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Shallow-Landslide Susceptibility Map of the Northwest Quarter of the Oregon City Quadrangle, Clackamas County, Oregon

2013

OPEN-FILE REPORT O-13-08

Landslide Hazard and Risk Study of Northwestern Clackamas County, Oregon

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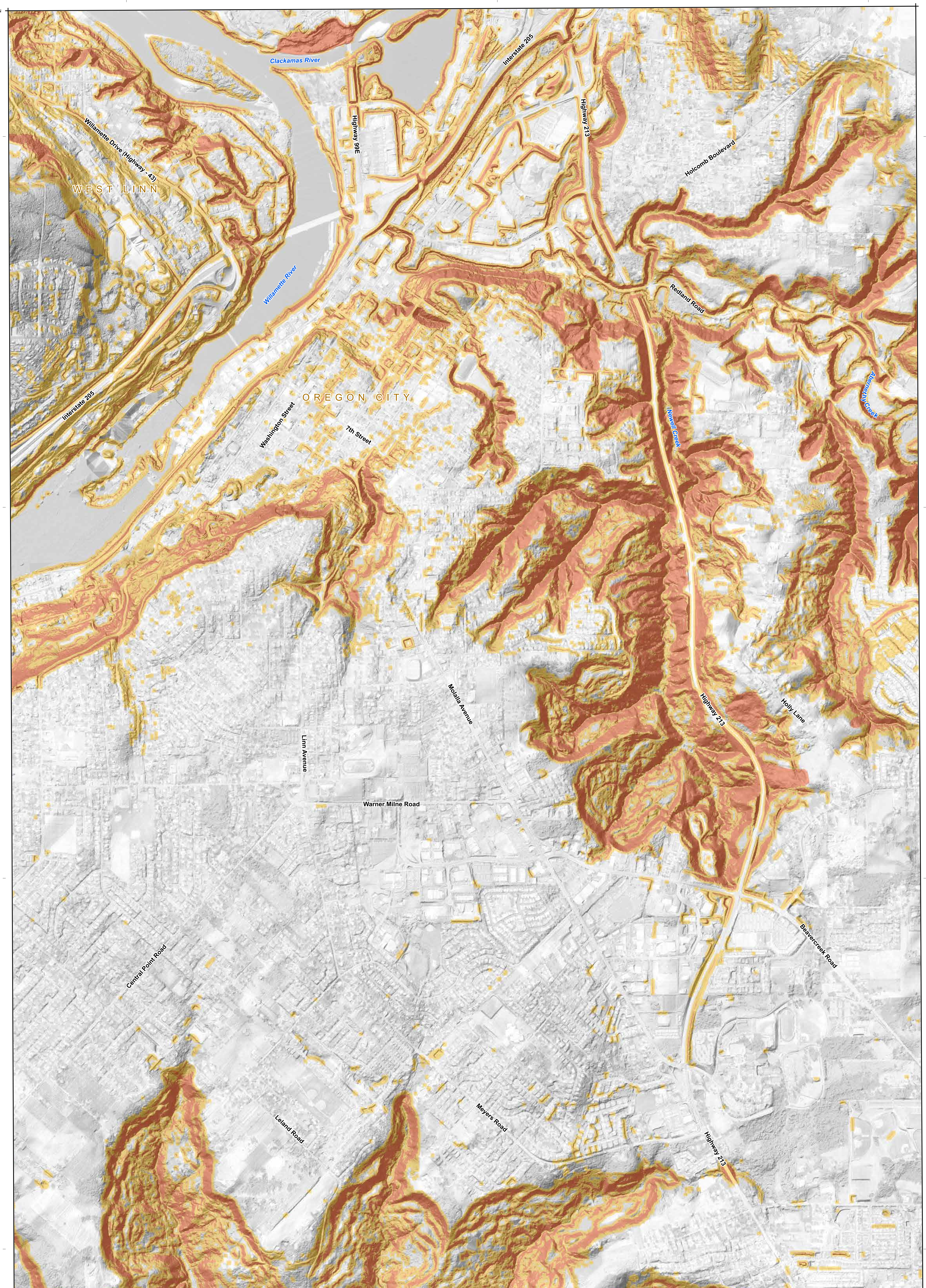
The project described in this publication was supported in part by Intergovernmental Agreement IGS 11-21-2011 from Clackamas County, Oregon

PLATE 51



EXPLANATION

This shallow-landslide susceptibility map identifies landslide-prone areas that are defined following the protocol of Burns and others (2012).

