Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-325

Proposal Title: Forecasting Minnesota Natural Hazards by Geospatial Intelligence Model

Project Manager Information

Name: Qizhi He

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Minnesota-calibrated geospatial artificial intelligence framework that integrates statewide satellite, hydrologic, and geologic data to map and forecast landslide and flood hazards and support early warning systems.

ENRTF Funds Requested: $516,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Resiliency (A)

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.

Minnesota is often characterized as a low-relief landscape; however, many regions contain steep slopes formed in weak, unconsolidated glacial sediments, particularly along river valleys, bluff systems, and coastal watersheds. These areas are prone to slope instability, and increasing frequency and intensity of heavy rainfall have elevated the likelihood of rainfall-triggered landslides. Meanwhile, flood hazards are intensifying due to changing precipitation patterns and hydrologic conditions. Landslides and floods are closely linked hazards: flood-driven streambank erosion can destabilize slopes, while landslides deliver sediment to rivers and lakes, degrading water quality, damaging infrastructure, and impacting ecosystems. Previous LCCMR-funded research (ENRTF ID: 2017-013-A) produced the first comprehensive landslide inventory across landslide-prone portions of the state and identified key factors controlling slope instability. However, existing analyses largely provide static susceptibility maps that identify where hazards may occur but do not forecast when they are likely to be triggered during extreme rainfall events. Moreover, flood and landslide forecasting models are typically developed independently, underestimating interactions between these processes. This proposal addresses this gap by developing a Minnesota-calibrated, AI-enabled geospatial modeling framework to support integrated flood–landslide hazard assessment, forecasting, and early-warning for climate resilience planning, while strengthening decision-support tools for emergency management and natural resource protection.

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 seek funding to develop and implement an integrated, AI-enabled geospatial modeling framework for assessing and forecasting landslide and flood hazards across Minnesota. The framework will leverage modern artificial intelligence (AI) and pretrained satellite-based Earth observation models—known as foundation models—to analyze relationships among terrain, hydrology, climate, and hazard occurrence. By integrating these models with Minnesota-specific geospatial datasets, the project will develop a hazard prediction system capable of identifying both where hazards are likely to occur and when they may be triggered during extreme rainfall events. The project includes three main components. First, we will build the Minnesota Geospatial Hazard Database by compiling and integrating multi-source datasets related to landslides and floods, including topography, land cover, precipitation, and hydrologic observations. Second, we will adapt and fine-tune a foundation model to capture Minnesota-specific geomorphic, hydrologic, and climatic conditions. Third, the model will be validated using landslide inventories and applied to assess rainfall-triggered landslide and flood hazards across Minnesota. The framework will be used to forecast hazard conditions during extreme rainfall events and evaluate how precipitation intensity, landslide magnitude, and event frequency may change under future climate scenarios, supporting multiple hazards monitoring and early-warning systems.

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?

A major outcome will be an open-source, Minnesota-calibrated geospatial modeling framework to support statewide assessment and forecasting of landslide and flood hazards. Besides providing hazard maps, the resulting tools will forecast rainfall-triggered landslides during extreme precipitation events and evaluate how future climate conditions may influence hazard occurrence. These outcomes will help identify vulnerable landscapes, protect water resources, and prioritize mitigation, land management strategies. Project results and tools will be shared with the Minnesota Department of Natural Resources, the Minnesota Department of Transportation, watershed districts, and local emergency management organizations to support long-term hazard preparedness and natural resource protection.

Activities and Milestones

Activity 1: Build Minnesota Geospatial Hazard Database

Activity Budget: $203,323

Activity Description:
We will develop a comprehensive geospatial natural hazard dataset across Minnesota:
i) Data collection: Datasets will be compiled from previous projects (ENRTF ID: 2017-013-A), state and federal agencies (e.g., MnDOT, MN DNR, NOAA, and USGS), peer-reviewed scientific studies, and satellite remote-sensing products. These datasets include land cover, soil and geologic maps, digital elevation data, precipitation records, hydrologic observations, and landslide inventory datasets.
ii) Data standardization and preparation: The compiled datasets will be standardized to a common coordinate reference system (WGS84), clipped to the Minnesota boundary, and resampled to a consistent spatial resolution. Processed datasets will be organized into multi-band GeoTIFF files to support training and fine-tuning of a multi-hazard geospatial foundation model.
iii) Hazard labeling: Landslide and flood labels will be generated using existing inventory datasets through pixel-based classification methods.

