Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-614

Proposal Title: Watershed-Scale Evaluation of Conservation Drainage Using Machine Learning

Project Manager Information

Name: Warren Formo

Organization: Minnesota Agricultural Water Resource Center

Office Telephone: (952) 237-9822

Email: warren@mawrc.org

Project Basic Information

Project Summary: This multi-year project will develop a watershed-scale tool to evaluate conservation drainage performance, enabling comprehensive, system-level assessment of storage efficiency, connectivity, resilience, and long-term impacts on soil and water resources.

ENRTF Funds Requested: $765,000

Proposed Project Completion: August 31, 2029

LCCMR Funding Category: Water (B)

Project Location

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

Region(s): SE, SW,

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.

Agriculture in the Midwest is increasingly exposed to climate volatility, with intensifying rainfall events, hailstorms, and prolonged droughts threatening productivity, farm viability, and regional economic vitality. In 2019, excessive spring precipitation across the Mississippi River Valley inundated nearly 20 million acres of farmland, preventing planting and causing major economic losses, while by 2023 severe drought contributed to more than $16 billion in crop losses nationwide. These extremes underscore the urgent need for adaptive water management strategies.

In Southern Minnesota, poorly drained soils and shallow water tables are widespread, and over half of agricultural land is tile-drained, a figure that continues to grow. Subsurface drainage is critical for crop production, improving trafficability, and yields by lowering water tables. Conservation drainage practices add benefits by retaining water, reducing nutrient losses, and increasing resilience to drought and heavy rainfall.

However, no standardized watershed-scale framework exists to evaluate the hydrologic, environmental, and economic performance of these projects across entire systems. Current assessments focus on individual sites, limiting understanding of cumulative impacts, climate resilience, and return on investment. This proposal develops a watershed-scale tool to assess how conservation drainage influences water storage, nutrient transport, and overall watershed resilience under changing climate conditions.

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.

This project will create a watershed-scale decision-support tool for conservation drainage that integrates field monitoring, remote sensing, economic analysis, and machine learning to evaluate system performance, resilience, and efficiency. Beyond peak-flow metrics, it will assess buffer capacity, storage surpluses and deficits, downstream channel exceedance, sensitivity to extreme rainfall, and redundancy across distributed storage.

Over two years, the team will collect hydrologic, water quality, spatial, and economic data, including soil moisture, groundwater levels, flows, nutrient loads, rainfall, landscape characteristics, costs, and landowner participation rates. Economic indicators such as cost per nutrient removed, cost per acre-foot stored, flood reduction benefits, maintenance burden, and adoption trends will inform scalability and long-term performance. Sites will leverage multiple practices and existing monitoring supported by other funding sources. Discovery Farm project results will be used to enhance project outcomes.

Machine learning will strengthen the watershed-scale evaluation framework by detecting drainage features and hydrologic connectivity from remote sensing and geospatial datasets, emulating computationally intensive hydrologic models for rapid scenario testing, and identifying nonlinear storm-response dynamics. These capabilities support efficient performance assessment across varying climate and land-use conditions, inform optimal siting of conservation practices, estimate environmental benefits, and enable fast, data-driven watershed resilience analysis.

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 will generate watershed-scale data and predictive models to quantify drainage storage efficiency, nutrient reduction, channel stability, and system resilience across varying climate and landscape conditions. By identifying storage deficits, channel exceedance risks, and erosion-prone areas, the tool will support protection of soil, surface water, and groundwater resources. Integrated economic and adoption analyses will identify practices that deliver the greatest environmental return per dollar invested. These outcomes will increase awareness of conservation drainage benefits among the agriculture stakeholders, clarify which practices perform best under specific conditions, and provide a data-driven framework to guide decisions and promote broader adoption.

Activities and Milestones

Activity 1: Conduct field monitoring and assemble similar data from existing Discovery Farm projects to gather comprehensive data on hydrology, water quality,

Activity Budget: $344,564

Activity Description:
The objective of this activity is to develop a multi-year dataset to evaluate hydrologic performance, water quality outcomes, and economic feasibility across conservation drainage projects implemented under varying landscape and management conditions. By integrating continuous flow monitoring, water quality sampling, spatial analysis, and cost data, the project will generate system-level evidence on drainage storage efficiency, nutrient and sediment reduction, and overall performance. Existing Discovery Farm project data from similar projects will be assembled for integration into the complete data set.

Hydrologic instruments and water sampling will collect data on flow, storage, soil moisture, and nutrient/sediment loads under different conditions. GIS and economic data will be used to analyze watershed characteristics, cost-effectiveness, and adoption factors. All data will be integrated to generate performance metrics and decision-support tools.

