STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
VICKI S. McCONNELL, STATE GEOLOGIST

Landslide Inventory Map of the Southeast Quarter of the Beaverton Quadrangle, Washington County, Oregon

2011

IMS-34
INTERPRETIVE MAP SERIES

Landslide Inventory Maps of the Beaverton Quadrangle, Washington County, Oregon

by William J. Burns, Ian P. Madin, and Katherine A. Mickelson

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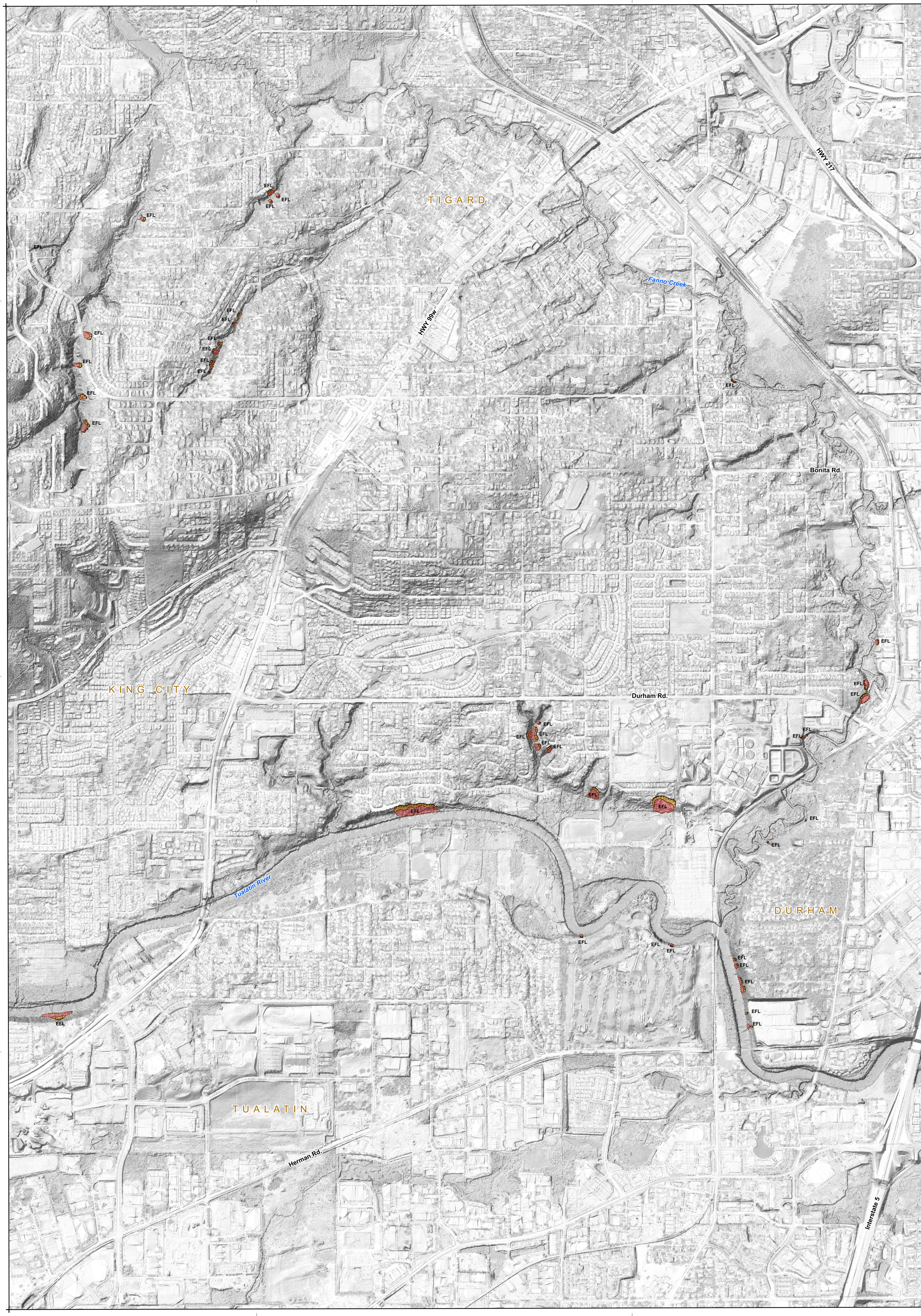
PLATE 3



EXPLANATION

This map is an inventory of existing landslides in this quarter quadrangle. The landslide inventory is one of the essential data layers used to delineate regional landslide susceptibility. This landslide inventory is not regulatory, and revisions can happen when new information regarding landslides is found or when future (new) landslides occur. Therefore, it is possible that landslides within the mapped area were not identified or occurred after the map was prepared.

