

**Environment and Natural Resources Trust Fund**

# M.L. 2025 Final Work Plan

## **General Information**

**ID Number:** 2025-275

**Staff Lead:** Lisa Bigaouette

**Date this document submitted to LCCMR:** June 9, 2025

**Project Title:** Portable Arsenic and Nitrate Detector for Well Water

**Project Budget:** $358,000

## **Project Manager Information**

**Name:** Tianhong Cui

**Organization:** U of MN - College of Science and Engineering

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## **Project Reporting**

**Reporting Schedule:** March 1 / September 1 of each year.

**Project Completion:** June 30, 2028

**Final Report Due Date:** August 14, 2028

## **Legal Information**

**Legal Citation:** M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 04v

**Appropriation Language:** $358,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to develop a small, cheap, and easy-to-use system to detect arsenic and nitrate in well water and determine whether well water is safe to drink.

**Appropriation End Date:** June 30, 2028

## **Narrative**

**Project Summary:** We propose to develop a tiny, cheap and easy-to-use detector for arsenic and nitrate. It can be used for well water to determine if the water is safe to drink.

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

In Minnesota, arsenic and nitrate contamination in well water poses a significant public health threat. Data from the Minnesota Department of Health reveals that approximately 10% of private wells exceed the U.S. Environmental Protection Agency's standards for arsenic (10 parts per billion) and nitrate (10 parts per million). These contaminants are linked to various health issues, including cancer, cardiovascular problems, and methemoglobinemia, and are particularly hazardous for infants and pregnant women. The reliance on private wells for drinking water exacerbates the issue, as they often lack regulations and routine monitoring. Moreover, Minnesota's geological composition, characterized by arsenic-prone aquifers, complicates the situation. Current detection methods rely on periodic water sampling and testing, which is often time consuming and costly. This intermittent testing increases the risk of contamination going undetected for extended periods, amplifying health risks. Given these challenges, urgent action is necessary to develop portable arsenic and nitrate detectors for well water. These detectors would enable fast, cheap on-site testing, improving the safety of well water statewide. Investing in such technology is crucial to safeguarding public health and ensuring access to clean drinking water for all Minnesotans.

**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.**

Our proposed solution to the pervasive issue of arsenic and nitrate contamination in well water in Minnesota is to develop a new detector for accurately determining arsenic and nitrate levels in water. This involves cutting-edge detection technologies: a graphene ion-sensitive field-effect transistor (ISFET) with arsenic and nitrate ion-sensitive membranes. Graphene ISFETs offer unparalleled sensitivity, enabling the detection of minute concentrations of ions or species in water. By incorporating ion-sensitive membranes tailored specifically for arsenic ions and nitrate species, our device can accurately and rapidly detect the presence of these contaminants in well water samples. This innovative approach addresses the shortcomings of current detection methods, providing a portable, cheap, and user-friendly solution. The graphene ISFET technology allows for on-site detection, eliminating the need for laborious and expensive laboratory analysis. Moreover, its sensitivity ensures early detection of contamination, mitigating health risks associated with prolonged exposure. This includes sensor and membrane development, followed by performance optimization to enhance sensitivity, stability, and accuracy. In collaboration with the Minnesota Well Owners Organization, field test will validate the technology's real-world effectiveness. These steps ensure a reliable, portable, and cost-effective solution for safeguarding public health and ensuring safe water.

**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?**

The project to develop a new detector to identify and evaluate the concentration of arsenic and nitrate in well water using graphene ISFET technology to directly support Minnesota's environmental goals. By safeguarding water quality and preventing further degradation, it contributes to the conservation of groundwater and preservation of ecosystems. Early detection of contaminants promotes sustainable resource management and protects public health, aligning with the state's commitment to environmental stewardship. Ultimately, the project enhances the resilience of Minnesota's natural resources, ensuring they remain viable for future generations while promoting the well-being of communities reliant on clean water sources in Minnesota.

## **Project Location**

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

**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

## **Activities and Milestones**

### **Activity 1: Development of arsenic and nitrate detectors using graphene ion-sensitive field-effect transistors for laboratory testing of water**