On the basis of several factors and past studies (described in detail by Burns and Madin [2009]), a depth of 15 ft (4.5 m) is used to divide shallow from deep landslides. This susceptibility map was prepared by combining three factors: 1) calculated factor of safety (FOS), 2) landslide inventory data, and 3) buffers applied to the previous two factors. The FOS was calculated using conservative values such as having a water table at the ground surface. The landslide inventory data were taken from the corresponding inventory map. The combinations of these factors comprise the relative susceptibility hazard zones: high, moderate, and low as shown by the Susceptibility Hazard Zone Matrix below. The landslide susceptibility data are displayed on top of a base map that consists of an aerial photograph (orthorectified) overlain on the lidar-derived digital elevation model. For additional detail on how this map was developed see Burns and others (2012).

SHALLOW-LANDSLIDE SUSCEPTIBILITY CLASSIFICATION

Each landslide susceptibility hazard zone shown on this map has been developed according to a number of specific factors. The classification scheme was developed by the Oregon Department of Geology and Mineral Industries (Burns and others, 2012). The symbology used to display these hazard zones is explained below.

Shallow-Landslide Susceptibility Zones: This map uses color to show the relative degree of hazard. Each zone is a combination of several factors (see Hazard Zone Matrix, below).

HIGH: High susceptibility to shallow landslides.

MODERATE: Moderate susceptibility to shallow landslides.

LOW: Low susceptibility to shallow landslides.

Shallow-Landslide Susceptibility Hazard Zone Matrix

Contributing Factors *	Final Hazard Zone		
	High	Moderate	Low
1 Factor of Safety (FOS)	less than 1.25	1.25 - 1.5	greater than 1.5
2 Landslide Deposits & Head Scarps (Shallow)	included	—	—
3 Buffers	2H:1V (head scarps)	2H:1V (FOS less than 1.5)	—

*See explanation of corresponding contributing factors below.

1 Factor of Safety

Factor of Safety (FOS) Map: The mechanics of slope stability can be divided into two forces: driving forces and resisting forces. These forces are a function of the material properties and the geometry of the slope. These two forces oppose each other, and slope stability can be thought of as their ratio.

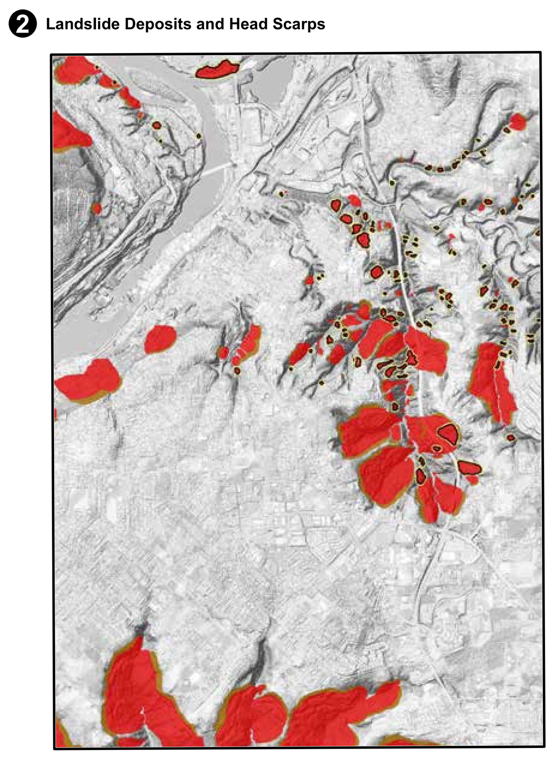
$$\text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

A FOS > 1 is theoretically a stable slope because the shear strength is greater than the shear stress. A FOS < 1 is theoretically an unstable slope because the shear stress is greater than the shear strength. A critically stable slope has a FOS = 1. Because of the inability to know all the conditions present within a slope, most geotechnical engineers and engineering geologists recommend that slopes with a FOS < 1.5 be considered potentially unstable (Turner and Schuster, 1996; Cornforth, 2005).