This inventory map was prepared by following the Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (Lidar) Imagery developed by Burns and Madin (2009). The three primary tasks included compilation of previously mapped landslides (including review of the Statewide Landslide Information Layer for Oregon, release 2 [Burns and others, 2011] and Geologic Map of Oregon City [Madin, 2009]), lidar-based morphologic mapping of landslide features, and review of aerial photographs. Landslides identified by these methods were digitally compiled into a GIS database at varying scales. The recommended map scale for these data is 1:8,000, as displayed on this map. Each landslide was also attributed with classifications for activity, depth of failure, movement type, and confidence of interpretation. The landslide data are displayed on top of a base map that consists of an aerial photograph (orthorectified) overlaid on the lidar-derived hillshade image.

This landslide inventory map is intended to provide users with basic information regarding landslides within the quarter quadrangle. The geologic, terrain, and climatic conditions that led to landslides in the past may provide clues to the locations and conditions of future landslides, and it is intended that this map will provide useful information to develop regional landslide susceptibility maps, to guide site-specific investigations for future developments, and to assist in regional planning and mitigation of existing landslides.

LANDSLIDE CLASSIFICATION

Each landslide shown on this map has been classified according to a number of specific characteristics identified at the time recorded in the GIS database. The classification scheme was developed by the Oregon Department of Geology and Mineral Industries (Burns and Madin, 2009). Several significant landslide characteristics recorded in the database are portrayed with symbology on this map. The specific characteristics shown for each landslide are the activity of landsliding, landslide features, deep or shallow failure, type of landslide movement, and confidence of landslide interpretation. These landslide characteristics are determined primarily on the basis of geomorphic features, or landforms, observed for each landslide. The symbology used to display these characteristics is explained below.

LANDSLIDE ACTIVITY: Each landslide has been classified according to the relative age of last movement. This map display uses color to show the activity.

HISTORIC and/or ACTIVE (movement less than 150 years ago): The landslide appears to have moved within historic time or is currently moving (active).

PREHISTORIC or ANCIENT (movement greater than 150 years ago): Landslide features are slightly eroded and there is no evidence of historic movement. In some cases, the observed landslide features have been greatly eroded and/or covered with deposits that result in smoothed and subdued morphology.

LANDSLIDE FEATURES: Because of the high resolution of the lidar-derived topographic data, some additional landslide features were identified. These include:

HEAD SCARP ZONE and FLANK ZONE(S): The head scarp or uppermost scarp, which in many cases exposes the primary failure plane (surface of rupture), and flanks or shear zones.

HEAD SCARP LINE and INTERNAL SCARP LINES: Uppermost extent of the head scarp and internal scarps within the body of the landslide. Hatching is in the down-dropped direction.

DEPTH OF FAILURE: The depth of landslide failure was estimated from scarp height. Failures less than 4.5 m (15 ft) deep are classified as shallow seated and failures greater than 4.5 m (15 ft) deep are classified as deep seated.

SHALLOW-SEATED LANDSLIDE: Estimated failure plane depth is less than 4.5 m (15 ft).

DEEP-SEATED LANDSLIDE: Estimated failure plane depth is greater than 4.5 m (15 ft).

CONFIDENCE OF INTERPRETATION: Each landslide was classified according to the confidence that the mapper assigns based on the likelihood that the landslide actually exists. Landslides are mapped on the basis of characteristic morphology, and the confidence of the interpretation is based on how clearly visible that morphology is. As a landslide ages, weathering (primarily through erosion) degrades the characteristic morphologies produced by landsliding. With time, landslide morphologies may become so subtle that they resemble morphologies produced by geologic processes and conditions unrelated to landsliding.

Landslides may have several different types of morphologies associated with them, and we define confidence through a simple point system (see table below) associated with these features. The point system is based on a ranking of four primary landslide features with a ranking of 0 to 10 points per feature. For example, if during mapping, the head scarp and toe of a landslide were identifiable and clearly visible, the mapper would apply 10 points for the head scarp and 10 points for the toe, equaling 20 points, which would be associated with a moderate confidence of identification.

The visual display of this landslide characteristic is through the use of different line styles as shown below.