**Activity Budget:** $174,133

**Activity Description:**The first activity aims to develop, manufacture, and assess individual sensors using graphene ion-sensitive field effect transistors (ISFETs) coupled with arsenic and nitrate ion-sensitive membranes (ISMs). Graphene is a monolayer of carbon atoms which is highly sensitive to pollutants in water. The following steps will ensure successful completion: Firstly, graphene ISFET sensing platform will be designed and fabricated, focusing on optimizing graphene channels, source-drain electrode design, and selecting cost-effective substrates while maintaining high sensing performance. Next, arsenic and nitrate ISMs will be synthesized by immobilizing ionophores within a polymer matrix to enable selective detection of different species in water. ISM compositions will undergo optimization to ensure long-term stability and heightened sensitivity. Subsequently, integration of arsenic and nitrate ISMs with graphene ISFETs will occur, followed by in-laboratory measurement and optimization. Validation of results will involve comparison with standard methods including ion chromatography (IC) for nitrate and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for arsenic. The sensors will be fabricated using microfabrication technology at the Minnesota Nano Center, University of Minnesota. Testing and evaluation of arsenic and nitrate detectors in laboratory settings will compare sensing results with standard methods such as Inductively Coupled Plasma Mass Spectrometry.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Approximate Completion Date** |
| Design, fabrication, and testing of arsenic detectors as testing prototypes in laboratory | December 31, 2025 |
| Design, fabrication, and testing of nitrate detectors as testing prototypes in laboratory | June 30, 2026 |
| Improvement and optimization of arsenic and nitrate detectors in laboratory | June 30, 2026 |

### **Activity 2: Development of a portable detection system integrated arsenic and nitrate sensors, detector system parameter optimization, and field tests**

**Activity Budget:** $183,867

**Activity Description:**The second activity of the proposed project aims to develop a portable detector system suitable for field testing by non-trained individuals. This involves four key milestones: (1) Designing and fabricating an integrated graphene ISFET platform comprising arsenic and nitrate sensors, which will undergo testing and optimization with synthesized ISMs. (2) Developing the detector's readout circuit, portable chassis, and user-friendly interface, with a modular design allowing for easy sensor replacement. (3) Conducting laboratory testing to validate the detector's performance against standard techniques like Inductively Coupled Plasma Mass Spectrometry. (4) Field-testing the detector for onsite arsenic and nitrate detection in well water, where environmental scientists will utilize it, providing valuable feedback for further optimization. Field tests will be performed at the free well-testing clinics for private well-owners throughout Minnesota, led by the Minnesota Well Owners Organization, where traditional analytical techniques will be used to confirm the ISFET sensor accuracy and inform technology optimization. By integrating advanced technology with accessible design, this portable detector system ensures efficient and reliable onsite detection of arsenic and nitrate contamination. Such advancements are crucial for safeguarding public health and preserving natural water resources, ultimately contributing to the broader goal of environmental sustainability and clean water access.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Approximate Completion Date** |
| Design, fabricating, and optimizing the integrated graphene ISFET platform for arsenic and nitrate detection | December 31, 2026 |
| Design and fabrication of the detector’s readout circuit, chassis, and user-interface | December 31, 2026 |
| In-lab validation and field test of the portable arsenic/nitrate detector for well water | June 30, 2027 |
| Field testing at MNWOO free testing clinics for accuracy assessments and technology optimization | June 30, 2027 |

## **Project Partners and Collaborators**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Organization** | **Role** | **Receiving Funds** |
| Cara Santelli | University of Minnesota | Co-PI; Be responsible for field tests and assessments of the developed sensors. | Yes |
| Jeffrey Broberg | Minnesota Well Owners Association | Organize and collaborate on nitrate and arsenic well-testing clinics for private well-owners. | Yes |

## **Dissemination**

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**Our dissemination efforts will focus on engaging beneficiaries, improving resource management, ensuring the longevity of project outputs, promoting behavioral changes, and informing the public about the achievements of our portable arsenic and nitrate detector for well water. We will publish our findings in peer-reviewed journals and present at national and international conferences, such as those hosted by the American Society of Mechanical Engineers (ASME) and the Institute of Electrical and Electronics Engineers (IEEE). Additionally, we will host workshops and seminars at the University of Minnesota to disseminate our findings to academic and industry partners. Collaborations with the Minnesota Department of Health and local environmental organizations will be established to share research results and provide training sessions, ensuring practical applications and awareness among local water management authorities and well owners.

Educational outreach will include the development of brochures, fact sheets, and instructional videos to explain the importance of water testing and the use of the portable detector. We will conduct outreach programs in schools and community centers to raise awareness about water contamination and ensure safe drinking water. Online dissemination will be facilitated through a dedicated project website hosting data, publications, and resources for public access, as well as social media platforms to share updates, milestones, and results. Data and results will be submitted to open-access repositories for broad accessibility and long-term preservation, and physical samples and detector prototypes will be shared with research institutions and public health agencies. Community engagement will be fostered through meetings and forums to discuss project findings and gather feedback from stakeholders, with easy-to-understand summaries distributed to impacted communities. Through these comprehensive efforts, we aim to maximize the impact of our project, benefiting those who need it most and contributing to the betterment of Minnesota's environment and public health.

