# Environment and Natural Resources Trust Fund

2025 Request for Proposal

## General Information

**Proposal ID:** 2025-257

**Proposal Title:** Facilitated Transport Hybrid Membranes for CO2 Separation

## Project Manager Information


**Name:** Jun Li

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

**Office Telephone:** (612) 626-0153

**Email:** junli1@umn.edu


## Project Basic Information

**Project Summary:** To capture CO2, we will develop advanced polymeric membranes infused with metal-organic framework nanoparticles. These membranes facilitate the passage and collection of CO2 while blocking the permeation of other gases.

**ENRTF Funds Requested:** $1,150,000

**Proposed Project Completion:** June 30, 2028

**LCCMR Funding Category:** Air Quality, Climate Change, and Renewable Energy (E)

## 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

## Narrative

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

$CO_2$ emissions have a huge impact on the global carbon cycle. It is well-documented that $CO_2$ is a greenhouse gas and one of the main contributors to global warming. Also, the accumulation of $CO_2$ in the atmosphere results in a reduction in the pH of the upper ocean. Reducing $CO_2$ emissions remains a major challenge to mankind. A solution that sequesters atmospheric $CO_2$ will bring enormous environmental benefits. Various $CO_2$ capture technologies include absorption, adsorption, membrane, biological capture, and cryogenic capture. Compared to other separation methods, membrane separation is generally more energy efficient and environmentally benign, thus has been intensively studied for $CO_2$ capture.

**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.**

We will design and develop highly permeable and highly selective membranes, termed facilitated transport hybrid membranes (FTHMs), by integrating functionalized metal-organic framework (MOF) particles into a polymer matrix. These tailored membranes aim to facilitate the transport of $CO_2$ molecules while effectively blocking other gases typically found in emission sources. FTHM would enable the capture and collection of $CO_2$ for subsequent utilization.

By harnessing the unique properties of functionalized MOFs, our membranes are expected to outperform conventional polymeric and hybrid membranes (HMs), which rely on inorganic nanoparticles. This superiority stems from (i) the chemical affinity and compatibility of MOFs with the polymer, and (ii) the incorporation of specific functional groups onto the MOFs to enable reversible reactions with $CO_2$, thereby boosting the efficiency of $CO_2$ transport across the membrane.

Our specific objectives are:

1. Develop MOFs for optimal facilitated transport and incorporation into FTHM.
2. Design a robust fabrication method that can uniformly distribute the MOF particles within the polymer matrix.
3. Deliver an FTHM and compare its $CO_2$ permeability and selectivity with that of state-of-the-art HMs for $CO_2$ capture.
4. Deliver a membrane contactor for $CO_2$ separation and compare its performance with that of state-of-the-art membrane contactors.

**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 proposed membranes are highly relevant to $CO_2$ emission in Minnesota, specifically to localized emission sources in industrial facilities that continue to use oil and natural gas to heat and operate. Emissions from these sources have risen 14% between 2005 and 2020 (Greenhouse gas emission in Minnesota 2005-2020, Report to the Legislature January 2023). The target membranes are intended to improve the performance of equipment that can reduce such emissions directly at their source.

## Activities and Milestones

### Activity 1: High performance molecular dynamics computational simulation studies of gas separation in a MOF-based FTHM (Dumitrică)

**Activity Budget:** $229,868

**Activity Description:**
These atomic level simulations are expected to fill key knowledge gaps in our understanding of the factors that limit and enhance the separation performances of FTHMs. Specifically, concentration gradient-driven non-equilibrium molecular dynamics simulations will quantify and characterize the gas transport dynamics at the polymer/MOF interface. We hypothesize that processes occurring at this interface exerts a pivotal influence on the performance of the FTHM. We will construct atomistic models of the polymer/MOF interface and utilize them to investigate the surface compatibility between the polymer and the MOF, both with and without functional groups. Our aim is to capture in the simulations the potentially detrimental effects of interfacial defects, like nonselective voids and the benefits of functional groups added to MOF, and ultimately to establish a connection between simulated compatibility and the real-world performance of FTHM. In addition to delivering an unprecedented microscopic picture of transport and formulating predictions (including idealized predictions) of the separation performance based on the individual constituents of a FTHM, the constituent screening afforded by these simulations (performed ahead of experimentation) will play a guiding role in the FTHM materials selection and interface design through MOF functionalization for the next-generation HMs for CO2 separation.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| 1.1 Simulation of membranes of polymer/UiO-66 MOF (nonfunctionalized) with and without interfacial voids | September 30, 2025 |
| 1.2 Computational optimization of membranes of polymer/UiO-66 (functionalized) with and without interfacial voids | December 31, 2025 |
| 1.3 Simulation of membranes of polymer/other MOFs (functionalized) with and without interfacial voids | September 30, 2026 |
| 1.4 Computational optimization of membranes of polymer/the most promising MOF (functionalized) | September 30, 2027 |
| 1.5 High throughput simulations for FHTM materials selection of next-gen membranes | March 31, 2028 |

