Environment and Natural Resources Trust Fund

M.L. 2026 Draft Work Plan

General Information

ID Number: 2026-384

Staff Lead: Noah Fribley

Date this document submitted to LCCMR: December 29, 2025

Project Title: Alleviating PFAS Impacts of Biosolids on Agricultural Lands

Project Budget: $300,000

Project Manager Information

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Project Reporting

Reporting Schedule: April 1 / October 1 of each year.

Project Completion: June 30, 2029

Final Report Due Date: August 14, 2029

Legal Information

Legal Citation:

Appropriation Language:

Appropriation End Date: June 30, 2029

Narrative

Project Summary: This project aims to monitor the impacts of PFAS-containing biosolids on farmland health and beneficial agricultural microbial species and develop a cost-effective PFAS bio-treatment method for remediating affected agricultural soil.

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

Biosolid fertilizers derived from treated sewage sludge in wastewater treatment plants are significant sources of Per- and Polyfluoroalkyl Substances (PFAS), and their applications have led to the contamination of 70 million acres of U.S. farmland with these "forever chemicals," a widely recognized term for PFAS. Although states have implemented PFAS biosolid strategies to regulate the land application of biosolids and prevent PFAS spread, managing affected biosolids in accordance with state regulations adds considerable costs – over 37% more than previous expenses. First, providing stakeholders with the required PFAS analysis for biosolids using Liquid Chromatography–Mass Spectrometry (LC-MS) is unreliable and expensive. This method involves complex sample processing to eliminate interference from the sample background matrix that can lead to quantification errors. This complexity hampers the timely monitoring of PFAS levels in both biosolid products and the farmlands where they are applied. Second, there is a lack of information regarding the impacts of PFAS-laden biosolids on land health. Specifically, we know very little about how PFAS affects microbial communities, which are essential for maintaining agricultural productivity. Finally, removing PFAS from contaminated biosolids or affected lands can be costly, and there is currently no reliable, low-cost method for remediating these impacted areas.

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.

New techniques need to be developed to manage the costly processes associated with PFAS biosolids in light of recently implemented state regulations, as mentioned above, and mitigate the hazardous impacts of PFAS on agricultural lands. To achieve this, we will first create a 19F Nuclear Magnetic Resonance (NMR)-based detection method for PFAS. This method will incorporate optimized NMR parameters and sample processing to enable rapid and reliable monitoring of PFAS levels in biosolids and affected farmlands. We will focus on measuring the total PFAS compounds regulated by the U.S. EPA and at regulatory levels of < 50 µg per kg of biosolids in Minnesota. To assess the impacts of PFAS biosolids on farm soil health, we will conduct a microbial community analysis. We will use a greenhouse pot design to measure and compare the microbial activities and soil properties in impacted soils with those in non-impacted areas. To treat the contaminated soils, we will explore a mycorrhizal fungi-enhanced phytoextraction method to enhance the removal of PFAS. Through combined technological development and environmental assessment, we anticipate alleviating the hazardous impacts of PFAS on agricultural lands by providing stakeholders with guidance to facilitate their decision-making processes on biosolids management.

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?

This project will develop an effective and reliable method for diagnosing PFAS in biosolids and farmland soils. By providing stakeholders with timely PFAS analytical information, we can reduce the management costs associated with PFAS biosolids and protect Minnesota's agricultural soils from contamination. While assessing the impacts of PFAS biosolids on soil health, the research will also explore an alternative, low-cost treatment method that can be further developed for field-scale PFAS treatment. The findings will offer valuable guidance to environmental regulators and farmers on how to manage the application and disposal of PFAS-laden biosolids, thereby minimizing their environmental impact.

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?

Region(s): Metro, Central,

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Creating a reliable and affordable 19F NMR method for diagnosing total PFAS in biosolids and farmland soils.

Activity Budget: $95,338

Activity Description:
This task will develop a reliable and cost-effective 19F NMR method to quantify total PFAS levels in biosolids and farm soils, thereby facilitating compliance with PFAS regulations for environmental agents and farmers. Compared to the standard LC/MS method, which costs approximately $200 per sample, our NMR approach will significantly reduce costs, enhance throughput, and eliminate quantification errors from sample processing and background matrix interferences. Our previous research has demonstrated the robustness of NMR in quantifying PFOA and Crotonic PFCA (see attachment Pub 1,2). Here, we will further optimize and expand its application to other PFAS species identified in the U.S. EPA regulations. We will optimize NMR parameters and sample processing methods, and acquire F-19 spectra using the Bruker Advance III HD 400 MHz equipped with a SampleXpress autosampler at the University of Minnesota facility. With these optimizations, we wish to expand the limit of quantification of total PFAS to the microgram per liter (µg/L) level, which is required for soil sample analysis. The results from NMR quantification will be validated and systematically compared with those from LC/MS. With the established procedures, samples from local suppliers and farms will be examined for their total PFAS levels.

