EMERGENCY MANAGEMENT USE CASE

Research Title:	**A numerical tool for risk assessment of soil slope failure to facilitate emergency management of embankments**
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Description:	**Background**: The stability and safety of geotechnical soil structures such as embankments, dams and levees are of critical importance to our society. Failure of these soil structures can cause catastrophic events. Although the safety and stability issues of soil structures will be carefully investigated during design phase, there always exists a certain level of uncertainty in our design due to the inherent variability of soil properties such as soil strength. This source of soil uncertainty can contribute to potential slope failure, especially when the structure is in face of an extreme external stressor such as a high-water event. **Research Outline:** The research presented here is an advanced numerical tool that can explicitly quantify the effect of soil variability on slope stability, where the likelihood and consequence of slope failure are estimated statistically. Generally, a larger variability of soil properties will lead to a higher likelihood of slope failure and pose a larger risk to our communities. As this Use Case is applied to multiple soil slopes and embankments with different geometries and soil properties, their likelihood of failure and failure consequence (i.e., probability of failure and risk) can be calculated. **Application:** Using the calculated probability of failure and risk for different embankments, the importance of the embankments and slopes can be ranked numerically. Thus, the numerical results for embankments of interest can facilitate prioritizing emergency management plans and activities related to embankment/dam/levee maintenance, construction, and restoration.
When Applied:	It can be used before or after an emergency/disaster happens to help prioritize maintenance, construction, and restoration of embankments/dams/levees. • For example, there are hundreds of miles of aging levees in Texas. Properly maintaining and inspecting these soil structures is time-consuming and costly. The estimated likelihood of section failure and risk of failure can help prioritize which levees or which sections of the levee should be inspected first and more frequently to ensure the levee's functionality and safety.
Who Applies:	Texas DOT; U.S. Army Corps of Engineers
Disaster Type:	Embankment failure induced flooding for levee systems; Embankment failure induced transportation system disruption.
Infrastructure Affected:	Roadway and railway embankments; earth dams; levees.
Industry Affected:	Public Transportation; Agriculture and Irrigation; Public waterworks.
Where Applied:	Anywhere embankment soil structures are used.
Agency Affected:	State and Federal Departments of Transportation; Federal Highway Administration; U.S. Army Corps of Engineers.
VOAD Affected:	NA

Who/What Affected:	The public, for example, low-land communities protected by levees against river and flooding, and suburban residents who commute frequently on embankment-supported highways, etc.
How Affected:	A proper and judicious application of the Use Case can help improve the efficiency of embankment maintenance, construction, and restoration, such that life loss and economic loss due to embankment failure can be reduced or even avoided.
Timing of Application:	The Use Case can be applied both before and after the disasters. It is suggested that the Use Case be applied at an early stage to reduce the impact of possible embankment failures.
Critical Points:	The entity applying the Use Case • Should have basic knowledge of statistics such as mean, standard deviation, and probability. • Should conceptually understand that soil has spatial variability. • Should be able to estimate soil spatial variability using soil boring data (algorithm provided in the Use Case). • Should have access to MATLAB program. • Should have fundamental engineering knowledge of soil mechanics and slope stability. • Should understand that the results produced by the Use Case are reference only, and careful decisions about the planning of embankment projects should be made by collectively considering other related information.
What Benefit:	The Use Case can identify the soil embankment structures that are more likely to fail and needs quick attention. The identification of potentially hazardous locations will facilitate decision-maker's actions to mitigate disastrous impacts.
Where Used:	There has been much research work on considering the impact of soil variability on the failure probability of soil structures. Notably, the consideration of soil variability in the design criteria of soil structures has been partially included in the Canadian Geotechnical Design Code.
Additional Research:	NA
Additional Information:	The theoretical background of the numerical tool can be obtained through the following publications: 1. Luo, Ning. 2017. Probabilistic analysis of unreinforced and reinforced soil slopes using the random finite element method, Ph.D. thesis, Queen's University. 2. Luo, Ning, Bathurst, R.J. 2017. Reliability bearing capacity analysis of footings on cohesive soil slopes using RFEM. Computers and Geotechnics, 89: 203-212. 3. Luo, Ning, Luo, Z., Risk assessment of footings on slopes in spatially variable soils considering random field rotation, ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, 8(3): 04022028. 4. Fenton, G.A., Griffiths, D.V. 2008. Risk Assessment in Geotechnical Engineering, John Wiley & Sons, Inc.
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Original Research:	https://qspace.library.queensu.ca/handle/1974/22749 https://ascelibrary.org/doi/full/10.1061/AJRUA6.0001252
What Risks:	The numerical model will provide statistical estimations to facilitate risk assessment and aid the decision-making process. However, it will require a sound judgment of experienced practice engineers, who normally will

	collectively consider other factors such as the importance of the infrastructure and come up with judicious decisions to prioritize their work.
Partner Agencies/Jurisdictions:	State and Federal Departments of Transportation; Federal Highway Administration; U.S. Army Corps of Engineers.
New Question:	NA
New Question:	NA
New Question:	NA

Research with a Technology Component Should Respond to the Following Questions

Research Requested:	No.
Why Better:	The current design standard of geotechnical soil structures uses a single value of soil strength in slope design, and the variability of soil properties is often neglected. This simplification can lead to false design and failure. Hence, the consideration of soil uncertainty is necessary. The geotechnical community is moving towards reliability-based design and probabilistic analysis in order to properly consider soil uncertainty, which is a modern approach that can lead to more resilient and sustainable design outcomes.
Reliability:	The risk assessment tool is an advanced tool that provides probability of failure and risk analysis for slope stability problems, which can explicitly consider soil variability. The numerical results are theoretically accurate. However, when it comes to reality, an embankment failure can be triggered by many factors, which include external factors such as earthquakes and high-water pressure, and internal factors such as variability of soil material and soil erosion. It is a scientific dream to include all factors in a single simulation to perfectly reproduce a real scenario, which is practically infeasible. Nevertheless, when the variability in soil properties is higher, there is a higher chance that stability problems will occur, and the embankment is more likely to fail in face of extreme external load.
Support Needed:	• A MATLAB program is needed to run the numerical tool. • Access to soil properties, preferably multiple borehole information should be available to allow assessment of soil variability and spatial variation. • Slope/embankment geometry should be known. • Slope/embankment foundation type should be known.
Citizen Impact:	No.
Training Required:	It is required that the practitioner has basic computer skills, basic knowledge of statistics, and engineering common sense. The use of the numerical results produced by the tool is under the discretion of a group of professionals, e.g., a discussion panel, who gather to discuss and investigate embankment problems. The likelihood of failure and the consequence of the failure of a slope provide valuable guidance on the decision-making process.
Public Accountability:	No.

Please Note: Questions or suggestions regarding the Use Case Template may be directed to Dr. MacGregor Stephenson at the Texas Division of Emergency Management at macgregor.stephenson@tdem.texas.gov.