Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 080-B**

Small Sensor Networks for Water Monitoring (Phase II)

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 980,758

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

This project is to develop small sensor networks based on sensors in Phase I, a very cheap and highly efficient approach for pollutants monitoring in lakes and rivers in Minnesota.

Name: Tianhong Cui

Sponsoring Organization: U of MN

Title: Professor

Department:

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

One Page Vidual Components

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Small Sensor Networks for Water Monitoring (Phase II)

I. PROJECT STATEMENT

This proposed project, building on an ongoing project funded through ENRTF 2016 appropriation, is to develop and demonstrate low-cost and high-performance sensor network and infrastructure for monitoring and collecting big data from more than 12,000 lakes and 92,000 miles of rivers in Minnesota. The specific objectives are (1) to optimize the sensors developed in Phase I for actual water from lakes and rivers, and (2) to develop and test sensor networks with wireless data transmission capability for automatic monitoring of pollutants including phosphate, nitrate, mercury, and chloride in selected MPCA's Watershed Pollutant Load Monitoring Network (WPLMN) stations. In phase I, we developed the sensors, proved its feasibility, and provided foundational knowledge for further development towards implementation. The sensor developed in Phase I is small, cheap, fast, and accurate. The low cost and high automation features of the technology will make large scale and frequent data collection technically and economically feasible. Phase II of this project will be focused on optimization of the sensors' performance in the complex conditions of actual lake and river waters, development of compact sensing units for harsh outdoor environments, and testing of sensor networks in multiple locations. Our techniques have the potential to replace off-site detections and analyses with bulky and expensive equipment currently practiced. The advanced manufacturing facilities at the University of Minnesota allow us to optimize and produce the sensors in a very high quantity at a super low cost, while surmounting the performance of pollutants detection using large equipment or devices. This will help the end-users including water quality control and regulatory agencies, researchers, and advocacy groups for continuous detection and analysis of Minnesota waters, and develop techniques to mitigate water contaminations. In the next phase of the research and development, we will closely collaborate with industry, state agencies, and water researchers, to implement and evaluate sensor networks for pollutants monitoring in broader water regions in Minnesota, and eventually commercialize the sensors and sensor networks in Phase III.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Optimize sensors and develop sensing units in actual waters* **Budget: $653,838**

The objective of this activity is to optimize sensors and further develop sensor units, each of which consists of an array of the sensors for detection of target pollutants, i.e., phosphate, nitrate, mercury, and chloride. First, the performance of the sensors and sensor array under different outdoor environmental conditions with actual pH, presence of particles, and temperature of water will be evaluated. Based on the experimental results, the sensors and sensor array will be conducted to optimize the performance. Next, a compact prototype sensing unit with hardware and software for operation control, data acquisition and display, and wireless data transmission will be designed and fabricated. Data receiving protocol and infrastructure will be developed. The prototype unit will be subjected to lab and in-field tests. The performance of the unit will be evaluated against conventional EPA methods. Last, test results will be used to design working units with improved sensing performance and operation features. Three working units will be fabricated for Activity 2.

Outcomes	Completion Date
1. The sensors and sensor array are optimized for monitoring of phosphate, nitrate, mercury, and chloride in harsh environments.	*6/30/2020*
2. Hardware and software are developed for a prototype unit with wireless data transmission capability. The prototype unit will be tested in lab and field. A design of working unit with improved performance and operation features will be produced.	*6/30/2020*
3. Three working sensing units will be fabricated for testing and operation described in Activity 2.	*6/30/2021*
4. Comprehensive assessment of the techniques of sensors and sensing units	*6/30/2021*

Activity 2: *Develop sensor networks for long-term field tests in lakes and rivers* **Budget: $326,920**