Activity Milestones:

Description	Approximate Completion Date
Optimize the 19F NMR parameters for detecting low-tier U.S. EPA regulated PFAS chemicals	December 31, 2026
Contact the farmland owners for soil sample collection for research-only purposes	December 31, 2026
Test sample processing methods for PFAS quantification in mocking soil samples	March 31, 2027
Provide the analytical information of the PFAS tiers in biosolids from local suppliers (deliverables)	June 30, 2027
Provide the analytical information of the PFAS tiers in local farmland soils (deliverables)	July 31, 2027
Submit paper for publishing: "A 19F NMR method for diagnosing PFAS levels in biosolids" (deliverables)	December 31, 2027

Activity 2: Assessing the impacts of PFAS biosolids on soil health and microbial activities in farmland.

Activity Budget: $102,127

Activity Description:
This task aims to assess the impacts of applying PFAS-containing biosolids on farm soil health by monitoring the dynamic changes in soil properties and microbial communities across various levels of PFAS contamination. To achieve this goal, we plan to design a greenhouse “corn pot” to mimic the soil environment of agricultural land, which will be subjected to biosolid treatments containing different levels of PFAS mixture of legacy PFASs. We expect this design to allow us to test the compound factors of biosolid and PFAS. With this design, the changing PFAS will be introduced along with biosolids as a single dependent variable, while the other factors, such as fertilizer, climate, and soil medium, will be held constant as invariants. We will focus on testing the impacts of PFAS on corn soil due to its economic significance to Minnesota and the ease of corn cultivation from seed to harvest. We will conduct analyses of soil properties and microbial communities in collaboration with the University of Minnesota Soil Testing Laboratory and Genomics Center. By combining the corn phenotypic tests, we aim to explore how PFAS biosolids have influenced the soil properties and microbial communities, thereby affecting soil productivity.

Activity Milestones:

Description	Approximate Completion Date
Growing the corn pot spiked with PFAS biosolids in greenhouse	December 31, 2027
Accomplish the soil PFAS and soil property analysis for the corn pot	December 31, 2027
Extract microbial DNA and analyze the microbiome in respond to PFAS in corn pot	March 31, 2028
Profile PFAS metabolomics from the biosolid-impacted pot soils.	June 30, 2028
Data compilations to discover the PFAS impacts on soil health and microbial communities	December 31, 2028
Paper write-up and submission for activity 2 (deliverables)	February 28, 2029

Activity 3: Developing a mycorrhizal fungi-enhanced phytoextraction method to treat PFAS-laden biosolids

Activity Budget: $102,535

Activity Description:

This task aims to explore an alternative remedial method that can leverage the synergistic action of arbuscular mycorrhizal fungi (AMF) and phytoextraction to enhance the PFAS-remediating efficiency of impacted soils. The proposed research will primarily focus on the greenhouse study for exploring the synergies between AMF and hemp plants in removing soil PFAS. We plan to test the co-culture effects of industrial hemp Cannabis sativa L. and its partner AMF Rhizophagus aggregatus BM-3 or Rhizophagus prolifer PC2-219F due to their well-known symbiotic relationships. To evaluate the phytoextraction efficiency, the above- and below-ground plant biomass will be harvested to quantify PFAS with NMR and calculate the bioconcentration factor (BCF), separately, relative to the control soil pots (i.e., 0 µg PFAS). BCF will be compared between the hemp/AMF co-culture and hemp-only treatments to assess the synergic effects on PFAS remediation. We will also collaborate with Dr. Yujie Men at the University of California, Riverside, to characterize the transformation products of AMF/hemp through LC/HR-MS. Through this research, we aim to provide an alternative phytoextraction method that can be further developed and scaled up for future field applications, thereby advancing the remediation of PFAS-polluted farm soils.

Activity Milestones:

Description	Approximate Completion Date
Test Mycorrhizal fungal species growth on PFAS chemicals	June 30, 2027
Test the capacities of Mycorrhizal fungal species to absorb and transform PFAS chemicals	September 30, 2027
Establish the AMF/hemp co-culture in greenhouse pot	March 31, 2028
Test the performance of AMF/hemp in removing biosolid PFAS in a soil pot setup	December 31, 2028
Accomplish PFAS, AMF and plant physicochemical analyses.	March 31, 2029
Submit paper for publication: "The mycorrhizal fungi enhance phytoremediation of PFAS" (deliverables)	May 31, 2029
Accomplish final data compilation and project write-up.	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Yujie Men	University of California, Riverside	PFAS transformation products' characterization	No
Dr. Corbin Dirkx	University of Minnesota Genomics Center	Microbiome & GBS Services; Microbial Community Sequencing.	No
Dr. Timothy J. Griffin	Center for Metabolomics and Proteomics, University of Minnesota	PFAS and metabolite analysis	No

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.
We will reach out to environmental regulators and farmers, providing them with a fast and effective method for diagnosing PFAS in biosolids and farmland soils. By providing stakeholders with timely PFAS analytical information, our goal is to reduce the management costs associated with PFAS biosolids and protect Minnesota's agricultural soils from contamination. In addition, we will provide information to stakeholders for monitoring the impacts of PFAS biosolids on soil health and to develop a low-cost treatment method to remove PFAS from affected soils. The findings will be disseminated not only to environmental regulators and farmers, but also to professional researchers through publications and presentations at relevant journals and conferences. We will ensure that the Environment and Natural Resources Trust Fund is acknowledged through the use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications, per the ENRTF Acknowledgment Guidelines.