Further statistical analyses will examine spatial and temporal patterns of topographic, hydrologic, climatic, and land-surface variables across Minnesota. These analyses will help identify areas with greater susceptibility to landslides and flooding and quantify the influence of environmental factors on hazard occurrence. In addition, an open-source computational pipeline will be developed to automate the collection, preprocessing, integration, and analysis of geospatial datasets, enabling efficient statewide multi-hazard assessment.

Activity Milestones:

Description	Approximate Completion Date
Geospatial data collection and compilation	December 31, 2027
Dataset standardization, labeling, preprocessing	March 31, 2028
Develop integrated Minnesota geospatial hazard database and statistical analyses	June 30, 2028
Open-source workflow development	September 30, 2028

Activity 2: Train AI-Enabled Hazard Prediction Models

Activity Budget: $142,309

Activity Description:
We will develop an AI-enabled model to predict landslide and flood hazards across Minnesota by adapting and fine-tuning pretrained geospatial foundation models, including NASA's Prithvi Earth observation model, with Minnesota geospatial hazard database collected and curated in Activity 1. The AI foundation models will be used as feature encoders to leverage representations learned from large global satellite datasets. Through transfer learning, the resulting AI model will be able to accurately and efficiently capture Minnesota-specific climatic and environmental conditions that influence landslide and flood hazards. The processed multi-band geospatial datasets will be converted into patch-based inputs suitable for deep learning training. The trained models will generate statewide landslide susceptibility maps, which will be compared with existing datasets for validation and benchmarking. These outputs will be integrated with precipitation and hydrologic data to support hazard prediction, short-term forecasting, and early warning assessments. Model performance will be evaluated using standard metrics including accuracy, recall, F1-score and ROC-AUC. Additional performance diagnostics will include residual analysis, error distribution assessment, and spatial performance evaluation to examine model uncertainty and prediction reliability across different regions of

Minnesota. Sensitivity analysis will also be performed to identify key environmental variables influencing hazard occurrence.

Activity Milestones:

Description	Approximate Completion Date
Implement geospatial foundation models within deep learning framework	December 31, 2028
Fine-tune pretrained models using Minnesota hazard datasets	March 31, 2029
Evaluate model performance, uncertainty, and environmental drivers	June 30, 2029

Activity 3: Landslide Mapping and Model Validation

Activity Budget: $87,548

Activity Description:
This activity will evaluate the landslide susceptibility maps developed in Activity 2, investigate the hydrologic conditions that trigger landslides in Minnesota, and develop rainfall threshold models to support landslide hazard prediction. Historical landslide inventory data compiled by Co-PI Gran and collaborators, together with recently documented landslide events, will be used to assess model accuracy and predictive reliability. Model performance will also be evaluated across representative regions of Minnesota such as state highway corridors where landslides frequently occur.

Following model evaluation, machine-learning approaches will be used to develop rainfall threshold models using precipitation intensity, rainfall duration, and antecedent rainfall as input variables. These models will identify rainfall conditions associated with elevated landslide probability. The derived rainfall thresholds will be applied to spatial precipitation datasets to generate rainfall threshold exceedance maps. These maps will be integrated with the landslide susceptibility maps developed in Activity 2 to produce statewide landslide hazard maps. The resulting maps will also be compared with existing landslide hazard datasets to further evaluate model reliability and improve hazard assessment across Minnesota.

Activity Milestones:

Description	Approximate Completion Date
Compile landslide records and precipitation datasets for validation	August 31, 2029
Develop rainfall-trigger threshold models for landslides	October 31, 2029
Validate landslide forecasting model across representative regions and provide landslide hazard maps	December 31, 2029
Publication/dissemination; Document data and codes in open-access repository	June 30, 2030

Activity 4: Flood forecasting pilot demonstration in the Twin Cities

Activity Budget: $82,820

Activity Description:
This activity will demonstrate flood forecasting and early-warning capabilities using the geospatial AI framework developed in earlier activities. Building on the statewide geospatial database and modeling tools developed in Activities 1–3, this activity will focus on forecasting flood hazards in the Minneapolis–St. Paul metropolitan region. The Twin Cities area experiences recurring flooding driven by intense precipitation, urban runoff, and river overflow, particularly along the Mississippi River. These conditions make the region an ideal testbed for evaluating flood forecasting and early-warning capabilities. Short-term flood forecasts will be generated for the seven-county Twin Cities metropolitan area using the developed geospatial modeling framework. The system will integrate precipitation observations, satellite data, land-surface characteristics, river stage records, and hydrologic datasets to estimate potential flood inundation. Model

forecasts will be evaluated using historical flood observations, river stage records, and existing flood hazard datasets to assess prediction accuracy and spatial consistency. Scenario simulations will also evaluate flood hazards under extreme precipitation conditions, demonstrating how the framework can support flood preparedness and climate resilience planning in Minnesota's metropolitan region. All programming, synthetic examples, and field data will be publicly available on GitHub for broader accessibility.

