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SUSCEPTIBILITY TO DEEP-SEATED LANDSLIDES IN ALASKA

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ABSTRACT

Alaska's vast and diverse mountainous regions experience numerous types of slope instabilities. Deep-seated landslides have proven to be one of the most destructive, deadly, and difficult hazards to predict. Limited historical data on past deep-seated landslides and inadequate remote sensing and elevation data have challenged mapping and assessment efforts. However, new landslide inventory and recent elevation data acquisition, mapping, and modeling initiatives are making great strides towards characterizing potential hazards in communities and infrastructure corridors. This statewide map depicts deep-seated landslide susceptibility based on a simple model that incorporates slope angle and rock strength information. In future modeling efforts we may implement larger-scale, deep-seated landslide susceptibility models and incorporate additional predictors and determine their importance as conditioning factors for landslide activity in different regions. The purpose of this statewide map is to inform the public and decision-makers about landslide susceptibility in Alaska, help direct planning and zoning activities in affected communities, and improve decision-making on landslide early warning systems and monitoring and mitigation efforts throughout Alaska.

INTRODUCTION

Methods

This study followed a well-tested protocol for modeling deep-seated landslide susceptibility used by state geological surveys in California (Wills and others, 2011) and Wyoming (Wittke and Stafford, 2019). The methodology involves resampling and classification of raster and vector data and assigning landslide susceptibility value based on combined rock strength and slope angle classes.

Slope Angle and Rock Strength

We processed digital elevation raster data and geological map unit vector data in Esri's ArcGIS Pro, version 3.3. First, the 5-meter IFSAR (U.S. Geological Survey, 2013) digital terrain model (DTM), which covers the entire state, was sampled to a 20-meter grid for processing efficacy and minimum landslide detection size. We used the DTM as input for calculating slope in degrees using a geodesic method and grouped the values into eight slope classes with increasing steepness as follows: class 1: <3 degrees; class 2: 3 to <5 degrees; class 3: 5 to <10 degrees; class 4: 10 to <15 degrees; class 5: 15 to <20 degrees; class 6: 20 to <30 degrees; class 7: 30 to <40 degrees; and class 8: > 40 degrees.

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Each rock unit from the Geologic Map of Alaska (Wilson and others, 2015, scale 1:1,584,000) was assigned a rock strength value after the classification described by Wills and others (2011). We constructed a comprehensive geologic map by compiling data from the *Geologic Map of Alaska* (Wilson and others, 2015; scale 1:1,584,000), which includes more than 240,000 geologic unit polygons. To reduce complexity, polygons were generalized using the *Description* and *GeoMaterial* attributes, resulting in 1,159 distinct geologic units. Rock strength values were subsequently assigned to each unit in accordance with the classification framework of Wills and others (2011). The three rock strength classes are: (1) Strong: crystalline rocks, well-cemented sandstones, and limestones; (2) Moderate: weakly cemented sandstones, low-grade metamorphic rocks, and weakly cemented volcanic rocks; and (3) Weak: pre-existing landslides, mudstone, shales, and unconsolidated surficial units. We then converted the rock strength vector layer to a raster layer and resampled it to 20 m, multiplied by a factor of 10, and added it to the classified slope value raster to obtain unique two-digit slope weakness identifiers, where the first digit represents rock strength and the second digit represents slope class:

$$(Rock\ strength\ \times 10) + Slope\ class = Unique\ Slope\ Weakness\ ID$$

Susceptibility

We converted the unique slope weakness identifiers to susceptibility according to Wills and others (2011) and Wittke and Stafford (2019; table 1) using nine susceptibility classes; an increasing value represents an increasing susceptibility to deep-seated landslides. This classification schema is derived from Jones and others (2008), who created landslide susceptibility classes by combining slope angle and rock strength information as proposed by Wilson and Keefer (1985).

Table 1. Unique slope weakness identifier and associated deep-seated landslide susceptibility.

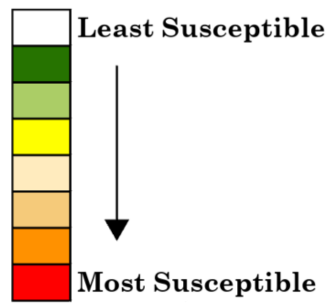
Unique Slope Weakness ID	Susceptibility
11	0
12	0
13	0
14	3
15	6
16	7
17	8
18	8
21	0
22	5
23	5
24	8

Unique Slope Weakness ID	Susceptibility
25	9
26	9
27	9
28	9
31	0
32	7
33	7
34	9
35	10
36	10
37	10
38	10

Table 2 illustrates how the combination of rock strength and slope class produces deep-seated landslide susceptibility. Generally, a low-angle slope with weak rock can still be highly susceptible to landslides (table 2). For weak rock (rock strength class 3), any slope steeper than 15 degrees falls into the highest category (10) on the susceptibility scale. For very gentle slopes (less than 3 degrees), landslide susceptibility is low regardless of rock strength, e.g., the susceptibility value of zero assigned to Unique Slope Weakness IDs of 21 and 31 (table 1).

