 31, 2026

Activity 3: Validation of multispectral imaging data with sampled water tests, data analysis, and hypotheses testing

Activity Budget: $80,000

Activity Description:
In this activity, the multispectral imaging data will undergo validation against laboratory-based testing of water samples. Once the reliability of the imaging data is confirmed, it will undergo thorough analysis to elucidate the presence and impact of water contaminants on water management practices. Leveraging high-precision multispectral data will aid in investigating the hypotheses outlined below.
H1) Increased levels of phosphorus, chloride, and nitrogen in Minnesota lakes will correlate with higher occurrences of algal blooms and turbidity, indicating a direct relationship between nutrient levels and water quality degradation.
H2) The spatial distribution of water contaminants, such as phosphorus and chloride, will exhibit significant variability across different regions of the lakes, with higher concentrations observed near urban and agricultural areas compared to remote or protected regions.
H3) Seasonal variations in water quality parameters, including phosphorus, chloride, and nitrogen levels, will coincide with changes in weather patterns, such as increased precipitation and temperature fluctuations, suggesting a link between climatic factors and water contamination.
H4) Multispectral imaging techniques will provide more accurate and efficient assessments of water contaminants compared to traditional sampling methods, leading to improved monitoring and management strategies for preserving Minnesota's water resources.

Activity Milestones:

Description	Approximate Completion Date
Complete multispectral image processing and data analysis	March 31, 2027
Multispectral imaging data validation and aerial sensor package development	April 30, 2027
Detailed testing of multispectral aerial sensor package in the field, calibrating and optimizing the aerial	May 31, 2027
Activity 3 summary report	May 31, 2027

Activity 4: Additional field testing to fine-tune aerial multispectral monitoring package, if necessary

Activity Budget: $15,000

Activity Description:
If our team identifies the need for additional field test data concerning a specific scenario or lake water contaminant, either due to inconclusive results from initial field testing or the discovery of intriguing contaminant behavior necessitating further investigation, we will revisit the same lakes identified in activity 1. Additional field data will be collected over several weeks during the subsequent season of Y2027, spanning from March to May, encompassing spring and summer contaminant dynamics. In the event that an insufficient amount of contaminants is found at these eight lakes, alternative lakes or waterbodies in southwest Minnesota will serve as backup options to validate and refine the aerial sensor package.

Activity Milestones:

Description	Approximate Completion Date
Complete additional field testing to recalibrate and fine-tune the multispectral sensor system, if necessary	May 31, 2027

Activity 5: Reporting, IP and patent filing, results dissemination, and journal paper writing

Activity Budget: $50,000

Activity Description:
This phase of the project will focus on the final data analysis and report writing. In addition to meeting the deliverable requirements of the LCCMR Fund, the project team will prepare manuscripts for submission to peer-reviewed journals and will communicate the results of the project to the Minnesota Pollution Control Agency (MPCA) as well as water resources management companies.

Activity Milestones:

Description	Approximate Completion Date
File IP and patents before any public disclose of research results	September 30, 2026
Finished writing the first draft of the journal/conference article	March 31, 2027
Activity 3 summary report	April 30, 2027
Final project report	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Janette Wilson	HySpex Cameras	Multispectral Camera R&D	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 work be funded?

Our project aims to develop an advanced yet affordable aerial monitoring system for Minnesota water bodies, utilizing a multispectral camera package to detect harmful contaminants like phosphorus, nitrogen, and chloride. Our goal is to improve detection and monitoring methods to safeguard Minnesota's water resources. We will share our findings with stakeholders such as the Minnesota Pollution Control Agency (MPCA) and the Department of Natural Resources (DNR). Additionally, we will collaborate with the UMN Office of Technology Commercialization to license and patent our integrated sensor technology for commercialization.

