Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 032-A**

Critical Insights from Historical Lake Water Quality Data

Category: A. Foundational Natural Resource Data and Information

Sub-Category:

Total Project Budget: $ 480,000

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

Derive ~40-year water quality database for >10,000 Minnesota lakes and analyze with in-lake, watershed, and economic factors to evaluate benefits to users and managers of improving or maintaining lake quality.

Name: Jeffrey Peterson

Sponsoring Organization: U of MN - Water Resources Center

Job Title: Director

Department:

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Geospatial, temporal and economic analysis of ~40-year satellite derived lake water quality database will inform data-driven management and provide “how, what, why” answers and benefits/costs of water quality changes.

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

PROJECT TITLE: **Critical Insights from Historical Lake Water Quality Data**

I. PROJECT STATEMENT

This project will derive historical water quality data from legacy Landsat satellite imagery to address three key questions: **1) how is water quality in our lakes changing; 2) what factors contribute to those changes; and 3) how do those changes effect lake use and economic conditions?** The project will use automated methods developed in our current LCCMR project to greatly expand the database on lake water quality by mining the **entire archive** of Landsat satellite imagery, make it readily accessible, and use that data to estimate the economic value of changes in water quality. When completed, these projects will produce a database containing almost **40 years of information** and maps of key water quality measures for **over 10,000 Minnesota Lakes**. We will use the database to 1) link differences in water quality and **ecosystem services** to in-lake and watershed factors via geospatial and temporal analyses, and 2) conduct an economic analysis to evaluate the economic value of water quality changes through lake-user surveys and property value analyses.

The current LCCMR-supported project (ML2018 Ch 214 Art4 Sec2 Subd 03b E8181LM) is developing an automated system to deliver near real-time water quality data from 2015 onward using current generation Sentinel 2 and Landsat 8 imagery. This project will modify the automated system to derive water quality products (e.g., water clarity and color) from the 30-year archive of **Legacy (1985-2015) Landsat** 5 and 7 imagery. The combined water quality database of almost 40 years will be ideally suited to identify lakes with changing water quality and to analyze in-lake factors, watershed stressors and climatic conditions that impact water quality.

The database will also enable economic analysis of lake water quality. Minnesotans derive economic value from lakes in various ways, including water-based recreation, scenic amenities from lakeshore property, and broader ecosystem services. As an initial but significant step, this project will estimate the value of changing water quality through data collected from surveys of lake visitors and lakeshore property value records, linked to remotely sensed water quality data. The results of this analysis will inform resource management, by identifying the settings where improved water quality yields the largest economic benefits to lake users, including the economic values of designated uses such as swimming, boating and fishing. The project creates a framework for future work, leading to a comprehensive assessment of the economic value of water quality to inform data-driven resource management.

This project is a compelling opportunity to take advantage of the **freely available** but largely **untapped** 30-year archive of Landsat 5 and 7 satellite imagery 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 is expanding water quality information and strengthening understanding of our changing water resources. This proposal was developed in cooperation with state (e.g., DNR, PCA) and local water management agencies and is designed to support their management needs.

The almost 40 years of spatial water quality data and maps for over 10,000 lakes from these projects will be available in an interactive web interface that is being developed in the current LCCMR project. We expect that the enhanced LakeBrowser, which will have more data and capabilities, will be even more popular than the current version (lakes.rs.umn.edu **~9,000 unique visitors monthly**), which is limited to late summer clarity every five years. This project will dramatically improve data-driven resource management decisions, benefit researchers, and inform the public about changing water quality conditions and the economic impact of those changes.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Modify and apply automated methods for measuring water quality in > 10,000 Minnesota lakes using historical (1985–2015) remote sensing imagery **Budget: $185,000**

We will modify image processing code to process the historical Landsat 5 and 7 imagery and retrieve water quality data using high performance computing techniques. The generated database of water quality data will be validated with field data, and added to an interactive web interface where citizens, researchers and lake managers can easily access and visualize the data.