### Activity 2: Fabrication and characterization of MOF-based FTHMs (Stein, Li)

**Activity Budget:** $499,803

**Activity Description:**
In Budget Period 1, we plan to optimize the design of the UiO-66-based FTHM based on a previous 3M-funded seed project and the computational guidance in Activity 1. Then, we will fabricate the optimized UiO-66-based FTHM. Following that, we will characterize the FTHM, focusing on the dispersion of the functionalized UiO-66 in the polymer matrix and the durability of the FTHM.

In Budget Period 2, we plan to fabricate FTHMs of polymer/other functionalized MOFs based on information from Activity 1. Specifically, we are interested in using 2D MOFs. Besides having reversible reactions with CO2, the 2D MOFs could also possibly act as diffusion barriers for other gases, assuming only weak interactions with those gases, to achieve high selectivities. We will use characterization to verify dramatically improved dispersion of the functionalized MOF throughout the membrane and extraordinary durability for the optimized FTHM. We anticipate seeing improvements in the facilitate transport mechanism for it, too, which will be reflected by a higher CO2 sorption coefficient of the FTHM.

In Budget Period 3, we plan to scale up the optimized MOF-based FTHM, in order to make our FTHM more ready technically and practically.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| 2.2 Fabrication of optimized FTHM of polymer/UiO-66 (functionalized) based on 1.2 | March 31, 2026 |
| 2.3 Characterization of FTHM from 2.2. Verify dispersion of functionalized UiO-66 and durability | June 30, 2026 |
| 2.1 Synthesis and characterization of MOF particles | December 31, 2026 |
| 2.4 Fabricate FTHMs of polymer/other MOFs based on 1.4 and 1.5 | June 30, 2027 |
| 2.5 Characterization of FTHMs from 2.4. Verify dispersion of functionalized MOFs and durability | September 30, 2027 |
| 2.6 Scale-up of optimized MOF-based FTHM | December 31, 2027 |

## Activity 3: Testing of CO2 permeation and sorption performance of MOF-based FTHMs (Li)

**Activity Budget:** $139,183

**Activity Description:**
In Budget Period 1, we will build a high-fidelity gas sorption test facility that can accurately quantify the facilitated transport performance for membranes. We will use an existing gas permeation test facility from a previous 3M-funded seed project to measure CO2 permeation performance for our membranes.

We will measure the CO2 permeability and selectivity of the FTHM developed in Activity 2.2 using the gas permeation test facility. We will verify that there is improved performance compared to previously developed UiO-66-based FTHMs from the previous 3M-funded seed project.

We will measure the CO2 solubility of the FTHM developed in Activity 2.2 using the gas sorption test facility. The CO2 sorption coefficient will be derived based on the results. We will use that to verify the improvements in the facilitate transport mechanism and the advantages of our design.

In Budget Period 2, we plan to perform the same tests described above to the FTHMs developed in Activity 2.4 (using other MOFs), which are supposed to have even higher performance than those from Activity 2.2. We will verify that the CO2 permeability and selectivity of optimized one are both dramatically higher than the state-of-the-art HMs.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| 3.1 Build-up of gas sorption test facility for membranes | March 31, 2026 |
| 3.2 Testing of the FTHM developed in Activity 2.2 | June 30, 2026 |
| 3.3 Testing of FTHMs developed in Activity 2.4 | June 30, 2027 |

## Activity 4: Testing of CO2 separation performance of membrane contactors using MOF-based FTHMs (Li)

**Activity Budget:** $181,146

**Activity Description:**
To make our technology more ready for applications, starting from Budge Period 2, we will build a test facility for membrane contactors for CO2 separation. We will also design and fabricate novel contactors for CO2 separation using the scaled-up, optimized MOF-based FTHM from Activity 2.6. Finally, we will test these membrane contactors.