Activity Milestones:

Description	Approximate Completion Date
Compile flood and hydrologic datasets for the Twin Cities metropolitan region	September 30, 2029
Validate predicted flood extent using historical flood observations	December 31, 2029
Conduct extreme rainfall scenario simulations and produce flood hazard maps	March 31, 2030
Publication/dissemination; Publish documented, reusable, open-source code to automate data acquisition, analysis, and visualization	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Karen Gran	University of Minnesota Duluth, Swenson College of Science and Engineering	Co-PI; Scientific support for hazard data collection, curation, model validation and supervise a graduate student	Yes
Andrew Wickert	U of MN - St. Anthony Falls Laboratory	Co-PI; Scientific support for hazard model design, provide supervision to postdoc and graduate students on data curation and model validation.	Yes
Robert Tipping	Minnesota Geological Survey	Provide geologic datasets, reports, and technical resources from the Minnesota Geological Survey and facilitate connections with relevant state agencies to support landslide and flood hazard 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.
To ensure project outcomes benefit Minnesota's natural resource management and reach a broad audience, results will be disseminated through scientific publications, stakeholder engagement, open data platforms, and outreach activities.

First, project findings will be shared with the scientific community through peer-reviewed publications and presentations at state, national, and international conferences, including the American Geophysical Union (AGU) and related geoscience and environmental engineering meetings. These publications will contribute to broader understanding of flood and landslide processes across Minnesota and the use of geospatial artificial intelligence for hazard forecasting.

Second, the project will engage state and regional stakeholders responsible for hazard mitigation and resource management. Hazard maps, rainfall-threshold analyses, and modeling tools will be shared with agencies including the Minnesota Department of Natural Resources (DNR), Minnesota Department of Transportation (MnDOT), watershed districts, and local emergency management offices. Webinars and technical briefings will demonstrate the developed tools and their applications for hazard monitoring, planning, and early warning.

Third, all modeling tools and datasets developed in this project will be publicly released to ensure long-term accessibility and reuse. Project data will be archived in the University of Minnesota Digital Conservancy (UDC) with persistent identifiers. Software developed under the project will be released as open-source through the PI's research group repository (https://github.com/IntelligentMechanicsLab) with documentation to support adoption by researchers and practitioners.

The Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement 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?

The modeling framework developed in this project will provide a foundation for long-term hazard monitoring and prediction across Minnesota. State agencies and watershed managers will use the resulting hazard maps and rainfall-trigger thresholds to support infrastructure planning, erosion mitigation, and emergency preparedness. The open-source computational tools developed through this project will enable the integration of additional datasets, including real-time precipitation observations and climate projections. Future work may expand the system into an operational hazard forecasting platform through partnerships with state agencies (e.g., MnDOT) and support from federal research programs such as NSF, NASA, and USGS.

Project Manager and Organization Qualifications

Project Manager Name: Qizhi He

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.

PI Dr. Qizhi He is an Assistant Professor in the Department of Civil, Environmental, and Geo-Engineering at the University of Minnesota and an affiliated faculty member with the College of Science and Engineering Data Science Initiative. His research focuses on computational modeling and artificial intelligence applications in hydrology and geosciences, with expertise in multiphysics modeling, inverse problems, and AI-enhanced numerical methods. Dr. He develops physics-informed machine learning approaches integrated with high-performance computing to improve simulation and prediction of flow processes in natural environmental systems, including applications in groundwater modeling, geohazard prediction, and environmental resilience. Before joining the University of Minnesota, Dr. He was a postdoctoral researcher at Pacific Northwest National Laboratory, where he worked on scientific machine learning for multiphysics environmental systems. He received his Ph.D. in Structural Engineering and Computational Science and an M.A. in Applied Mathematics from the University of California, San Diego. Dr. He serves on the editorial board of Computers and Geotechnics and has authored more than 25 peer-reviewed journal publications on data-driven modeling and computational mechanics, including research related to flood and landslide processes relevant to this project. His interdisciplinary expertise and experience leading computational research projects position him well to manage and successfully deliver the proposed work.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota (UMN) is one of the nation's leading public research universities, recognized for advancing knowledge and innovation in science, engineering, and environmental sustainability. This project will be conducted within the College of Science and Engineering, specifically in the Department of Civil, Environmental, and Geo-Engineering (CEGE), a nationally recognized program focused on addressing critical societal challenges related to water resources, infrastructure resilience, and environmental protection through interdisciplinary research and education.