Outcome	Completion Date
1. System to automatically retrieve, prepare and process historical Landsat images for water quality measurements (e.g., water clarity, color) in > 10,000 lakes	June 2021
2. Water quality database creation (1985–2015)	September 2021
3. Validation of results with **available** citizen and agency collected water quality data	Jan 2022
4. Add historical (1985–2015) water quality data to interactive Web Interface	July 2022

Activity 2: Geographic, Temporal and Economic Analysis of Lake Water Quality **Budget: $295,000**

This activity involves three components. 1) The database developed in Activity 1 will be analyzed statistically for spatial distributions, seasonal and temporal trends, and relationships with in-lake conditions (depth, size, invasive species…) and watershed-landscape factors (e.g., land use, population and drainage density, BMPs) that potentially affect lake quality and ecosystem services. Using this analysis and consultation with agency lake managers, we will identify representative lakes in different regions throughout the state for economic analyses. 2) We will conduct lake-user surveys at statistically sampled pairs of lakes distributed in different regions (e.g., metro, southern, Ely and Brainerd areas) throughout the state to quantify recreational expenditures, and by doing so, estimate visitors' value. Each pair of lakes will differ in water quality and/or water quality history, but be similar in other socio-economic factors, allowing the value estimates to be driven by water quality differences. We will conduct the surveys with undergraduate researchers and estimate the value of the changing water quality by sampling hundreds of people over multiple weeks. 3) We will analyze the monetary impact of changing water quality using publicly available property value information. Statistical analyses will yield estimates of the economic value of changes in measured lake water quality variables, as well as the socioeconomic and spatial factors associated with higher quality benefits.

Outcome	Completion Date
1. Geospatial and temporal analysis of the database with in-lake and watershed factors	June 2022
2. Surveys of lake-users	October 2022
3. Analysis of property values in relation to changing water quality	June 2022
4. Statistical analysis of survey data and property values	June 2023

III. PROJECT PARTNERS:

Name	Title	Affiliation	Role
A. Partners receiving ENRTF funding			
Jeffrey Peterson	Director WRC	UMN WRC	PI
Leif Olmanson	Research Associate	UMN FR	Co-PI/Technical PI
Lucia Levers	Research Associate	UMN WRC	Co-PI
Benjamin Page	Research Fellow	UMN WRC	Co-I
David Porter	Research Associate	UMN MSI	Co-PI
B. Partners NOT receiving ENRTF funding			
Marvin Bauer	Professor emeritus	UMN FR	Co-I
Patrick Brezonik	Professor emeritus	UMN CSE	Co-I

IV. LONG-TERM- IMPLEMENTATION AND FUNDING: The Water Resources Center will maintain the system into the future, with capability to incorporate new data sources and data products driven by user demand.