All dissemination materials, including publications, presentations, outreach materials, and digital content, will acknowledge the support of the ENRTF. The ENRTF logo and attribution language will be included in printed and electronic media, such as research papers, brochures, fact sheets, instructional videos, and the project website. Any public-facing presentations at conferences, workshops, and seminars will include a slide or statement recognizing ENRTF’s contribution. Additionally, signage at outreach events and community engagement activities will display the ENRTF logo, ensuring clear visibility of the fund’s role in supporting this work. These acknowledgments will adhere to the ENRTF Acknowledgment Guidelines to maintain consistency and transparency in communicating the project's funding source.

## **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?**A portable arsenic and nitrate detector will be developed. Patents based on the developed prototypes will be applied for commercialization. The systems will be used for well waters in Minnesota. Further work will focus on the highly integrated pre-processing and post-processing units and field tests for a broader area. Other federal funding from NSF (i.e., programs including the funded Convergence Accelerator, the funded Regional Innovation Engine, etc.), USDA (i.e., the AFRI Foundational and Applied Science Program), EPA, USGS, or private funds will be applied as potential funding sources for further development of arsenic and nitrate sensors.

## **Budget Summary**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category / Name** | **Subcategory or Type** | **Description** | **Purpose** | **Gen. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified Staff?** | **$ Amount** |
| **Personnel** |  |  |  |  |  |  |  |  |
| Tianhong Cui |  | Principal Investigator |  |  | 27.06% | 0.24 |  | $56,399 |
| Cara Santelli |  | Co-PI |  |  | 27.06% | 0.24 |  | $37,240 |
| Research Assistants |  | Research Assistants |  |  | 42.97% | 3 |  | $185,757 |
|  |  |  |  |  |  |  | **Sub Total** | **$279,396** |
| **Contracts and Services** |  |  |  |  |  |  |  |  |
| MNWOO | Subaward | Running well-testing clinics for local community members to bring well water samples. Arsenic and nitrate levels will be quantified by traditional analytical techniques and sensors will be tested to determine accuracy and optimization needs. |  |  |  | 2 |  | $27,000 |
| UMN Nano Center | Internal services or fees (uncommon) | Scientific Service at the University of Minnesota’s Minnesota Nano Center and the Characterization facility. Fabrication and characterization costs of the arsenic and nitrate detectors in central facilities |  |  |  | 0 |  | $21,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$48,000** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Tools and Supplies | Silicon wafers, polymer substrates, graphene, chemicals, and components for testing set-up | Materials and supplies for various items required to fabricate and characterize the arsenic and nitrate detector |  |  |  |  | $18,104 |
|  |  |  |  |  |  |  | **Sub Total** | **$18,104** |
| **Capital Expenditures** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Acquisitions and Stewardship** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel In Minnesota** |  |  |  |  |  |  |  |  |
|  | Miles/ Meals/ Lodging | Travels in Minnesota | Sampling and field tests in Minnesota waters |  |  |  |  | $12,500 |
|  |  |  |  |  |  |  | **Sub Total** | **$12,500** |
| **Travel Outside Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Printing and Publication** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Other Expenses** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
|  |  |  |  |  |  |  | **Grand Total** | **$358,000** |

### **Classified Staff or Generally Ineligible Expenses**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category/Name** | **Subcategory or Type** | **Description** | **Justification Ineligible Expense or Classified Staff Request** |

### **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 | $167,626 |
|  |  |  | **Non State Sub Total** | **$167,626** |
|  |  |  | **Funds Total** | **$167,626** |

**Total Project Cost: $525,626**

**This amount accurately reflects total project cost?**
 Yes

## **Attachments**

### **Required Attachments**

#### ***Visual Component***

File: [469e0d75-692.pdf](https://lccmrprojectmgmt.leg.mn/media/map/469e0d75-692.pdf)

#### ***Alternate Text for Visual Component***

Comparison of the current and proposed technologies for detection of arsenic and nitrate...

### **Supplemental Attachments**

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

|  |  |
| --- | --- |
| **Title** | **File** |
| USGS Support Letter | [cab3ae5b-8ec.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/cab3ae5b-8ec.pdf) |
| MNWOO Letter | [bfda9035-3ae.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/bfda9035-3ae.pdf) |
| University Support Letter | [ce2fcc8e-6d2.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/ce2fcc8e-6d2.pdf) |

## **Difference between Proposal and Work Plan**

#### ***Describe changes from Proposal to Work Plan Stage***

No Changes. Just an expansion from the original proposal to this work plan.

## **Additional Acknowledgements and Conditions:**

The following are acknowledgements and conditions beyond those already included in the above workplan:

**Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?**
 N/A

**Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?**
 Yes, I understand the UMN Policy on travel applies.

**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?**
 No

**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")?**
 Yes

**Do you certify that background checks are performed for background check crimes, as defined in Minnesota Statutes, section 299C.61, Subd. 2, on all employees, contractors, and volunteers who have or may have access to a child to whom children's services are provided by your organization?**
 Yes

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

 Alexandra Sullivan <sull1129@umn.edu>

**Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR’s reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements**
 N/A