Multi-Scale Multi-Season Land-Based Erosion Modeling and Monitoring for Infrastructure Management

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ABSTRACT

Motivation

Soil erosion and landslides are a major concern for DOTs, roadway planners, and designers, impacting the cost to maintain transportation networks and other critical infrastructure. With limited operational resources and funding available for maintenance and repairs, effective screening tools can aid in assessing erosion and landslide susceptibility, improving the decision-making ability for transportation operations and planning.

Methods

- Reviewed existing slope stability design standards, available datasets, and GIS-based modeling approaches and case studies for slope stability.
- Categorized slopes using key input parameters and used SLOPE/W to quantify soil slope stability risk levels based on Factors of Safety (FoS) against rotational failure.
- Used a rotational failure evaluation that represents an enhancement compared to currently available models based on a simplified "infinite-slope" analysis that don't assess the risk of deep-seated circular failure.
- Compared our results to existing MGS landslide susceptibility maps and known failure locations to ground-truth the modeled risk designations.
- Developed a nine-layer prototype toolkit using ESRI ModelBuilder.

Results

The prototype toolkit highlights high hazard areas and allows easy screening for potential slope/erosion issues spatially in a GIS mapping platform. Future development may include DOT hosting of the toolkit for state and local maintenance or repair planning.

DATA

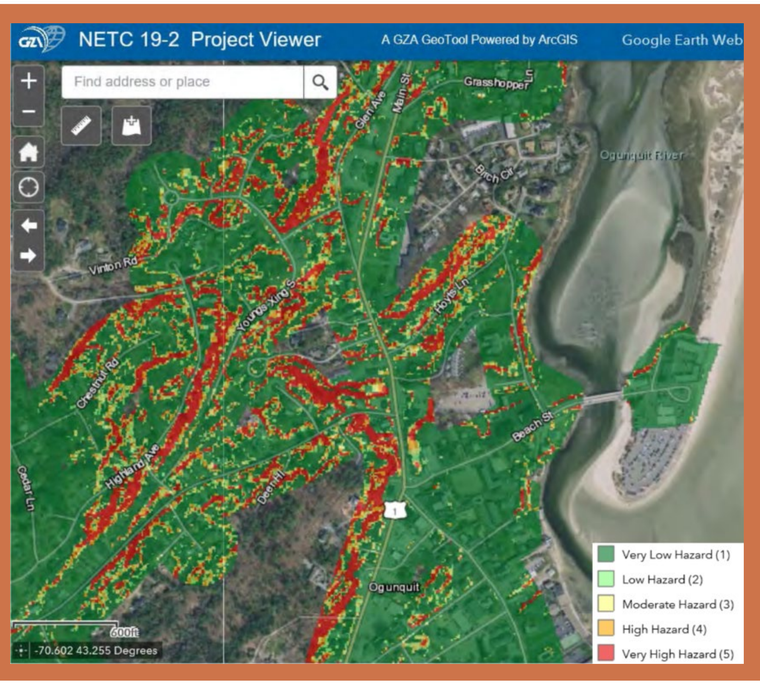
GZA developed a GIS application to evaluate and screen potential for erosion and slope instability along roadway corridors where instability could impact roadways. Key input parameters were selected from topography, geology, land cover, roadway, hydrography, and flood hazard datasets, including nine layers:

- Proximity to surface water
- Proximity to culvert
- Relative aspect
- Slope types (support slope or source slope)
- Proximity to FEMA's special flood hazard areas
- Surficial material types
- Factor of Safety (FoS)
- Slope hazard index
- Culvert hazard index

ANALYSIS

The slope stability software SLOPE/W was used estimate FoS against rotational failure for a range of soil types, slope angles and groundwater conditions. GZA then used the parametric analyses to estimate the FoS specific to each 10-foot by 10-foot area along the roadways. The estimated Fos was combined with other inputs such as flood risk and slope orientation relative to the road to create a location-specific slope stability risk index that ranged from very low risk to very high risk. The color-coded risk indices for roadway-impacts were then included in an interactive ESRI web-based viewer.

Ground-truthing of the hazard mapping model included review of several locations with site-specific subsurface information and a known history of instability. GZA also compared our modeled results to Maine Geological Survey (MGS) landslide susceptibility maps. Both of these comparisons showed that the model successfully identified the areas of increased risk and flagged the high risk that had a known history of slope failure. Due to the necessary simplifying assumptions, the model results represent a conservative, screening level assessment of risk of impacts to roadways.



FoS	Risk Designation	Color Coding	Remarks
>= 1.5	Very Low	Deep Green	Significant destabilizing factors needed to initiate failure
1.3 – 1.5	Low	Green	Moderate destabilizing factors needed to initiate failure
1.1 – 1.3	Moderate	Yellow	Minor destabilizing factors needed to initiate failure
0.9 – 1.1	High	Orange	Stabilizing factors required to prevent failure
< 0.9	Very High	Red	Significant stabilizing factors required to prevent failure

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CONCLUSIONS

The prototype toolkit has a user-friendly ESRI GIS interface that allows users to conservatively assess vulnerabilities in the roadway systems in the State of Maine. Users such as the engineers, planners and maintenance personnel from state transportation agencies, municipal public works, and local and regional planners may identify at-risk roadway segments for use in emergency response planning, project planning, and maintenance and repair prioritization. The prototype was developed using available GIS based data layers that vary based on state, regional and national dataset availability. The model can be readily expanded to other states and regions due to the plug and play architecture of the prototype.