Working closely with MPCA staff, we will select three stations from the following locations for field test: (1) Minnesota River at Fort Snelling State Park, MN (33143004), Site Type: Basin; (2) Cannon River at Morristown, CSAH16 (39091001), Site Type: Sub-watershed; (3) Cannon River at Welch, MN (39004002), Site Type: Major Watershed; (4) St Croix River at Stillwater, MN36 (37061001), Site Type: Basin; and (5) Mississippi River L&D #3 Red Wing, Lock and Dam Rd (38014001), Site Type: Basin. Each unit installed on site will be protected from damage by debris and animals by proper housing. The data collection center will be located on the UMN St. Paul campus. Tests will be conducted during spring, summer, and fall seasons. We will compare the date collected from the sites with lab test and the data from the WPLMN, and calibrate our units when necessary. We will demonstrate the test stations to the stakeholders and LCCMR committee members and officials.

Outcomes	Completion Date
1. Select monitoring stations and install working units in stations to form sensor networks	*12/31/2021*
2. Acquire data and compare the results with those from MPCA labs	*12/31/2021*
3. Demonstrate the technology on-site	*6/30/2022*

III. PROJECT PARTNERS:

A. Project team members receiving ENRTF funding

Name	Title	Affiliation	Role
Tianhong Cui	Professor	University of Minnesota	PI
Roger Ruan	Professor	University of Minnesota	Co-PI
Paul Chen	Professor	University of Minnesota	Co-PI

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Lee Ganske	Agent	MPCA	Collaborator

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

Water is an important resource for Minnesota. In order to monitoring the water quality, the MPCA successively launched “Milestone” monitoring network and Watershed Pollutant Load Monitoring Network. However, the water sample collection, monitoring and testing are tedious, costly and labor intensive process, therefore only a few points in Minnesota can be monitored. In our phase I project, we have successfully developed and tested the feasibility of low-cost and easy-to-use sensors for phosphate, nitrate, mercury, and chloride determination. Using the sensor networks, water quality information in vast water resources in the Minnesota is assessed and monitored remotely and continuously, to make the large-scale water monitoring and potentially large-scale water quality database development feasible, reliable, convenient and cheap. With the establishment of the sensor network, more sites can be added to the network, and the collected large database could support more comprehensive analysis and assessment of the Minnesota waters. This will provide a solution to current resources strapped monitoring programs in Minnesota, ultimately help implement the MPCA’s clear water strategy, and thus enhance the ecological benefits of Minnesota waters. In addition, we will plan to file patents on the proposed sensors and sensor networks for commercialization in the future.

V. TIME LINE REQUIREMENTS:

This project is for 3 years from July 1, 2019 to June 30, 2022. The first two years will focus on the optimization of sensors and sensor networks, and the third year focuses on prototype unit, data transmission protocol and hardware, and field test. The results will be disseminated through presentations by faculty and students involved in the project, briefings to the LCCMR as requested, and other publications. We will work closely with the Minnesota Pollution Control Agency and environmental protection advocacy groups. We also intend to present progress on this project periodically to relevant personnel who have been aware of this project.

2019 Proposal Budget Spreadsheet

Project Title: Small Sensor Networks for Water Monitoring (Pahse II)