Table 2. Susceptibility classification based on rock strength and slope class, where 0 = least susceptible and 10 = most susceptible. Adapted from Wills and others, 2011.

Slope Class	Rock Strength 1	Rock Strength 2	Rock Strength 3
1	0	0	0
2	0	5	7
3	0	5	7
4	3	8	9
5	6	9	10
6	7	9	10
7	8	9	10
8	8	9	10



RESULTS AND DISCUSSION

We adopted a simple and well-tested approach using slope angle and rock strength information to provide an overview map of deep-seated landslide susceptibility in Alaska. The map may capture susceptible areas which currently may be underrepresented in available landslide inventories.

Broad regions of Alaska are comprised of weak (class 3) rock but lack topographic relief (e.g., Southwest Alaska). These regions have low susceptibility to deep-seated landslides, except for areas like steep riverbanks, cliff-featured shorelines, and man-made roadcuts. In contrast, parts of Southcentral, Interior, and portions of Southeast Alaska feature weak rock combined with very rugged relief, which makes these areas the most susceptible regions to potential deep-seated landslides.

The map presented here is the first step in a larger effort to model landslide susceptibility across Alaska. Future versions of larger-scale, deep-seated landslide susceptibility models may incorporate additional landslide predictors (e.g., topographic wetness index, land use, peak ground acceleration, landslide inventory, distance to active and Quaternary faults) and determine their importance as conditioning factors for landsliding activity in different regions. These iterative maps will help inform the public and decision-makers in local governments about landslide susceptibility in their region.

LIMITATIONS

We recommend that map users consider the following limitations:

- The deep-seated landslide susceptibility map does not account for susceptibility to shallow landslides, debris flows, or rock fall, which are influenced by additional factors, nor does it incorporate effects from seismic shaking.
- Geologic units were originally mapped at a 1:1,584,000 scale (Wilson and others, 2015), while this map is presented at a 1:3,750,000 scale; the results herein should be interpreted at comparable scale and are not suitable for site-specific evaluation.
- The susceptibility model results have not been validated against the Alaska Landslide Inventory, an internal database maintained and referenced by Alaska Division of Geological & Geophysical Surveys staff. Future work may include model validation and comparison with other susceptibility models (e.g., Mirus and others, 2024).
- This map does not indicate frequency, magnitude, or mobility of potential landslides (Mirus and others, 2024), and thus, does not convey landslide probability or risk level.
- Susceptibility was modeled solely from slope angle and rock strength. Incorporating additional contributing factors and more advanced modeling approaches may improve future products.

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REFERENCES

Jones, L.M., Bernknopf, R., Cox, D., Goltz, J., Hudnut, K., Mileti, D., Perry, S., Ponti, D., Porter, K., Reichle, M., Seligson, H., Shoaf, K., Treiman, J., and Wein, A., 2008, The ShakeOut Scenario: U.S. Geological Survey Open-File Report 2008-1150 and California Geological Survey Preliminary Report 25, 312 p. http://pubs.usgs.gov/of/2008/1150

Mirus, B.B., Belair, G.M., Wood, N.J., Jones, J., and Martinez, S.N., 2024, Parsimonious high-resolution landslide susceptibility modeling at continental scales: American Geophysical Union Advances, v. 5, no. 5, 25 p. https://doi.org/10.1029/2024AV001214

U.S. Geological Survey, Earth Resources Observation and Science (EROS) Center, 2013, Digital elevation - Interferometric synthetic aperture radar (IFSAR) - Alaska: U.S. Geological Survey. https://doi.org/10.5066/P9C064CO

Wills, C.J., Perez, F.G., and Gutierrez, C.I., 2011, Susceptibility to deep-seated landslides in California: California Geological Survey Map Sheet 58, 3 p., 1 sheet. https://www.conservation.ca.gov/cgs/documents/publications/map-sheets/MS_058.pdf

Wilson, F.H., Hults, C.P., Mull, C.G, and Karl, S.M, comps., 2015, Geologic map of Alaska: U.S. Geological Survey Scientific Investigations Map 3340, 196 p., 2 sheets, scale 1:1,584,000. https://alaska.usgs.gov/science/geology/state_map/interactive_map/AKgeologic_map.html

Wilson, R.C., and Keefer, D.K., 1985, Predicting areal limits of earthquake-induced landsliding, *in* Ziony, J.I., ed., Evaluating earthquake hazards in the Los Angeles region-an earth-science perspective: U.S. Geological Survey Professional Paper 1360, p. 317–345.

Wittke, S.J., and Stafford, J.E., 2019, Susceptibility to deep-seated landslides in Wyoming: Wyoming State Geological Survey Open File Report 2019-7, scale 1:850,000.