Our design target is the effectiveness of our best membrane contactor for $CO_2$ separation is much higher than that of state-of-the-art membrane contactors.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| 4.1 Build-up of the test facility for membrane contactors for $CO_2$ separation | September 30, 2027 |
| 4.2 Novel design of membrane contactors for $CO_2$ separation | September 30, 2027 |
| 4.3 Fabrication of $CO_2$ separation membrane contactors using FTHMs developed in Activity 2.6 | March 31, 2028 |
| 4.4 Testing of membrane contactors developed in Activity 4.3 | June 30, 2028 |

## Activity 5: Field testing of $CO_2$ separation membrane contactors using MOF-based FTHMs (Li, contractor)

**Activity Budget:** $100,000

**Activity Description:**
This activity aims to examine the performance of our $CO_2$ separation membrane contactor in the field. We plan to hire a professional $CO_2$ emission evaluation organization as a contractor to finish this activity. Near the end of Budget Period 2, we will start to identify a facility to test our membrane contactor. Our focus will be industrial $CO_2$ emission facilities. We will fabricate a membrane contactor using FTHMs developed in 2.6 and provide it to the $CO_2$ emission evaluation organization to test.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| 5.1 Identify an industrial $CO_2$ emission facility for field testing | December 31, 2027 |
| 5.2 Fabrication of a $CO_2$ separation membrane contactor using FTHMs developed in 2.6 | March 31, 2028 |
| 5.3 Install the $CO_2$ separation membrane contactor and testing instrumentation onsite. Test the contactor | June 30, 2028 |

## Project Partners and Collaborators

| Name | Organization | Role | Receiving Funds |
|---|---|---|---|
| Andreas Stein | U of MN - College of Science and Engineering | Professor Stein's expertise includes zeolite and MOF syntheses, zeolite membranes, and functionalization of delaminated clay or graphene oxide materials for polymer nanocomposite fabrication with improved structural and barrier properties. He will lead the synthesis, functionalization, and characterization of the MOF particles, as well as the characterization of FTHMs. | Yes |
| Traian Dumitricã | U of MN - College of Science and Engineering | Professor Dumitrică's expertise includes molecular dynamics computations for describing the fundamental mechanical deformations of nano-materials, determining optimal equilibrium nano-structures, and investigating the transport properties of nano-system. He will lead the molecular dynamics computational effort to provide design guidance for the component materials of our FTHMs. | Yes |
| Michael Kesti | 3M Company | 3M will work with us as an industrial partner. They will provide perspectives from the industry. They are also considering providing us with their proprietary MOFs. They will look into opportunities to commercialize our research outcomes (i.e. contactor and membranes) after the project provided the results are promising. | No |

## 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?**
The findings and results will be disseminated to federal and state agencies, industries, and other interested parties, through open-access publications and conference presentations.

3M, as our industrial partner, will scale up our technology and commercialize our technology provided that the results for membranes and contactors in this project are promising.

If new avenues for research emerge from this combined experimental-computational research effort, we will apply for funding from federal sources such as the U.S. Environmental Protection Agency (EPA), the National Science Foundation (NSF), the Department of Energy (DOE), etc.

## Project Manager and Organization Qualifications

**Project Manager Name:** Jun Li

**Job Title:** Richard and Barbara Nelson Assistant Professor

**Provide description of the project manager's qualifications to manage the proposed project.**
Prof. Jun Li will serve as the project manager. Prof. Li's research to-date has involved polymer and surface sciences for anti-icing and antifouling applications, liquid-vapor phase separation and distribution in microchannel heat exchangers, and in-tube phase-change heat transfer. Prof. Li's postdoctoral research focused on surfaces and coatings for anti-icing and antifouling applications. His Ph.D. research mainly focused on heat transfer, multiphase flow, and thermal systems. At UMN, Prof. Li's research focuses on polymer science. He designs synthetic materials for carbon capture and designs synthetic coatings to control the accretion of various matters and applies them to thermal fluid components and systems, with the end goal of decarbonization for the energy sector of the society.

In this project, Prof. Li will handle the overall project management and planning. On the fabrication side of the project, he will lead the synthesis of the polymer matrix for the FTHMs, the fabrication of the FTHMs, and the scale-up of the FTHMs. On the testing side of the project, he will lead the CO2 permeation and sorption tests to verify the performance of the membranes. He will also design and fabricate novel membrane contactors using the optimized FTHMs, and then verify the improved performance of the membrane contactors compared to the state-of-the-art.