Project Manager and Organization Qualifications

Project Manager Name: Sayan Biswas

Job Title: Benjamin Mayhugh Assistant Professor

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

Prof. Sayan Biswas, Benjamin Mayhugh Assistant Professor of Mechanical Engineering, is an expert in clean energy, remote sensing, multispectral and hyperspectral imaging, and novel laser-based sensing and diagnostics, will lead this project. PI Biswas has utilized multispectral imaging to solve challenging problems, including the detection of wildlife and trace amounts of harmful chemicals. Besides remote sensing, PI Biswas has extensive experience developing optical sensors for energy applications. His research has received support from the Department of Energy (DOE), Advanced Projects Research Agency-Energy (ARPA-E), Office of Naval Research (ONR), National Science Foundation (NSF), and several clean energy companies. He manages an annual research portfolio of $2.5M. Before joining the University of Minnesota in 2020, Dr. Biswas spent 3+ years at the Sandia National Laboratories and 5+ years at Purdue University, working on clean energy and developing advanced light/laser sensing systems. To date, PI Biswas has published 20+ journal articles, 40+ conference articles, 1 single-authored book, 6 book chapters, and holds 1 US patent. PI Biswas leads a highly diverse research group consisting of 6 PhD, 2 MS, and 10+ UG students. His lab actively participates in educating the community about our energy future and in K-12 outreach activities, inspiring the next generation of scientists and engineers, and providing an open and equitable learning atmosphere for women, minorities, and indigenous students. Prof. Biswas serves on several technical and advisory committees, volunteering for his professional societies and local Minnesota-based organizations.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota, Twin Cities is a public land-grant research university in the Twin Cities of Minneapolis and Saint Paul, Minnesota, and one of the most comprehensive research universities in the nation. The University leadership acknowledges that the University of Minnesota Twin Cities is built within the traditional homelands of the Dakota people. It is the flagship institution of the University of Minnesota System and is organized into 19 colleges, schools, and other major academic units. The University advances Minnesota state and US society through new ideas, technologies, treatments, and cures, and continues to create and transfer technology to companies for the development of new products and services that benefit the public good and foster economic growth. The University's College of Science and

Engineering received $141.9 million in research funding in FY2015. The University of Minnesota College of Science and Engineering (CSE) ranks #4 in the country for the best bachelor's degree in engineering. In other rankings, CSE majors traditionally rank among the top 20.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Sayan Biswas		Principal Investigator			27.06%	0.24		$33,708
Post Doctoral Associate		Post Doctoral Associate			21.32%	2		$145,736
Research Assistant		Research Assistant			43.64%	1		$120,290
							Sub Total	**$299,734**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Sensor mounting, lenses, weatherproof box for multispectral camera housing, wiring supplies, plumbing parts, camera maintenance and mechanical parts and fasteners	Tools and supplies (e.g., fasteners, sensor mounting boards, etc.), power and charging in remote areas, laptop and control software for field study					$18,266
							Sub Total	**$18,266**
Capital Expenditures								
		Multispectral camera (2 cameras, $35k each), drone and accessories ($20k), sensor mounting, remote sensing controls, data acquisition hardware ($5k for the rest)	Multispectral imaging of water contaminants	X				$95,000
							Sub Total	**$95,000**
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								

	Miles/ Meals/ Lodging	a) Travelling to eight different MN lake test sites, biweekly/monthly for 6 months, b) One trip per year for one PI and a postdoc/graduate student to a relevant conference	Testing campaign, knowledge dissemination and attract potential customers/end-users					$7,000
							Sub Total	**$7,000**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	One trip per year for one PI and a postdoc/graduate student to a relevant out-of-state conference	Knowledge dissemination and attract potential customers/end-users	X				$3,000
							Sub Total	**$3,000**
Printing and Publication								
	Publication	Publication cost in open source journals	Open source journal let everyone access the research results at free of cost					$2,000
							Sub Total	**$2,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$425,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		Multispectral camera (2 cameras, $35k each), drone and accessories ($20k), sensor mounting, remote sensing controls, data acquisition hardware ($5k for the rest)	To the best of the author's knowledge, the simultaneous use of two multispectral cameras for rigorous field-based water quality determination has never been done. PI Biswas has been conducting research in chemical substance detection using multispectral technology for the past two years and possesses a multispectral sensing system designed for lab-scale short-distance measurement. However, for this project, a camera capable of imaging from 50-200 feet above the water surface is required. As such, two additional systems will be procured, totaling two multispectral camera systems that will simultaneously monitor the lake water space. This innovative approach will provide unprecedented insights into contaminant distribution in lake waters, representing a novel advancement in the field. The project's success hinges entirely on the simultaneous measurement of the entire water space using multispectral cameras. **Additional Explanation :** For this project, a setup comprising two multispectral cameras attached to a drone and remotely controlled from the ground, facilitated by robust long-range receivers, will be developed. This configuration will not only capture imagery of all eight lakes throughout the project's duration but will also remain valuable in the years to come.
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	One trip per year for one PI and a postdoc/graduate student to a relevant out-of-state conference	It is crucial to disseminate the project's knowledge and insights to relevant stakeholders in other states across the US

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	unrecovered F&A calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$161,984
			Non State Sub Total	**$161,984**
			Funds Total	**$161,984**

Total Project Cost: $586,984

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 4bf2b1b5-660.pdf

Alternate Text for Visual Component

The visual illustrates the challenging situation facing Minnesota lakes, which are marked by levels of phosphorus, chloride, and nitrogen. Highlighted are our innovative multispectral imaging technology package, our research team, and the planned experimental measurements using multispectral cameras....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Multispectral camera system	ab99ba55-a56.pdf
UMN SPA Letter of Support	39589033-eee.pdf
Water-Quality Monitoring with a UAV-Mounted Multispectral Camera in Coastal Waters	d2a61263-3a8.pdf
Water Turbidity Retrieval Based on UAV Hyperspectral Remote Sensing	29c3d16b-c45.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Alex Sullivan, U of MN