LANDSLIDE RISK ASSESSMENT DELIVERABLES

Table L-1. LANDSLIDE RISK ASSESSMENT Products and Deliverables

Task	Task Description	Goal

Landslide Inventory	**TASK 1: [LANDSLIDE INVENTORY] – A statewide landslide incident inventory from various sources: WV GES, WV DOT, USGS, FEMA landslide buy-out properties, etc.**
	
	• Inventoried 205,442 landslide features from LiDAR mapping and historical landslide data collections. (UPDATED 2023)
	  ○ LiDAR Mapping
	    ▪ 116,399 landslide points mapped using high resolution (1- or 2-m) LiDAR.
	      – 100,469 Landslides mapped using high resolution FEMA 1-meter QL2 LiDAR
	      – 15,920. Landslides mapped from other LiDAR sources but verified with newer FEMA 1-meter LiDAR sources.
	  ○ Other Sources
	    ▪ 89,903 from historical and other sources
	      – 46,330 landslide polygons digitized based on WV Geological and Economic Survey 1976 study.
	      – 41,307 landslide polygons digitized based on a USGS 1975-1985 study.
	      – Other studies and 2016 WV DOT points (n=1,406)
	      – FEMA landslide buyout properties
	• LiDAR Mapping: Most common landslides mapped were slides and slumps (97%). Landslide locations were mapped throughout West Virginia using LiDAR elevation data products, including hillshade and slopeshade grids. Mapped failure types included slide, debris flow, lateral spread, multiple failures (when several failures were present in a small area, but were too small or close together to map separately), rock falls, and undetermined failure type. The nature of the West Virginia landscape and the LiDAR imagery limited mapping to landslides at least 33 feet wide.
	• FUTURE DIRECTIONS: Landslide mapping of areas where LiDAR coverage was incomplete; LiDAR for these areas was delivered by FEMA in fall 2021.
		Goal L1

Landslide Method Development	**TASK 2: [LANDSLIDE METHOD DEVELOPMENT] – Methodology and validation of landslide susceptibility models**
	
	• Created a statewide landslide susceptibility map
	  ○ Performed using machine learning of which the "Random Forest" method was determined to be the most efficient.
	  ○ Performed for various Major Land Resource Areas (MLRA) to minimize heterogeneity in physiographic conditions that may influence landslide susceptibility.
		Goal L2

Task	Task Description	Goal
	○ Main Landslide contributing factors: Slope, soil type, and geology. Steeper slopes, unconsolidated soils, and less resistant rock units like shale and siltstone will increase landslide susceptibility. ○ Anthropogenic disturbances contribute heavily to landslide risk ○ FUTURE WORK: Rerun models after new LiDAR-based landslide mapping is complete. *Study Team.* The West Virginia University Study Team included Dr. Steve Kite (Geomorphologist), Dr. James Thompson (Soil Scientist), Dr. Aaron Maxwell (Geologist/Modeler), and Dr. Maneesh Sharma (Geologist/GIS). *Methodology:* Site characteristics and terrain variables, such as slope, lithology, soil type, and distance to roads and streams, were extracted from the mapped landslide locations. Using a random forest machine learning algorithm, these variables were used as inputs to calculate a probabilistic landslide susceptibility grid. A majority of the mapped landslide locations were used to train the model, and the remaining locations were used to validate the model's accuracy. The resulting grid cells were classified into low, medium, and high susceptibility areas using professional judgement and model statistics. On average, over 95% of known failure locations were found to occur within the modeled high susceptibility areas (Maxwell et al., 2020). *Regional Models:* Landslide susceptibility was modeled by Major Land Resource Area (MLRA). Models were generated for each MLRA in West Virginia to take advantage of similarities in physiographic conditions that may influence landslide susceptibility. *Landslide Predictors:* The most important predictors of landside susceptibility include topographic variables such as slope angle, slope curvature, and topographic roughness. *Published Research Paper:* "Assessing the Generalization of Machine Learning-Based Slope Failure Prediction to New Geographic Extents"	
County level landslide map and report generation	**TASK 3: [COUNTY LEVEL LANDSLIDE MAP AND REPORT GENERATION] – Generation of landslide County maps** • **55 County Landslide Susceptibility Maps.** Created landslide susceptibility maps for all 55 counties. Susceptibility is classified according to low, medium, and high probability of slope failure. ○ Low Risk: 0-30% probability of slope failure ○ Medium: 30-70% probability of slope failure ○ High: 70-100% probability of slope failure • **Map Limitations.** The map is for informational purposes regarding landslide susceptibility at the county scale. It may not be used to identify susceptibility and site specific locations. To address susceptibility at a sub county scale, geotechnical evaluations should	Goal L3

