**PROJECT TITLE: Unprecedented change threatens Minnesota’s pristine lakes**

**I. PROJECT STATEMENT**

**Minnesota’s most pristine lakes are changing unexpectedly and we don’t know why!** Where we expect to find hundreds of our most beautiful and remote lakes—with little development or protected within state and national forests and parks—we instead often find green lakes, thick with noxious blooms of algae. Lakes turn green when we add nutrients to them, but in protected or remote settings, typical sources of excess nutrients (land use change, erosion, sewage) are not obvious. Based on our past work, we predict that climate change is working in concert with atmospheric deposition of nurients to drive the changes that have already begun to affect our pristine lakes. ***Importantly****, it is possible that by missing climate and atmospheric effects on lakes we could be misattributing the causes of blooms and misdirecting resource-management efforts and dollars.*

**Summary: We will determine why Minnesota’s nicest lakes are unexpectedly turning green using:**

**1)** a ***first of its kind in-lake and atmospheric monitoring system*** for Minnesota
**2)** historical sediment analysis to show ***how, when, and why pristine lakes are changing***
**3)** lake simulations to determine ***which lakes are most at risk***
**4)** communication of findings with resource managers and lake users on how and why nice lakes are changing.

 ***This project will fundamentally change lake management strategies everywhere in Minnesota*.**

**Climate, weather and atmospheric deposition change everything**.Sediment cores from wilderness lakes show two causes of unprecedented noxious algae growth. First, climate change results in longer ice-free season, stronger thermal stratification, increased inputs of dissolved organic carbon (“tannins”), and correlates with an alarming increased frequency of blue-green (cyanobacteria) blooms. Second, in lakes with no watershed runoff we find large increases in mineral matter and greater growth of algae (see visual). If that mineral matter and its nutrients did not come from the watershed, it must be coming from dustfall or precipitation.

**Nutrients in lakes can originate from many sources—local, regional, and global.** The 16 lakes (deep vs shallow lakes, across watershed size, and along an E-W transect ) selected for this study will be entirely within northern Minnesota’s protected areas, so we can rule out local landuse inputs. Climate change along with regional and global landuse changes well beyond Minnesota may be working in concert to change our pristine lakes. Climate affects lakes directly and indirectly to change how nutrients are cycled within lakes and their watersheds. In other regions of the US and world, dustfall is linked to eutrophication and biological changes in alpine and arctic lakes. We need to know if Minnesota’s lakes are similarly imperiled by climate change and dust-borne nutrients, and rule out other potential causes of wilderness lake change so our management dollars are not wasted.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1: *Use water and air quality monitoring to assess the cause of changing water quality in our “pristine” lakes*** **Description:** Water quality in remote lakes is rarely monitored and air quality monitoring in Minnesota does not measure dry deposition (dustfall). We will do high resolution monitoring of water quality for 2 years on 16 state and national forest and park lakes. We will simultaneously establish a state-of-the-art dustfall network with 5-7 sites in north and central Minnesota in partnership with NADP to measure and map dustfall patterns and nutrient delivery. **ENRTF BUDGET: $348,365** |  |

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| **Outcome** | **Completion Date** |
| *1. Measure nutrients and algae for two years from 16 study lakes* | *October 2022* |
| *2. Establish state-of-the-art dustfall monitoring network in north and central Minnesota* | *October 2022* |

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| **Activity 2: Use sediment cores to determine if our best lakes are imperiled****Description:**Every lake accumulates sediments that record its history. We will collect sediment cores from the 16 study lakes and determine when and how much they have changed—their biology, nutrient levels, dust inputs—using analysis of multiple biological and geochemical measures. We will reconstruct the influence of climate and dust-borne nutrients through time on each lake to understand why they changed, when they changed, and which lakes are most imperiled.**ENRTF BUDGET: $406,817** |  |

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| **Outcome** | **Completion Date** |
| *1. Collect, date, and analyze sediment cores from 16 study lakes* | *January 2023* |
| *2. Compare historical climate and dustfall records from sediment cores with modern monitoring to determine when and why lakes are changing* | *January 2023* |

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| **Activity 3: Use lake simulations to determine which lakes are most at risk and how to protect them****Description:**Computer simulations allow us to understand how lakes have changed in the past and how they might change in the future. MINLAKE is a simulation program that estimates lake thermal and oxygen dynamics. Importantly, input variables in the program let us test interactive effects of other forces that may be affecting our protected lakes such as changing weather patterns and ice-on/off. Model results will be paired with monitoring and sediment core histories to predict which protected lakes are most at risk.**ENRTF BUDGET: $94,210** |  |

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| **Outcome** | **Completion Date** |
| *1. Create a MINLAKE model for 16 study lakes to measure historical changes in lake function* | *January 2023* |
| *2. Develop a framework for predicting which protected lakes are at risk* | *January 2023* |
| *3. Develop scientific reports, informational factsheets, and engage social media to inform managers and lay-persons on the state and fate of Minnesota’s most protected lakes* | *June 2023* |

**III. PROJECT PARTNERS AND COLLABORATORS:**

This project will be led by the St. Croix Watershed Research Station (Dr. Mark Edlund, Dr. Adam Heathcote, and a lake modeler). MPCA-Air Quality will advise on our air quality monitoring network, and Jesse Anderson, MPCA-Water Quality, will advise on lake choice and sampling sites.

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:**

This project establishes a new air monitoring network, provides the first baseline data on dustfall in northern Minnesota, its effect on our best lakes, and determines which lakes are at risk. This project leverages collaborations with other research groups on dustfall and previous ENRTF and NPS funding on wilderness lakes across northern Minnesota, including the DNR Sentinel Lakes and the NPS Inventory & Monitoring programs.

**V. SEE ADDITIONAL PROPOSAL COMPONENTS:**

**A. Proposal Budget Spreadsheet**

**B. Visual Component or Map**

**F. Project Manager Qualifications and Organization Description**

**G. Letter or Resolution**