The project will produce a comprehensive dataset, estimates of load reduction, cost-effectiveness analyses, and cross-site comparisons. This dataset will support machine learning and predictive modeling to evaluate system performance, identify key drivers of efficiency and resilience, and improve forecasting. Outcomes will be evaluated based on data quality, strength of cross-site comparisons, and predictive accuracy of the developed models.

Activity Milestones:

Description	Approximate Completion Date
Collect baseline data for all sites	September 30, 2027
Source, procure, monitoring equipment	October 31, 2027
Install monitoring equipment	October 31, 2027
Ongoing data collection for 2 years	August 31, 2029
Compile and quality-check datasets	August 31, 2029

Activity 2: Remote Sensing and Machine Learning Assessment of Landscape Drainage Features

Activity Budget: $76,131

Activity Description:
This activity aims to identify landscape-scale drainage features like hydrologic connectivity and already established conservation drainage practices by using inverse modeling (ML) and remote sensing, to assess conservation drainage performance and system resilience. Directly identifiable landscape features such as channelized streams and land cover changes will be identified using measurable attributes from aerial and satellite imagery, including spectral signatures, geomorphic forms, and vegetation indices. Foundation models will be fine-tuned to map channelized streams, wetland modifications, and land use changes, while analyzing spatial patterns to estimate hydrologic connectivity and its effects on runoff, sediment, and nutrients. Subsurface tile drainage will be inferred using geospatial data, with ML models generating probabilistic maps to improve watershed characterization.

Thus, this step will provide spatial datasets of channelization, land use change, and probable tile drainage locations, along with quantitative connectivity metrics across the watershed. These datasets will be used to feed predictive modeling and the watershed-scale evaluation tool, improve understanding of storage efficiency, nutrient reduction, and

resilience, and support informed conservation drainage decisions. Outcomes will be evaluated through model validation against field data and their utility in guiding tool development and watershed management strategies.

Activity Milestones:

Description	Approximate Completion Date
Inverse modeling drivers, response, and aerial imagery data collection	September 30, 2027
Data organization, ground truthing and data labeling for foundational model	December 31, 2027
Inverse modeling, training, and evaluation	August 31, 2028
Foundational modeling, training, and evaluation	August 31, 2029

Activity 3: Process-based modeling for Hybrid and Targeted Machine Learning Watershed Processes

Activity Budget: $95,985

Activity Description:
This activity will develop physical process-based hydrologic model for simulating the complex controlled drainage practices and processes which will be used for developing rigorous and representative datasets for ML. The input/output datasets will be generated through exercising various possible combinations of climate, soil types, practice and bench geometry, and drainage spacing etc. Thus, a representative watershed model will be developed to simulate scenarios spanning variations in land use, drainage networks, and climate conditions. Outputs from these simulations will generate training datasets for a machine learning emulator capable of approximating the model's behavior. Once trained, the ML emulator will act as a surrogate model, which can rapidly evaluate new scenarios in seconds, a process that would otherwise require hours or days in a fully distributed physically based framework. This approach enables fast, system-level assessment of conservation drainage performance and watershed resilience. In parallel, non-complex processes such as bank erosion during storm events will directly be modeled using ML utilizing direct ground-truth observations collected in 1st activity which includes rainfall intensity, storm duration, antecedent soil moisture, and observed discharge. This will provide the ability to identify peak discharge responses and erosion-prone locations without requiring full watershed-scale simulation.

Activity Milestones:

Description	Approximate Completion Date
Data Organization for physical-based model	August 31, 2027
Process-based model development (3 practices)	August 31, 2028
Calibration and Validation of the process-based model	May 31, 2029
Scenario generation across various datatypes and combinations	August 31, 2029

Activity 4: Designing/Developing a watershed-scale evaluation tool utilizing integrated ground-truth hydrologic, environmental, and economic performance metrics and stakeholder input

Activity Budget: $102,138

Activity Description:
The ultimate objective is to design and implement the watershed-scale evaluation tool using outputs from machine learning analyses and stakeholder input. The data collected/generated from the former activities, i.e., integrated hydrologic, environmental, geomorphologic ground-truth datasets corresponding to the various processes and preestablished conservation drainage practices, input/output data generated through process-based modeling, and the inventory of practices identified or estimated using Activity 2 will now be used to develop a multimodal ML model, which would then be used to develop watershed-scale drainage performance assessment tool. The tool developed

during this phase will enable users to simulate management scenarios across different counties, compare practices, evaluate system performance like resilience and storage efficiency, and support informed adoption and planning decisions. Iterative prototyping and testing will ensure technical accuracy, usability, and applicability for agencies and landowners. The expected outputs of this project would include an ML emulator for rapid scenario evaluation, a detection framework for spatial identification of erosion-prone reaches, and predictive datasets linking land use, drainage network, and climate to system responses. These results will support development of the watershed evaluation tool, enhance understanding of hydrologic and geomorphic behavior, and provide actionable guidance for planning, management, and adoption of effective conservation