The FOS was calculated using the infinite slope equation with conservative parameters. Saturated conditions were used so that a "worst case" scenario could be evaluated. Because of limitations related to a grid type analysis, isolated areas with small (less than 4 ft (1.2 m) high) elevation change were removed using a standardized process (Burns and others, 2012).

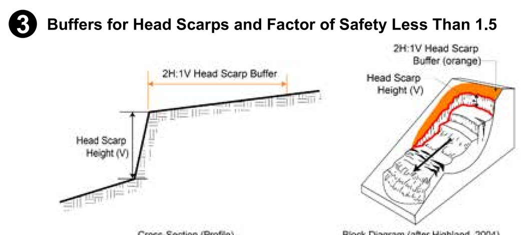
This map uses color to show the change in the factor of safety across the map as explained below.

2 Landslide Deposits and Head Scarps

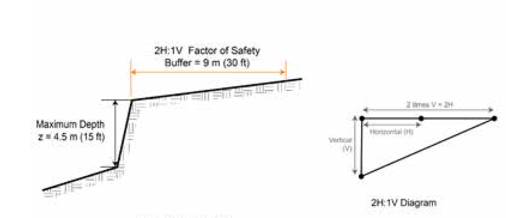


Landslide Deposits and Head Scarps Inventory Map: This map is an inventory of all existing landslides in this area. This inventory map was prepared by compiling all previously mapped landslides from published and unpublished geologic and landslide mapping, lidar-based geomorphic analysis, and review of aerial photographs. Each landslide was also attributed with classifications for activity, depth of failure, movement type, and confidence of interpretation. The inventory was created by using the protocol developed by Burns and Madin (2009). This map uses color to show different landslide features across the map as explained below. The shallow landslides were extracted from the inventory and used to create the shallow-landslide susceptibility map as shown above in the Hazard Zone Matrix.

3 Buffers for Head Scarps and Factor of Safety Less Than 1.5



Buffer for Head Scarps: This buffer was applied to all head scarps from the landslide inventory. The buffer consists of a 2:1 horizontal to vertical distance (2H:1V). This buffer is different for each head scarp and is dependent on head scarp height. For example, a head scarp height of 6 ft (2 m) has a 2H:1V buffer equal to 12 ft (4 m).



Buffer for Factor of Safety Less Than 1.5: This buffer was applied to all areas with a calculated FOS less than 1.5. The buffer consists of a 2:1 horizontal to vertical distance (2H:1V). For example, if the maximum depth for shallow landslides is 15 ft (4.5 m), then the 2H:1V buffer would equal 30 ft (9 m).

LIMITATIONS

Several limitations are worth noting and include the following.

1) Every effort has been made to ensure the accuracy of the GIS and tabular database, but it is not feasible to completely verify all of the original input data.

2) The shallow-landslide susceptibility maps are based on three primary sources: a) calculated factor of safety, b) landslide inventory, and c) buffers. Factors that can affect the level of detail and accuracy of the final susceptibility map include the following:

a) Factor of safety calculations are strongly influenced by the accuracy and resolution of the input data for material properties, depth to failure surface, depth to groundwater, and slope angle. The first three of these inputs are usually estimates (material properties) or conservative limiting cases (depth to failure surface and groundwater), and local conditions may vary substantially from the estimated values used to make these maps.

b) Limitations of the landslide inventory, which are discussed by Burns and Madin (2009).

c) Infinite slope factor of safety calculations are done on one grid cell at a time without regard for the adjacent grids. The results sometimes underestimate or overestimate the level of stability for a certain area. We developed buffers for areas with low factors of safety to try to counter the tendency to underestimate susceptibility. We developed the focal relief method to try to reduce the problem of overestimation of susceptibility due to steep slopes with low relief. However, the overestimation and underestimation of susceptible areas is still likely in some isolated areas.

3) The susceptibility maps are based on the topographic and landslide inventory data available as of the date of publication. Future new landslides may render this map locally inaccurate.