IV. TOTAL ENRTF REQUEST BUDGET *[3]* **years**

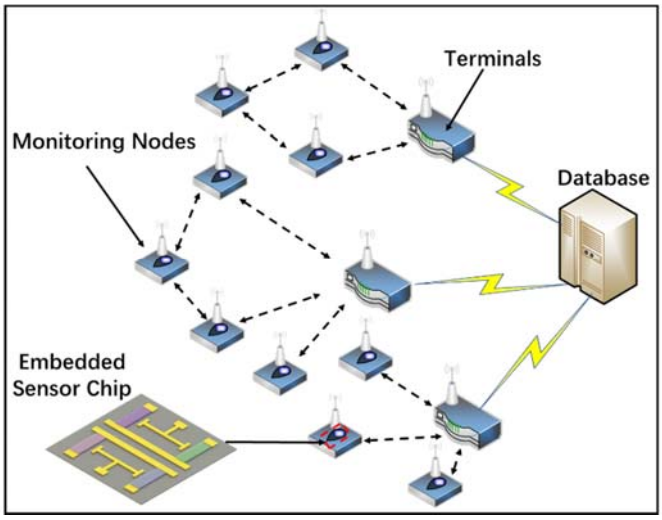
BUDGET ITEM	AMOUNT
Personnel:	**$788,258**
Tianghong Cui, PI/PD ($70,903)	
Roger Ruan, PI/PD, 1 month/year, 3 years, including 33.5% benefits, leading and managing lab and field testing project, leading demonstration, supervising postdocs ($65,000)	
Paul Chen, co-PI, 1 month/year, 3yrs, including 33.5% benefits, project coordination, conducting R&D, project evaluation, progress report ($33,000)	
Postdoctoral Associate, 12 months, 3 yrs, including 2.14% benefits ($178,148)	
1 BBE research associate 50%, 3yrs, including 22.40% benefits, conducting R&D, operations, demonstration, data analysis ($145,000)	
2 ME Graduate Research Assistants, 50%, 3yrs, including 15% benefits plus tuitions, conducting R&D, operationg, demonstration ($296,207)	
Equipment/Tools/Supplies:	**$83,000**
Lab supplies, instrument and equipment consumables, minor equipments for settting up lab and field experimental and testing systems	
Travel:	**$15,500**
for researchers to travel to collect samples in fields and between campus and demonstration site over the 3yrs project period	
Additional Budget Items:	**$94,000**
Outside analysis service ($13,000)	
Scientific Services (ie. Characterization Facility) - Nano Center ($42,000)	
Scientific Services (ie. Characterization Facility) - charact facility ($24,000)	
Instrument and equipment maintanance and repair ($15,000)	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$980,758**

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

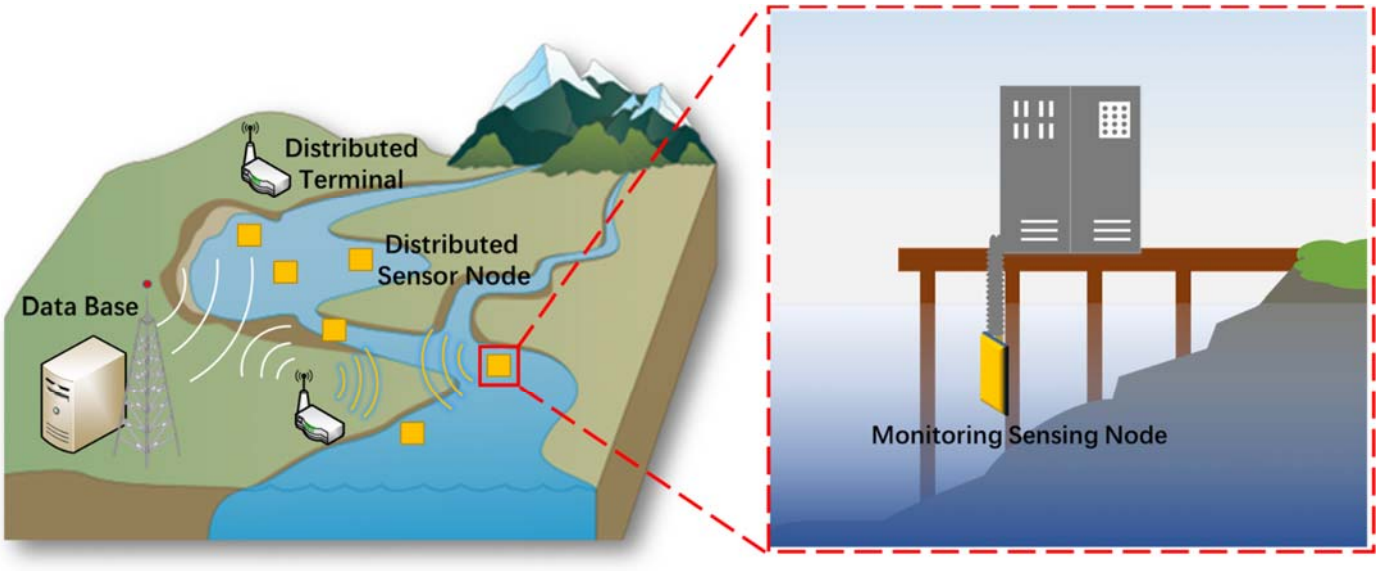
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:		
Other State $ To Be Applied To Project During Project Period: University of Minnesota Overhead	$ 442,040	*Secured*
In-kind Services To Be Applied To Project During Project Period:		
Past and Current ENRTF Appropriation:		
Development of Innovative Sensor Technologies for Water Monitoring (ML 2016)	$ 509,000	Ending in 2019
Other Funding History:		