Activity Milestones:

Description	Approximate Completion Date
Dataset Organization and multimodal emulator architecture development	February 28, 2029
Multimodal emulator training and evaluation	August 31, 2029
Model deployment	August 31, 2029

Activity 5: Stakeholder Engagement, Training, and Demonstration of the Evaluation Tool

Activity Budget: $146,182

Activity Description:
This activity will translate project findings into practical application by sharing results with stakeholders and demonstrating the use of the watershed-scale evaluation tool to support drainage planning and management decisions. Project results will be synthesized into clear, decision-oriented materials tailored to landowners, watershed managers, agency staff, and conservation professionals.

Workshops and technical training sessions will be conducted to present findings and provide hands-on demonstrations of the tool's functionality. Participants will be guided through scenario testing, interpretation of model outputs, and application of results to real-world drainage planning questions. Case studies from monitored sites will illustrate how remote sensing, hybrid modeling, and machine learning outputs inform assessments of resilience, buffer capacity, and cost-effectiveness.

To ensure long-term usability, user guides, technical documentation, and recorded training modules will be developed and distributed. Structured feedback from participants will be collected to refine tool features, improve clarity of outputs, and strengthen alignment with practitioner needs.

Activity Milestones:

Description	Approximate Completion Date
Development of outreach and training materials	August 31, 2029
Provide 4 stakeholder workshops and applied demonstrations	August 31, 2029
Adoption Support and Feedback Integration	August 31, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Joe Magner	University of Minnesota	Lead machine learning development, including model design, training, and analysis to identify impacts of drainage features and support watershed-scale assessment.	Yes
Julie Blackburn	I &S Group Inc	Project coordination, water quality/economic analysis, model validation and verification, educational materials and programming lead	Yes
Michael Schultz	Le Sueur SWCD	Outreach and landowner meetings and workshops	No
Jerad Bach	Blue Earth SWCD	Outreach and landowner meetings and workshops	No
name needed	Lake Washington Association	Water quality assessment project sites and outreach	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.
Workshops and technical training sessions will be conducted to present findings and provide hands-on demonstrations of the tool's functionality. Participants will be guided through scenario testing, interpretation of model outputs, and application of results to real-world drainage planning questions. Case studies from monitored sites will illustrate how remote sensing, hybrid modeling, and machine learning outputs inform assessments of resilience, buffer capacity, and cost-effectiveness.

To ensure long-term usability, user guides, technical documentation, and recorded training modules will be developed and distributed. Structured feedback from participants will be collected to refine tool features, improve clarity of outputs, and strengthen alignment with practitioner needs.

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?
Project results will be implemented by sharing the watershed-scale evaluation tool, datasets, and practice guidance with watershed districts, county drainage authorities, and state agencies to inform conservation drainage planning and management. Findings will be disseminated through workshops, technical documents, and online platforms to support adoption by producers and planners. Ongoing use and updates will be supported through integration with agency programs. Results will also be published in a scientific journal and presented at scientific conferences.

Project Manager and Organization Qualifications

Project Manager Name: Warren Formo

Job Title: Executive Director

Provide description of the project manager's qualifications to manage the proposed project.
Warren Formo has served as Executive Director of the Minnesota Agricultural Water Resource Center since 2008. In this role he serves as a liaison between farmers, farm organizations, and local, state, and federal agencies involved in agriculture. The MAWRC connects more than 50,000 ag professionals with environmental research and helps identify

practical water quality solutions for farmers. The MAWRC is also the lead partner in the Minnesota Discovery Farms Program, an edge-of-field water monitoring program developed to provide detailed information on nutrient and sediment movement from farm fields. Warren attended the University of Minnesota, where he received a Bachelor of Science degree in agricultural education.

As an Executive Director, Warren has extensive experience managing collaboratively, in producer-focused initiatives, including multiple watershed-scale projects and water quality assessments across Minnesota. His work has focused on evaluating nutrient dynamics, soil health, and conservation practices within diverse agricultural systems, with an emphasis on translating findings into practical, on-farm solutions.

As Project Manager Warren, will oversee the project execution, partner coordination, and dissemination of results, ensuring alignment with farmer needs and MAWRC's mission to improve water quality while supporting productive agriculture.