4) The lidar-based digital elevation model does not distinguish elevation changes that may be due to the construction of structures like retaining walls. Because it would require extensive GIS and field work to locate all of these existing structures and remove them or adjust the material properties in the model, such features have been included as a conservative approach and therefore must be examined on a site-specific basis.

5) Some landslides in the inventory may have been mitigated, thereby reducing their level of susceptibility. Because it is not feasible to collect detailed site-specific information on every landslide, potential mitigation has been ignored.

REFERENCES

Burns, W.J., and Madin, I.P., 2009, Protocol for inventory mapping of landslide deposits from light detection and ranging (lidar) imagery: Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p.

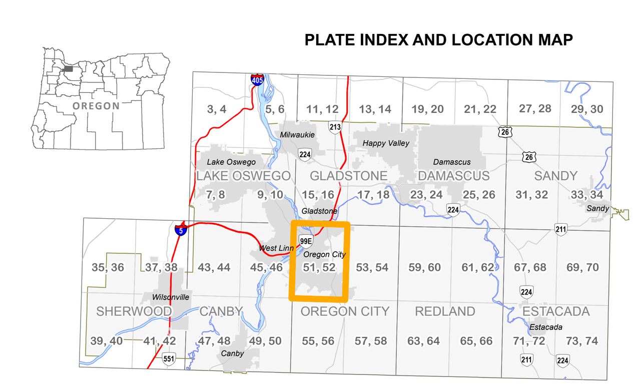
Burns, W.J., Madin, I.P., and Mickelson, K.A., 2012, Protocol for shallow-landslide susceptibility mapping: Oregon Department of Geology and Mineral Industries Special Paper 45, 32 p.

Cornforth, D.H., 2005, Landslides in practice: Investigation, analysis, and remedial/preventative options in soils: Hoboken, New Jersey, John Wiley and Sons, Inc., 596 p.

Highland, L., compiler, 2004, Landslide types and processes: U.S. Geological Survey Fact Sheet 2004-3072 (ver. 1.1), 4 p.

Turner, A.K., and Schuster, R.L., eds., 1996, Landslides: Investigation and mitigation: Transportation Research Board, National Research Council, Special Report 247, 673 p.

PLATE INDEX AND LOCATION MAP



U.S. Geological Survey 7.5-minute quadrangle maps are divided into quarter quadrangles. Each quarter quadrangle has two plate numbers; the first plate number indicates the shallow-landslide susceptibility map, and the second plate number indicates the corresponding deep-landslide susceptibility map. Plates 1 and 2 (not shown here) are overview maps for this publication.

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Base map for plates in this publication:

Lidar data from DOGAMI Lidar Data Quadrangle LDQ-2009-45122C3-Estacada, LDQ-2009-45122C4-Redland, LDQ-2009-45122C5-Oregon City, LDQ-2009-45122C6-Canby, LDQ-2009-45122C7-Sherwood, LDQ-2009-45122D3-Sandy, LDQ-2009-45122D4-Damascus, LDQ-2009-45122D5-Gladstone, LDQ-2009-45122D6-Lake Oswego.
Digital elevation model (DEM) consists of a 3-foot-square elevation grid that was converted into a hillshade image with sun angle at 315 degrees at a 60-degree angle from horizontal. The DEM was multiplied by 5 (vertical exaggeration) to enhance slope areas.

2005 orthophoto imagery is from Oregon Geospatial Enterprise Office and is draped over the hillshade image with transparency.

Projection: North American Datum 1983, UTM zone 10 North.

Software: Esri ArcMap 10, Adobe Illustrator CS2.

Source File: Project\Clackamas Landslide\ClackamasStudy.mxd

16½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2012

SCALE 1:8,000

1,300 650 0 1,300 2,600 3,900 5,200 Feet

0.25 0.125 0 0.25 0.5 0.75 1 Miles

0.25 0.125 0 0.25 0.5 0.75 1 Kilometers

Cartography by William J. Burns and Katherine A. Mickelson, Oregon Department of Geology and Mineral Industries.

This map also benefited from internal review and comments by Ian Madin, DOGAMI Chief Scientist.

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