Currently, Prof. Li is working as the Principle Investigator (PI) for a 3M-funded seed project with Prof. Andreas Stein. This experience will provide a seamless transition for Prof. Li to continuously work with Prof. Stein for the LCCMR project, with 3M being the industrial partner. Besides that, Prof. Li has submitted a large-scale (~$2M) research proposal (currently under review) to the U.S. Department of Energy as the PI. In that proposal, he coordinated a team of UMN, a Fortune 500 company that delivers HVAC technologies, and a technical consulting firm.

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

**Organization Description:**
The University of Minnesota is the main research and graduate teaching institution in the state of Minnesota. The Department of Mechanical Engineering is building on the past, responding to the present, and leading the way to the future by driving innovative research with significant real-world impact through our five impact areas: Environment & Sustainability, Energy Transition, Human Health, Next-Gen Manufacturing, and Robotics & Mobility. For Environment & Sustainability, from the atmosphere to ground water and everything in between, mechanical engineering is essential in the advancement of environment and sustainability studies. Researchers in the Department of Mechanical Engineering work on air and water pollution, seawater desalination, engine efficiency, alternative fuels, biodegradables, and more to combat climate change and work toward a greener future.

## Budget Summary

| Category / Name | Subcategory or Type | Description | Purpose | Gen. Ineligible | % Benefits | # FTE | Classified Staff? | $ Amount |
|---|---|---|---|---|---|---|---|---|
| **Personnel** | | | | | | | | |
| Jun Li | | PI | | | 27.06% | 0.27 | | $37,818 |
| Traian Dumitrica | | Co-PI | | | 27.06% | 0.27 | | $46,713 |
| Andreas Stein | | Co-PI | | | 27.06% | 0.27 | | $58,747 |
| ME Research Assistants | | Research Assistants | | | 43.64% | 4.5 | | $549,465 |
| Chem Research Assistants | | Research Assistants | | | 51.32% | 1.5 | | $179,294 |
| | | | | | | | **Sub Total** | **$872,037** |
| **Contracts and Services** | | | | | | | | |
| TBD | Professional or Technical Service Contract | We plan to hire a professional CO2 emission evaluation organization to perform field tests for our CO2 separation membrane contactor. We will identify a facility to test our membrane contactor. The professional service will install the membrane contactor and testing instrumentation onsite and evaluate our membrane contactor. | | | | 0 | | $100,000 |
| | | | | | | | **Sub Total** | **$100,000** |
| **Equipment, Tools, and Supplies** | | | | | | | | |
| | Equipment | Maxwell Robotics UB-C-1106-004 thermoelectric heater/chiller module. Quantity: 1 | Build-up of gas sorption test facility for membranes | | | | | $4,500 |
| | Equipment | Maxwell Robotics UB-C-1106-003 Dual-pressure range pressurization system. Quantity: 1 | Build-up of gas sorption test facility for membranes | | | | | $4,500 |
| | Equipment | Maxwell Robotics UB-C-1106-002 gas injection valve. Quantity: 5 | Build-up of gas sorption test facility for membranes | | | | | $7,495 |
| | Equipment | Swagelok Diaphragm Valves 6LVV-DPHFR4-P-C. Quantity: 4 | Build-up of gas sorption test facility for membranes | | | | | $2,000 |
| | Equipment | Thermo-Fisher temperature controller. Quantity: 1 | Build-up of gas sorption test facility for membranes | | | | | $1,505 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Equipment | Thermo-Fisher SC-150 temperature controller. Quantity: 2 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $5,660 |
| | Equipment | MKS Baratron 622D11TBE capacitance manometer. Quantity: 4 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $4,200 |
| | Equipment | Feed solution pump. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $2,500 |
| | Equipment | Absorption solution pump. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $2,500 |
| | Equipment | ATO variable frequency drive (VFD) + Dayton general purpose motor. Quantity: 2 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $4,000 |
| | Equipment | Customized stainless steel feed tank. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $4,000 |
| | Equipment | Customized absorption tank. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $4,000 |
| | Equipment | Customized gas mixer. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $900 |
| | Equipment | Customized gas-liquid separator. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $950 |
| | Equipment | Danfoss condenser. Quantity: 2 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $1,600 |
| | Equipment | Fisherbrand Maxima rotary vane vacuum pump. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $1,930 |
| | Equipment | OMEGA HX85BA hygrometer. Quantity: 2 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $1,900 |
| | Equipment | Swagelok diaphragm valves. Quantity: 5 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | | $1,930 |
| | Equipment | Membrane contactors for CO2 separation. Quantity: 5 | Fabrication of CO2 separation contactors using the FTHMs for in-lab tests and field tests | | | | | | $6,000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Equipment | Omega absolute pressure transducer. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | | | | | $893 |
| | Tools and Supplies | Chemicals and general laboratory supplies and consumables. Quantity: N/A | Synthesis of MOFs and polymers needed for FTHM fabrication | | | | | $30,000 |
| | | | | | | | **Sub Total** | **$92,963** |
| **Capital Expenditures** | | | | | | | | |
| | | Maxwell Robotics UB-201-X control system. Quantity: 1. | Build-up of gas sorption test facility for membranes | X | | | | $15,000 |
| | | ThermoFisher TRACE gas chromatography (GC) analyzer. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | X | | | | $15,000 |
| | | Micro Motion ELITE mass flow meter and transmitter. Quantity: 1 | Build-up of the test facility for membrane contactors for CO2 separation | X | | | | $15,000 |
| | | | | | | | **Sub Total** | **$45,000** |
| **Acquisitions and Stewardship** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel In Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel Outside Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Printing and Publication** | | | | | | | | |
| | Publication | Open access publication fee. Quantity: N/A | Disseminating the work and make our results publicly available. | | | | | $4,000 |
| | | | | | | | **Sub Total** | **$4,000** |
| **Other Expenses** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Scientific Services. Quantity: N/A | Characterization of materials synthesized in this project (MOFs and membranes) at the UMN Characterization Facility and UMN Polymer Characterization and Processing Facility. | | | | | $36,000 |
| | | | | | | | **Sub Total** | **$36,000** |
| | | | | | | | **Grand Total** | **$1,150,000** |

