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

Project Title: **ENRTF ID: 003-A**

Providing Critical Water Quality Information for Lake Management

Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 477,000

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

Summary:

Create a semi-automated system to acquire, process, and deliver new satellite derived water quality data (water clarity, algae, turbidity and color) for all Minnesota lakes ~biweekly and in near real-time

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Provides a summary of what water quality (water clarity, algae, turbidity and color) data can be measured with satellite imagery, how the data will be processed and distributed to users and the resource management benefits of the data that will be provided.

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

PROJECT TITLE: Providing Critical Water Quality Information for Lake Management

I. PROJECT STATEMENT

This project will create an automated system delivering near real-time data and maps of key water quality measures for all Minnesota Lakes. In a current LCCMR-supported project, we have developed methods to expand remote sensing capabilities beyond water clarity to include algae, turbidity and color. This project will apply those methods in a fully automated system that acquires, processes, and delivers new satellite derived water quality data as it becomes available (approximately biweekly). Citizens, government agencies, and researchers will have routine access to the data via an interactive web interface linked to a spatial database that will operate at nominal cost for years to come. This unique data source will dramatically improve data-driven resource management decisions and will inform the public about changing water quality conditions.

The project is a compelling opportunity because it takes advantage of new data streams from recently operational satellites and the high performance computing resources at the University of Minnesota. The Water Resources Center (WRC) will coordinate the project and disseminate its products within a larger agenda that the WRC is advancing on "digital water" which seeks to harness rapidly expanding water quality information and strengthen understanding of our changing water resources. This proposal was developed in cooperation with staff from state water management agencies and is designed to support their management needs.

Our project goals are to:

1. Develop automated methods to process satellite images to retrieve near real-time data on algae, water clarity, turbidity, and color based on conventional methods we developed with previous R&D;
2. Create a dynamic database of satellite-based water quality during the open-water season in Minnesota's lakes using high performance computing and visualization technologies;
3. Work with key government agencies to deliver rigorous data products customized to their monitoring and management needs;
4. Provide robust and detailed datasets to drive advances in understanding fish habitat dynamics, harmful algal blooms (HABs), and effects of land use changes on water quality;
5. Develop a digital outreach program to raise public awareness of water quality issues via a web portal with visualizations including maps, animations, and infographics.

The remotely sensed components of water quality (water clarity, algae, turbidity, color) generated by this project will be useful for many applications. One example would be for MPCA and MDNR managers to account for differences among lakes across a range of spatial scales and follow changes through time. By being able to see regional anomalies and changes over time, managers will be able to target field monitoring where needed, leading to more effective decision making and improved water quality and habitat conservation outcomes. Another example, would be to enhance existing fish habitat models by accounting for key components that affect dissolved oxygen and temperature, the primary determinants of fish habitat quality. The MDNR is very interested in using these products to assess the impacts of changing land cover and atmospheric conditions on fish habitat and prioritize funding decisions for protection vs. restoration and other management activities.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Build advanced near real-time methods for measuring water quality in surface waters of Minnesota using remote sensing* **Budget: $255,000**

We will develop computer code to automate methods for acquisition and processing of satellite imagery for water quality monitoring using high performance computing techniques. Water quality data resulting from the computerized system will be validated with field data to provide confidence in the results.

Outcome	Completion Date
1. System to automatically acquire and prepare satellite images for further processing	*June 2019*
2. Automated method to apply water quality algorithms from previous R&D to open water pixels for comprehensive and frequent water quality monitoring of Minnesota lakes	*December 2019*
3. Validation of satellite results with routine water quality data collected by citizens, local, state agencies and targeted monitoring (50 optically complex waters yr. 2&3) by our group	*June 2021*

Activity 2: *Build comprehensive water quality geospatial database and provide it to the government agencies, the research community, and citizens* **Budget: $222,000**

We will develop a spatial database to store continually updated water quality maps at the pixel level to visualize seasonal and annual changes in water quality. The data will also be summarized spatially at the basin level and by time (e.g., seasonal averages) in collaboration with agency staff who will advise us on data needs to improve management and better meet their missions. An upgraded and enhanced version of the Lake Browser (lakes.gis.umn.edu) will provide easy access to lake water quality data.