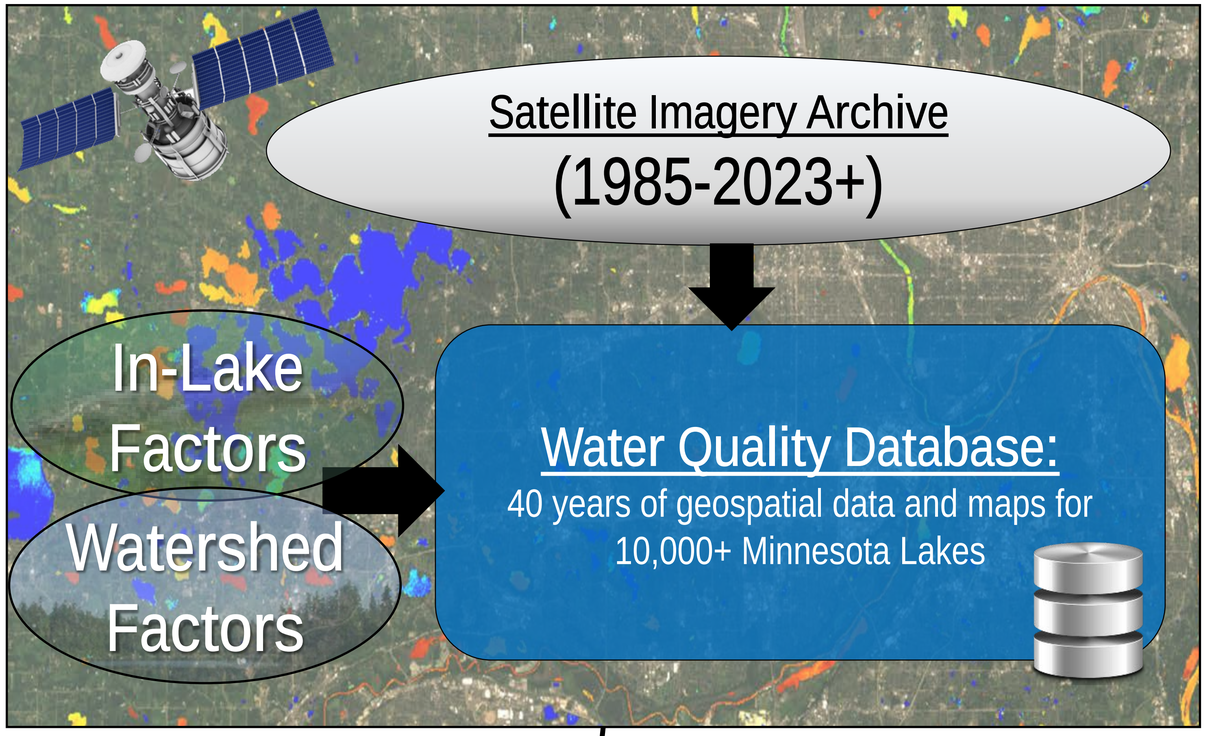
Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Jeff Peterson
Project Title: Critical Insights from Historical Lake Water Quality Data
Organization: Water Resources Center, University of Minnesota
Project Budget: **$ 480,000**
Project Length and Completion Date: 3 Years, July 1, 2020 through June 30, 2023
Today's Date: 4/15/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	**$ 448,085**	**$ -**	**$ 448,085**
Professor: Peterson $7,455 at 1% FTE per year for 3 years. 36% fringe			
Researcher 5: Page $115,950, 50% FTE per year for 3 years; 36% fringe			
Researcher 5: Levers $54,586 at 20% FTE per year; 36% fringe			
Researcher 6: Olmanson $114,951 at 40% FTE per year for 3 years; 36% fringe			
Researcher 5: Porter $66,103 at 20% FTE per years 1 & 2; 36% fringe			
GIS/Web specialist: Unknown $42,235 at 15% FTE per years 2 & 3; 36% fringe			
Graduate Assistant: One graduate student (MS) $29,524 at 50% FTE for one academic semester			
Undergraduate Research Assistants: $17,280 Salary for 4 undergraduate research assistants for one			
Equipment/Tools/Supplies	**$ 11,600**	**$ -**	**$ 11,600**
Data purchases for property values from CoreLogic	$ 7,000		
Tablets (4) and protective convers for onsite survey administration $400 ea (surveys are conducted on site with Qualtrics, an online survey software that allows real time survey flexibility in response to initial survey answers)	$ 1,600		
Survey materials (uniforms to identify students as UMN staff, paper copies of survey, survey log	$ 2,000		
Camping equipment (Undergraduate researchers will conduct on-site surveys of lakes and will stay overnight in camping facilities. Students will need camping equipment)	$ 1,000		
Travel expenses in Minnesota	**$ 20,315**		**$ 20,315**
Fleet vehicles for travel to and from survey locations for survey data collection: $3,474 (Summer fleet leases: $2400 for two vehicles; plus gas: $1,074)	$ 3,474	$ -	
Lodging for Undergrads: $5,040 ($20 a day for 63 days per summer for 4 students)	$ 5,040		
Per Diem: $7,560 ($30 a day for 63 days per summer for 4 students)	$ 7,560		
In state conferences $4,241 - 3 years. This will cover registration fee and travel cost for researchers and student to present our outcomes at	$ 4,241		
Other	**$ -**		**$ -**
COLUMN TOTAL	**$ 480,000**	**$ -**	**$ 480,000**