## Classified Staff or Generally Ineligible Expenses

| Category/Name | Subcategory or Type | Description | Justification Ineligible Expense or Classified Staff Request |
| --- | --- | --- | --- |
| **Capital Expenditures** | | Maxwell Robotics UB-201-X control system. Quantity: 1. | The Maxwell Robotics UB-201-X control system, as the system controller, is an indispensable for the gas sorption test facility. The UB-201-X is an embedded Linux computer system with a touch screen interface. It coordinates all system functions, such as gas flow sequencing, pressure control, temperature control, etc.<br>**Additional Explanation :** The Maxwell Robotics UB-201-X control system is an indispensable part of the gas sorption test facility. It will be used as long as the gas sorption test facility is used for testing $CO_2$ sorption. |
| **Capital Expenditures** | | ThermoFisher TRACE gas chromatography (GC) analyzer. Quantity: 1 | Gas chromatography (GC) analyzer is used to separate and quantify each compound in a gas mixture. We will use it to analyze the downstream flow after the membrane contactor. It is a necessary piece of instrument for the test facility.<br>**Additional Explanation :** The GC analyzer will stay with the test facility for membrane contactors. The test facility will be used continuously for measuring the performance of various membrane contactors for $CO_2$ separation. |
| **Capital Expenditures** | | Micro Motion ELITE mass flow meter and transmitter. Quantity: 1 | The mass flow meter is necessary for measuring the mass flow rate of separated $CO_2$ flow in the test facility for membrane contactors for $CO_2$ separation. We will need this quantity to derive the effectiveness of $CO_2$ separation by the membrane contactor.<br>**Additional Explanation :** The mass flow meter is an indispensable part of the test facility for membrane contactors for $CO_2$ separation. It will be continuously used for the same kind of research. |

## 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 | $488,888 |
| | | | **Non State Sub Total** | **$488,888** |
| | | | **Funds Total** | **$488,888** |

**Total Project Cost: $1,638,888**

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

Yes

# Attachments

## Required Attachments

*Visual Component*

File: 8672ac73-37a.pdf

*Alternate Text for Visual Component*

Summary chart to demonstrate the project plan...

## Supplemental Attachments

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

| Title | File |
|---|---|
| 3M Letter of Support | 74ce1e2d-fde.pdf |
| University of Minnesota Authorization Letter | 03e435fd-20a.pdf |

# Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**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?**

Yes

**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")?**

No

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

N/A