Outcome	Completion Date
1. Near real-time water quality data integrated into a continually updated, publically accessible web database and mapping tool	*June 2020*
2. Customized data summaries distributed for multiple management and research needs	*June 2021*
3. An Interactive web interface maintained by the University of Minnesota's Water Resources Center that provides easy access to lake water quality data	*June 2021*
4. At least a three year database with ~bi-weekly water clarity, algae, turbidity and color	*June 2021*

III. PROJECT STRATEGY

A. Project Team/Partners

This project combines expertise in remote sensing, aquatic ecology, computer science and fisheries. The project team at the University of Minnesota consists of Principal Investigator (PI) Jeffrey Peterson, Co-PIs Leif Olmanson, David Porter and Jacques Finlay and Co-Is Patrick Brezonik and Marvin Bauer. We are collaborating with Peter Jacobson and Gretchen Hansen (MDNR) on data needs to improve fish habitat models used for planning purposes and with Pam Anderson (MPCA) and Judy Sventek (Metropolitan Council) to leverage their data to validate our water quality models and to advise us on data needs to better meet their agencies' missions (letters submitted). We also will integrate our methods with ongoing LCCMR research on HABs led by Daniel Engstrom (Science Museum of MN) to scale up results of site-specific studies to understand HAB bloom formation in MN lakes.

B. Project Impact and Long-Term Strategy

This project directly addresses LCCMR funding priorities for Foundational Natural Resource Data and Information and Water Resources. It builds on previous R&D to move to routine, operational applications of satellite remote sensing for analysis and management of Minnesota lakes. This proposal will develop a system for near real-time monitoring using high performance computing of algae, water clarity, turbidity, and color that will enable enhanced understanding of Minnesota's freshwater resources and improved water quality and fisheries management. Because water quality affects fisheries, drinking water, emerging contaminants, and mercury, our project results will be of immediate use to MPCA, MDNR, the Metropolitan Council and others in decision-making and prioritization of resources. The University of Minnesota's Water Resources Center will maintain the system into the future, with ability to incorporate new data sources and data products driven by user demand.

C. Timeline Requirements.

Development of the semi-automated system, web interface, and distribution of three years of results will be completed in three years.

2018 Detailed Project Budget

Project Title: Providing Critical Water Quality Information for Lake Management

IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Jeffrey Peterson, PI (75% salary, 25% benefits); 4% per year	$ 26,218
Leif Olmanson, Co-PI (75% salary, 25% benefits); 7.2 months per year	$ 148,878
David Porter, Co-PI (75% salary, 25% benefits); 2.4 mo. Yr1, 1.4 mo. Yrs 2&3	$ 59,255
Jacques Finlay, Co-PI (75% salary, 25% benefits); 0.5 months per years 2 & 3	$ 15,180
Marvin Bauer, Co-I (75% salary, 25% benefits); 0.5 months per year	$ 17,729
Patrick Brezonik, Co-I (75% salary, 25% benefits); 0.5 months year 2	$ 7,360
Thomas McGowan, Co-I (75% salary, 25% benefits); 2.4 mo.yrs 2 & 3 Build spatial database	$ 44,985
Junior Scientist (79% salary, 21% fringe) - 50% FTE per year to oversee infomatics	$ 86,876
Civil Service (79% salary, 21% fringe) - 4% FTE per year computer administrator all years	$ 14,201
Civil Service (79% salary, 21% fringe) - 25% FTE per year to oversee laboratory analysis yr 2&3	$ 26,098
2 Undergraduate Students (100% salary, 0% fringe) Students will gain in depth research experience and training while assisting with research.	$ 12,431
TOTAL Personnel Expense =	$ 459,211
Equipment/Tools/Supplies General operating supplies	$ 600
Lab/Field Supplies: The materials and supplies budget will be used to purchase chemicals, glassware, and disposable items needed to perform the proposed research ($800). Other supply funds are requested for bottles, gloves, and filters required for collection, transport, and storage of samples, and for preparation for lab manipulations ($1,000). Costs of analyses of a suite of basic parameters in our labs for each site sampled in the field sampling. The lab analyses cost includes instrument time, gases, reference standards and reagents for colored organic matter concentration and spectral properties/EEMS, suspended sediments, particulate organic carbon and chlorophyll a ($4,200).	$ 6,000
Travel: funds are requested for travel to field sites (3 day trips) 3 times per year 2 and 3. This includes boat expenses ($2,000), vehicle rental/mileage ($2,248), hotel ($1,320), and meals ($1,560), estimated according to UMN guidelines, for PIs, Co-Is and undergraduates for the field sampling campaigns each year. In addition, funds are requested for travel to meetings with collaborators and state agencies.	$ 7,128
Lab fees: Lab sevices fee ($500 per year 2 & 3) and Remote Sensing and Geospatial Analysis Laboratory Fee ($800 per year 1, 2 & 3)	$ 3,400
TOTAL Non-personnel Expense =	$ 17,128
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 476,339