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?
We will pursue the real-world applications of the 19F NMR-based PFAS forensic analysis to monitor PFAS levels in biosolids and affected farmlands. This technique can be further developed to assess PFAS levels in other regulated products and environments as outlined in Minnesota’s PFAS Blueprint. We will leverage the results of this research to seek funding from upcoming LCCMR programs, DoD-funded SERDP & ESTCP programs, or NSF-SBIR to develop the field-scale applications for PFAS treatment. The future funding will not only enable us to establish field applications but also help investigate additional mechanisms involved in the bioremediation of PFAS.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
PFAS Fungal-Wood Chip Filtering System	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 08f	$189,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Lead PI - summer salary only		Direct all research and personnel, conduct analysis			36.6%	0.42		$68,145
Postdoc		Conduct research, data interpretation, and result dissemination			25.9%	2.4		$195,626
							Sub Total	**$263,771**
Contracts and Services								
U of Minnesota	Internal services or fees (uncommon)	Microbial community sequencing at UMN Genomics Center (UMGC)				0		$4,000
U of Minnesota	Internal services or fees (uncommon)	NMR tests at the Dept. of Chemistry				-		$2,000
Yujie Meng's lab at U of California, Riverside	Service Contract	PFAS and transformation products quantification and characterization by MS		X		0		$4,000
							Sub Total	**$10,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Task 1: Chemicals, PFAS, NMR tubes, falcon tubes, dishes, flasks, and other lab consumables for measuring NMR	To create the 19F NMR method to quantify the PFAS levels in biosolids and farm soils.					$6,029
	Tools and Supplies	Task 2: Supplies used for greenhouse cultivation; Molecular reagents and DNA extraction kits used for extracting microbial DNA for community sequencing; PFAS processing reagents.	To grown corn plant in soil pot and analyze the microbial communities and soil properties impacted by PFAS biosolids.					$8,100
	Tools and Supplies	Task 3: Chemicals, PFAS, dishes, flasks, and other lab consumables for growing fungi and plants; PFAS	To develop the mycorrhizal fungi-enhance phytoremediation of PFAS from soils.					$8,100

		processing reagents for testing fungal removal rates of PFAS.						
							Sub Total	**$22,229**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication fee in professional journals at Year 2	To disseminate research results: An 19F NMR method for diagnosing PFAS levels in biosolids and impacted soils					$2,000
	Publication	Publication fee in professional journals at Year 3	To disseminate the research results: The mycorrhizal fungi enhance phytoremediation of PFAS					$2,000
							Sub Total	**$4,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$300,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Contracts and Services - Yujie Meng's lab at U of California, Riverside	Service Contract	PFAS and transformation products quantification and characterization by MS	This is purchased for the lab service from out-of-state, as the analysis will rely on the collaborator's knowledge and expertise at UC-Riverside in using HR-MS for PFAS analysis, which in-state services can not accomplish.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Waived UMN overhead	Waived UMN overhead	Secured	$165,000
			Non State Sub Total	**$165,000**
			Funds Total	**$165,000**

Total Project Cost: $465,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: a4bfbaca-053.pdf

Alternate Text for Visual Component

PFAS in biosolids are polluting agricultural lands, and their management requires new, cost-effective solutions. This project aims to address the impacts of PFAS in biosolids by developing an affordable and reliable diagnostic method, monitoring the impacts of PFAS on farm soil health, and providing an alternative fungal-facilitated treatment solution....

Supplemental Attachments

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

Title	File
Pub 1	7fa36efb-d47.pdf
Audit	e855411d-13b.pdf
Support letter from UMGC	93c667cf-9aa.doc
UMN authorization letter for submission_2026_384	eaad9d88-9d5.pdf
Pub 2	fd3690c7-da3.pdf
Support letter from CMSP	f5abb7ba-dc0.doc
Support letter from UC, Riverside	f7d5f249-b89.pdf
Revised Research Addendum_2026-384_Zhang_Fina	03d1dbe1-090.docx

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

No significant changes have been made.

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?

N/A

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 project:

Wendy Moylan, accountant at the Department of Bioproducts and Biosystems Engineering at U of Minnesota

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

Yes, I understand