Task	Task Description	Goal

	be performed by professional engineers or geologists. This map is not to be used for regulatory use.
	• **Reports.** Created a statewide and 11 regional landslide reports in support of local and state hazard mitigation plans.
	
	• **Landslide Risk Assessment Results.** (*Refer to the landslide risk assessment reports and tables for more information*).
	  ○ Risk assessment performed at sub-county scale
	  ○ 53% area in high/medium susceptibility. Note that areas of low susceptibility may be downslope of high/medium susceptibility areas and thus at risk.
	  ○ 11% roads in high/medium risk
	  ○ Structures- majority located in high/medium landslide susceptibility area are Residential buildings
	  ○ Kanawha and Monongalia counties rank 1st and 2nd
	  ○ Harrison and Ohio counties rank 1st and 2nd for Commercial asset values
	  ○ Essential Facilities – 14 located in high/medium susceptibility area
	  ○ Relative risk to humans and related infrastructure is highest in Region 6, which ranks either 1st or 2nd in all five road and structure risk analysis categories	

Web Application	**TASK 4: [WEB APPLICATION] – Interactive web application of landslide incidents and susceptibility zones**
	
	• Created interactive web applications for viewing known landslide incidence and susceptibility in West Virginia
	  ○ WV Landslide Tool
	  ○ WV Flood Tool (RiskMAP View)
		Goal L4

Update State Hazard Mitigation Plan	**TASK 5: [UPDATE STATE PLAN] – Update State Hazard mitigation plan**
	
	• Created various landslide risk assessment products in support of local and state hazard mitigation plans.
	  ○ Statewide landslide incident and susceptibility maps
	  ○ Risk assessments performed at the community-level scale for roads, structures/parcels (building dollar exposure), essential facilities, and total area.
		Goal L5

Product Summary	**SUMMARY OF KEY RISK LANDSLIDE ASSESSMENT PRODUCTS:** **Reports and Maps:** • Regional and Statewide Landslide Risk Assessment Reports • County Scale Landslide Susceptibility Maps for all 55 counties • Landslide Characteristics by 5 MLRA Regions	

<table>
<tr><th>Task</th><th>Task Description</th><th>Goal</th></tr>
<tr><td></td><td>
Web Tools showing Landslide Incidents and Susceptibility:

WV Landslide Tool
WV Flood Tool (RiskMAP View)

Published Methodology Paper: Assessing the Generalization of Machine Learning-Based Slope Failure Prediction to New Geographic Extents

Landslide Risk Directory: Directory of reports, susceptibility maps, educational brochures, methodology papers, GIS data, community risk assessment tables, graphics, etc.

Outreach Materials:

Brochures

Community: Mitigating Landslide Risk through Planning
Homeowner: Recognizing Landslide Risk on Your Property

Story Maps

Causes of Landslides in Mountain State
WV Landslides and Slide-Prone Areas, WVGES 1976

Presentations:

Landslide Risk Assessment (April 2022) PDF | PPTX
GSA Poster Kite et al. (2021) PDF | PPTX

</td><td></td></tr>
</table>