Organization: Minnesota Agricultural Water Resource Center

Organization Description:
The Minnesota Agricultural Water Resource Center is a non-profit research and education organization that works with farmers across Minnesota to address water quality issues. We are a farmer-led organization dedicated to science-based solutions and environmental innovation. We conduct numerous farmer-focused educational events each year, and are the primary partner in the Discovery Farms Program in Minnesota, an edge of field water monitoring program conducted in partnership with farmers, local conservation professionals, and the Minnesota Department of Agriculture.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Tim Radtz		Project Manager			0%	0.45		$24,000
Warren Formo		Project Coordinator and Principal in Charge			0%	0.21		$12,000
							Sub Total	**$36,000**
Contracts and Services								
Rose Mumbi	Subaward	Soil Scientist will be responsible for research design and field data monitoring, data synthesis, and manuscript review and editing and support model integration, model testing and verification, training, and outreach.				1.08		$81,590
I & S Group staff	Subaward	Staff will provide long term field monitoring, maintenance, and troubleshooting, of hydrologic instruments				0.8		$81,940
I & S Group	Subaward	Develops educational handouts and materials for workshops and assists in in-person workshops, and surveys				0.2		$17,680
Julie Blackburn	Subaward	The consultant will advise on field implementation and support data review, model testing and verification, training and outreach, and overall project quality assurance.				0.27		$29,290
Joe A Magner	Subaward	Professor at University of Minnesota will oversee field & lab operations, model creation, verification, and testing, and advise on training and outreach programs.				0.6		$12,793
John Nieber	Subaward	Professor at University of Minnesota to provide support in hydrologic modelling				0.54		$12,793
Post Doctoral Associate	Subaward	Machine learning and evaluation tool development and preparation for publication				3		$134,417
Graduate Student 1	Subaward	Data collection, sorting, and modeling support				1		$114,457
Undergraduate 1	Subaward	Will assist with data organization and curation.				0.25		$3,000
TBD Lab sample analysis	Service Contract	Lab Services				0		$146,700

							Sub Total	**$634,660**
Equipment, Tools, and Supplies								
							Sub Total	**-**
Capital Equipment								
		Automated Water Samplers (4)	Collecting continous water quality data from project sties.	X				$32,000
		Flow meters and sensors (4)	Flow meters and sensors will be used to determine flow weighted mean concentrations of water quality data to account for loading under varying flow conditions.	X				$32,000
							Sub Total	**$64,000**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travel to project sites for sampling and maintenance; Estimate 26 trips	Travel for sampling, installation, and maintenance of equipment					$18,240
	Miles/ Meals/ Lodging	Mileage for travel for 4 training events	Travel for 4 MN regional stakeholder workshops and training events					$4,000
							Sub Total	**$22,240**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	Two domestic conference trips for 1–2 participants	Present results of LCCMR-funded work at nationally relevant conferences	X				$7,500
							Sub Total	**$7,500**
Printing and Publication								

	Printing	Outreach, training, and educational materials	Provide adequate trainng on new approach to evaluating projects.					$600
							Sub Total	**$600**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$765,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Equipment		Automated Water Samplers (4)	The cost is over $5000 and the equipment will be used throughout the entire project period. **Additional Explanation :** All sites will be monitored throughout the entire project timeframe and into the future through the same program.
Capital Equipment		Flow meters and sensors (4)	The cost is over $5000 and the equipment will be used throughout the entire project period. **Additional Explanation :** All sites will be monitored throughout the entire project timeframe and into the future through the same program.
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	Two domestic conference trips for 1–2 participants	Plan to attend American Society of Agricultural and Biological Engineers (ASABE) and Conservation Drainage Network (CDN) conferences to present results of this ENRTF-funded work

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	I & S Group, Inc. (dba ISG, Inc.)	Use of computer, office, and vehicles for monitoring, meetings, coordination, and training.	Secured	$10,000
In-Kind	I & S Group, Inc. (dba ISG, Inc.)	Marketing Personnel for graphics, materials, and project support.	Secured	$10,000
			Non State Sub Total	**$20,000**
			Funds Total	**$20,000**

Total Project Cost: $785,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 9f7f97da-a8d.pdf

Alternate Text for Visual Component

This is a visual abstract of the anticipated project on a watershed scale....

Financial Capacity

Title	File
Tax Statement	c771289a-fd7.pdf
Certificate of Good Standing	909ea222-a95.pdf

Board Resolution or Letter

Title	File
MAWRC Organizational Authorization	ed810c21-53c.pdf

Supplemental Attachments

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

Title	File
Conservation Drainage Graphics	76cbd1da-318.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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 Commissioner's Plan applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

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:

Julie Blackburn and Rose Mumbi from ISG, Inc., Shubham Aggarwal and Joe Magner, University 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