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**
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: *unrecovered Indirect costs (54% MTDC)*	$ 257,223	*Secured*
In-kind Services To Be Applied To Project During Project Period: *Value of Landsat **satellite imagery** from EROS Data Center The estimated net value of Landsat imagery over the project period is **$489,600** (~816 images X $600/per image). **Minnesota Supercomputing Institute** is providing 300,000 core hours of compute time MSI's Linux cluster, 5 TB of primary (POSIX compliant) data storage and 10 TB of tier 2 (object oriented CEPH) data storage at a value of **$24,900** .The **Minnesota Department of Natural Resources** will provide 100 hours per year for 3 years in-kind support to this project, for a value of **$32,200. The Minnesota Polution Control Agency and The Metropolitan Council Environmental Services** will provide their lake and river water quality data in support of calibration and validation of remote sensing results. Estimate value $150 per sample x 400 samples **$60,000.***	$ 606,700	*Secured*
Past and Current ENRTF Appropriation: *ENRTF: 2016 PI Jacques Finlay - Assessment of Surface Water Quality with Satellite Sensors - Activity 1 unspent funds available.*	$ 148,391	*Secured*
Other Funding History: *The National Science Foundation Award # 1510332 PI Raymond Hozalski "Spatial and Temporal Variability in CDOM at Large Regional Scales by Optical Remote Sensing: Effects on Water Quality, Water Treatment, and Aquatic Ecosystem Properties". Funds will all be expended before July 1, 2018.*	$ 230,000	*Secured*

Providing Critical Water Quality Information for Lake Management

Goals: This project develops an operational, near real-time **automated** system to process new **satellite** data for key **water quality** characteristics of Minnesota's 10,000+ lakes. It will provide easy-to-use, strategic information to **improve lake monitoring, management and fish habitat**.

Background:

Water clarity of lakes and rivers is controlled by:

Algae

Suspended solids (turbidity)

Dissolved organic color

These key water quality characteristics have **different causes** and **distinct consequences** for aquatic habitat management and are measurable by satellite imagery.

Approach:

EROS Data Center

Automated satellite imagery pipeline

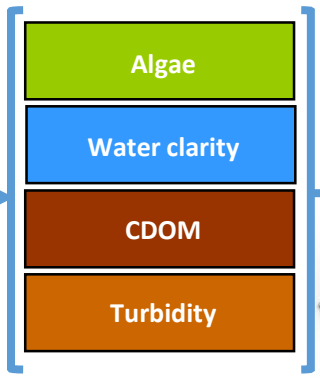
UMN high performance computing systems

Recently launched satellites:
Landsat 8
Sentinel-2
Sentinel-3

Normalize images

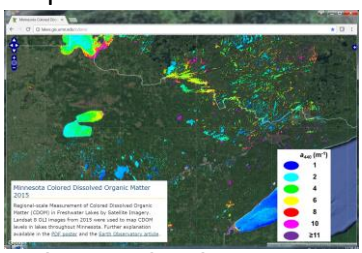
Remove land, clouds, shadows, haze…

Prepare images using new automated methods.