The project will involve collaboration with the Department of Earth & Environmental Sciences at UMN and researchers at the University of Minnesota Duluth, strengthening expertise in geology, hydrology, and natural hazards. Part of this project will also be supported by the St. Anthony Falls Laboratory (SAFL), a world-renowned research center specializing in environmental and geophysical fluid mechanics. SAFL provides state-of-the-art experimental and field capabilities that support research on hydrologic processes, river systems, and environmental flows.

The project will leverage computational resources from Dr. He's Computational Intelligence and Multiphysics Simulation

Lab, located in the Civil Engineering Building and equipped with NVIDIA GPU-enabled workstations for machine learning and scientific computing. In addition, the project will utilize the Minnesota Supercomputing Institute (MSI), which provides advanced high-performance computing and data infrastructure. These combined

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Qizhi He		Principal Investigator and project manager; Oversee all project activities and manage the project, supervise grad students and postdoc to develop AI-enabled hazard modeling framework			36.6%	0.24		$47,081
Karen Gran		Co-PI; Provide landslide expertise and statewide landslide inventory data; guide interpretation of geomorphic processes, support data curation and model validation, and supervise a graduate student.			36.6%	0.12		$26,675
Andrew Wickert		Co-PI; Scientific support for model design, provide supervision to postdoc and graduate students on data curation and model validation.			36.6%	0.12		$28,064
Post Doctoral Associate		Develop and implement the Minnesota-calibrated geospatial artificial intelligence framework, integrate multi-source environmental datasets, and perform hazard prediction modeling and analysis.			26.1%	3		$249,834
Graduate Research Assistants (Benefits include 24.2% health + tuition)		Support data collection, preprocessing, model training, validation, and development of statewide landslide and flood hazard maps.			24.2%	0.93		$107,677
UMD Graduate Research Assistants (Benefits include 24.2% health + tuition)		Assist with landslide inventory compilation, geospatial data processing, and validation of landslide hazard predictions.			24.2%	0.31		$32,941
							Sub Total	**$492,272**

Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Minnesota Supercomputing Institute (MSI) high-performance computing and storage services (2 years)	Storage and processing of geospatial datasets and training of machine-learning models for flood and landslide hazard analysis.					$19,478
							Sub Total	**$19,478**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	1 to 2 trips, 1 to 2 people per year	Present results of LCCMR-funded work, outreach, and demonstration of the new capabilities of the new Minnesota hazard modeling AI tool					$1,150
							Sub Total	**$1,150**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	1 domestic conference trips for 1 person: Registration ($900); Lodging for 4 nights ($950), Flight ($600), and meals ($350).	Present results of LCCMR-funded work, outreach, and demonstration of the new capabilities of the new Minnesota's machine learning powered hazard modeling software	X				$2,800
							Sub Total	**$2,800**
Printing and Publication								

	Printing	Posters (about $100/year x 3 years)	To share results with the scientific community and the general public					$300
							Sub Total	**$300**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$516,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	1 domestic conference trips for 1 person: Registration ($900); Lodging for 4 nights ($950), Flight ($600), and meals ($350).	This travel is to participate in a formal presentation of project findings at the American Geophysical Union (AGU) conference. AGU is a major conference for natural hazard modeling-related topics. Important information can be acquired, and project outcomes can be disseminated by attending and presenting at the conference.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $516,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 0a16f017-a1c.pdf

Alternate Text for Visual Component

The graphic illustrates an AI-enabled geospatial framework for forecasting landslide and flood hazards in Minnesota. Statewide geospatial datasets—including satellite imagery, topography, precipitation, and hydrologic records—are integrated into a database and used to train a dedicated Earth observation AI model, supporting hazard prediction, forecasting, and early-warning applications across Minnesota....

Supplemental Attachments

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

Title	File
Support letter from Minnesota Geological Survey	564aff51-253.pdf
Support letter from MnDOT	ba6a6f4a-c2a.pdf
SPA letter UMN	a55c4e93-cf0.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 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?

Yes, Sponsored Projects Administration

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:

Karen Gran (Co-PI, UM Duluth), Andrew Wickert (Co-PI, U of MN - St. Anthony Falls Laboratory); Enoch Pan (CEGE Accountant) <pan00121@umn.edu>; Christina Doherty (UMN Sponsored Projects Administration) <Doher170@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