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: Unrecovered Indirect Cost - 54% minus tution	pending	$ 254,883	$ -	$ 254,883
State:		$ -	$ -	$ -
In kind: Value of Landsat satellite imagery from EROS Data Center. The estimated net value of 30 years (1985-2015) of Landsat imagery over the project period is $820,800 (~1,368 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 $18,000. 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.	Secured	$ 863,700	$ -	$ 863,700

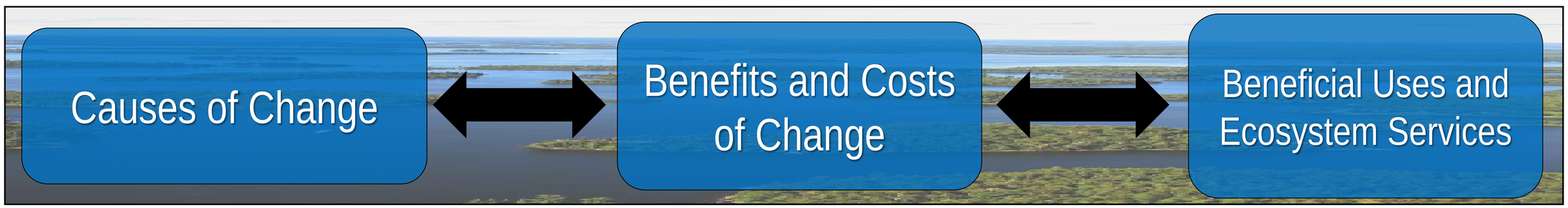
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
Past and Current ENRTF Appropriation: ENRTF: ML2018 Ch 214 Art4 Sec2 Subd 03b E8181LM PI Jeffery Peterson - Providing Critical Water Quality Information for Lake Management - $250,000 with unspent funds available.	$ 180,180	$ 250,000	$ 69,820	$ 180,180
Past and Current ENRTF Appropriation: ENRTF: 2018 PI Jacques Finlay - Assessment of Surface Water Quality with Satellite Sensors - Ends	$ 19,765	$ 345,000	$ 325,235	$ 19,765

CRITICAL INSIGHTS FROM HISTORICAL LAKE WATER QUALITY DATA



Geospatial + Temporal + Economic Analysis

Informing Data-Driven Resource Management for Water Quality



Project Manager Qualifications and Organization Description

Jeffrey Peterson, PhD.
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, Dr. Peterson provides overall leadership for the WRC's research, outreach, and teaching activities involving faculty and students across the university. He will provide overall leadership for project and coordinate the project's outreach activities with agencies and the public.

Leif Olmanson, PhD.
Co-PI/Project Manager; Research Associate. Remote Sensing and Geospatial Analysis Laboratory, Dept. of Forest Resources. Dr. Olmanson has worked for over 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 correction methods, cloud, haze and shadow masking and algorithm development that will be essential to the success of this project. He will contribute to developing computer code for prototype image pre-processing and algorithms to derive water quality products, and will oversee the geospatial and temporal analysis portion of this project.

Lucia Levers, PhD.
Co-PI; Research Associate, University of Minnesota's Water Resources Center. Dr. Levers incorporates natural resource, ecological, and environmental economics into interdisciplinary research projects. She will be leading the economic valuation and analysis portions of the project, and supervising the student researchers.

David Porter, PhD.
Co-PI; Scientific Computing Consultant, Minnesota Supercomputing Institute. Dr. Porter has worked for over 30 years developing and optimizing a variety of simulation and data processing applications. 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 addition of the historical water quality data into the Enhanced LakeBrowser.

Benjamin Page, MS.
Co-I; Research fellow, University of Minnesota's Water Resources Center. Mr. Page has an extensive background in satellite-based remote sensing and geospatial analysis of inland waters. His current work focuses on calibrating Landsat and Sentinel imagery to characterize optically active constituents in Minnesota's > 10,000 inland water bodies for the near real-time water quality monitoring system. He will be involved in the remote sensing and geospatial and temporal analysis 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.