Project Title: Small Sensor Networks for Water Monitoring (Phase II)

Current Technology



New Technology Proposed



Future applications to continuous pollutants monitoring in Minnesota waters

Project Manager Qualifications and Organization Description

Tianhong Cui is currently Distinguished McKnight University Professor in Mechanical Engineering and an Affiliate Senior Member of the graduate faculty in Department of Electrical and Computer Engineering at the University of Minnesota. He joined the faculty of the University of Minnesota in 2003. He was also a visiting professor at University of Freiburg in Germany in 2006. He is an international leading expert on micro sensors and advanced manufacturing. He has more than 290 publications and 5 US patents in the relevant area. As an editor-in-chief, he founded the first engineering journal of Nature Publishing Group titled *Microsystems & Nanoengineering*, and he is also responsible for another Nature Journal, *Light: Science & Applications*. In the meantime, he is serving as an associate editor for *Journal of Nanoscience and Nanotechnology* and *Journal of Nano Research*, and he was a past editor for *IEEE Sensors Journal*.

The proposed fabrication work will be done in Minnesota Nano Center (www.nfc.umn.edu) at the University of Minnesota in a 7000 square foot facility, including 3000 square feet of class 10 clean room. The Lab contains all of the major pieces of processing equipment. Minnesota Nano Center well maintains these systems, keeps safe operating procedures, and trains students. State support, support from NSF through NNIN, and industry usage allows Minnesota Nano Center to offer academic rates that are normally less than half of the actual cost of operation. In 2014, NFC took possession of a second clean room as part of a new Physics and Nanotechnology Building. The new building is across the street from the ECE Building which houses the existing clean room. At 5000 square feet under filter and almost 10,000 square feet gross, it is more than double the existing space. In addition to expanding the suite of clean room tools available, the lab will also operate two new non-clean core labs that support research in nanomaterials and nanotechnology.

The design and characterization of the sensor networks proposed here will be performed in the Technology Integration & Advanced Nano/Microsystems Laboratory (TIAN Lab), located in room ME4128 of the Mechanical Engineering Building, on the Minneapolis campus of the University of Minnesota. The lab is equipped with the state-of-the-art instrument and facilities to conduct the proposed research. TIAN Laboratory resources include a variety of fabrication and characterization equipment and tools, sufficient for Professor Cui and his Ph.D. student to design, fabricate, characterize and analyse the proposed sensor networks for pollutant monitoring.

The Center for Biorefining directed by Professors Roger Ruan and Paul Chen is a University of Minnesota research center and helps coordinate the University efforts and resources to conduct exploratory fundamental and applied research on renewable energy, materials, and environmental mitigation. The Center's research programs are founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state-of-the-art analytical instruments, and processing facilities ranging from bench to pilot scale for characterization and field testing of this project.

Professor Tianhong Cui in Mechanical Engineering will serve as the PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. He will also develop the sensor networks, portable units, and data transfer protocols. Professor Roger Ruan in Bioproducts and Biosystems will be a collaborator responsible for setting up and conduct field tests of the proposed techniques. Paul Chen, associate professor in Bioproducts and Biosystems, will be another collaborator responsible for lab analysis of water quality using conventional and the proposed techniques.