Apply water quality models from previous LCCMR-funded R&D

Maps, data, statistical summaries, time-trend plots and animations

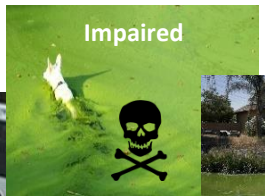


Enhanced Lake Browser

Provide customized information to agencies, researchers, and citizens.

Applications:

Results of this project will improve **monitoring** of 10,000+ lakes to assist agency decision-making for **lake protection** vs. **restoration**, provide better data to assess **fish habitat**, evaluate **recreational suitability**, and help citizens evaluate and protect **property values**.



Providing Critical Water Quality Information for Lake Management

Project Manager Qualifications and Organization Description

Jeffrey Peterson, Project PI; Professor and Director of the University of Minnesota's Water Resources Center. The Water Resources Center (WRC; wrc.umn.edu) is a joint unit of the College of Food, Agricultural, and Natural Resource Sciences and University of Minnesota Extension. As Director, Peterson provides overall leadership for the WRC's research, outreach, and teaching activities involving faculty and students across the university. His research focuses on the economic and policy aspects of water use and water quality impacts from agriculture. He will provide overall leadership for project and coordinate the project's outreach activities with agencies and the public.

Leif Olmanson, Co-PI/Technical PI; Research Assoc. Remote Sensing and Geospatial Analysis Laboratory, Dept. of Forest Resources, has worked for 20 years on developing remote sensing applications for water quality and was a co-developer of the popular Lake Browser (water.rs.umn.edu). He has been working on validation of atmospheric normalization correction methods and algorithm development that will be essential to the success of this project. He will be responsible for working with David Porter to develop computer code for prototype image pre-processing and algorithms to derive water quality products. He will assist with identification of optically complex lakes in collaboration with agency staff that will be targeted by our group for field collection of water quality data. That data along with routinely collected data by other groups will be used to validate the results from the automated workflow and identify any anomalies that need to be remedied in the computer code. He will work with the remote sensing, water quality, fisheries, MSI and WRC groups to execute the project objectives.

David Porter, Co-PI; Scientific Computing Consultant, Minnesota Supercomputing Institute, has worked for over 30 years developing and optimizing a variety of simulation and data processing applications. His background in computational physics, high performance computing, data post-processing, analysis and visualization of high resolution spatially and temporally structured data, and computationally intensive work flows on very large (petascale) data is well suited for this project. He will oversee all supercomputing aspects from developing applications and automated workflows for ingestion of the imagery from national centers, using the MSI's HPC resources for pre-processing and processing of the imagery into water quality products. He will also oversee the development of the water quality web portal and enhanced Lake Browser with assistance from MSI staff **Thomas McGowan** and **Kevin Prigge** to allow easy access to the data products. He will work with the remote sensing and water quality teams to meet project goals.

Jacques Finlay, **Co-PI; Prof., Dept. of Ecology and Evolutionary Behavior,** studies how watersheds influence carbon, nitrogen, phosphorus, and mercury processing in aquatic ecosystems. His work has concentrated on linking terrestrial and aquatic ecosystems with research focusing on the environmental controls of mercury bioavailability and the hydrologic and biogeochemical factors influencing carbon and nitrogen availability in rural watersheds. He has been involved in multiple projects tracing the sources and fates of nutrients in urban and rural ecosystems. He will oversee the field and laboratory work to provide validation data for optically complex lakes that are typically not represented well in routine monitoring efforts, provide scientific guidance, and participate in all aspects of the project.

Organization Description
All personnel are based at the University of Minnesota, one of the largest, most comprehensive, and most prestigious public universities in the US (umn.edu/twincities). The labs and offices of the investigators and collaborators are equipped with the necessary space and facilities needed for the proposed work.