HIGH CONFIDENCE (≥30 points)

MODERATE CONFIDENCE (11-29 points)

LOW CONFIDENCE (≤10 points)

Landslide Feature	Points
Head scarp	0-10
Flanks	0-10
Toe	0-10
Internal scarps, sag ponds, compression ridges, etc.	0-10*

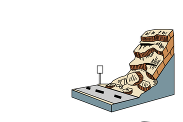
*Applied only once so that total points do not exceed 40.

CLASSIFICATION OF MOVEMENT: Each landslide was classified with the type of landslide movement. There are five types of landslide movement: slide, flow, fall, topple, and spread. These movement types are combined with material type to form the landslide classification. Not all combinations are common in nature, and not all are present in this quadrangle.

EFL

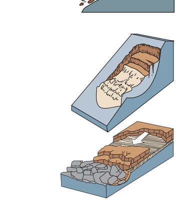
EFL – Earth Flow – Abbreviation for class of slope movement. The table below displays the types (Varnes, 1978). Generalized diagrams (some modified from Highland, 2004) showing types of movement are displayed below the table.

Type of Movement	Type of Material		
	Rock	Debris	Soil
Fall	**RF** rock fall	**DF** debris fall	**EF** earth fall
Topple	**RT** rock topple	**DT** debris topple	**ET** earth topple
Slide-rotational	**RS-R** rock slide-rotational	**DS-R** debris slide-rotational	**ES-R** earth slide-rotational
Slide-transitional	**RS-T** rock slide-transitional	**DS-T** debris slide-transitional	**ES-T** earth slide-transitional
Lateral spread	**RSP** rock spread	**DSP** debris spread	**ESP** earth spread
Flow	**RFL** rock flow	**DFL** debris flow	**EFL** earth flow
Complex	**C** complex or combinations of two or more types (for example, ES-R + EFL)		



Falls are near-vertical, rapid movements of masses of materials, such as rocks or boulders. The rock debris sometimes accumulates as talus at the base of a cliff.

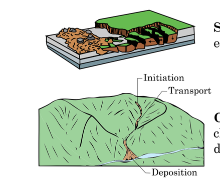
Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.



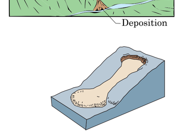
Slides are downslope movements of soil or rock on a surface of rupture (failure plane or shear zone).

- Rotational slides move along a surface of rupture that is curved and concave.
- Translational slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.

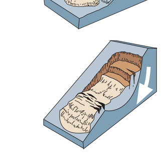
Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.



Channelized Debris Flows commonly start on a steep, concave slope as a small slide or earth flow into a channel. As this mixture of landslide debris and water flows down the channel, the mixture picks up more debris, water, and speed, and deposits in a fan at the outlet of the channel.



Earth Flows commonly have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.



Complex landslides are combinations of two or more types. An example of a common complex landslide is a slump-earth flow, which usually exhibits slump features in the upper region and earth flow features near the toe.

LIMITATIONS

This landslide inventory was developed with the best available data, using the protocol of Burns and Madin (2009). However there are inherent limitations as discussed below. These limitations underscore that this map is designed for regional applications and should not be used as an alternative to site-specific studies in critical areas.

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 original input data.
2. Burns and Madin (2009) recommend a protocol to develop landslide inventories that is based on four primary tasks: 1) interpretation of lidar-derived topographic data, 2) compilation and review of previously mapped landslides, 3) review of historic air photos, and 4) limited field checking. These tasks can affect the level of detail and accuracy of the landslide inventory. We expect the lidar data quality to improve in the future, which will likely result in the identification of more landslides with greater accuracy and confidence. Due to time limitations some previously mapped landslides have likely been missed. In some locations, historic air photos may not be available. Because field work is time consuming and therefore expensive, field checking may be extensive in some locations and very limited in other locations.
3. The lidar-based mapping is a "snapshot" view of the current landscape that may change as new information regarding landslides becomes available and as new landslides occur.
4. Because of the resolution of the lidar data and air photos, landslides that are smaller than 100 square meters (1,075 square feet) may not be identified. Some small landslides were included if they were reported by a local governmental agency, a site-specific study, a regional study report, or a local area landslide expert, and are found to be accurately located by the mapper.
5. Even with high-quality lidar-derived topographic data, it is possible that some existing landslides will be missed, overlooked, or misinterpreted by the map author. This database and map were prepared in accordance with a published protocol (Burns and Madin, 2009) and were reviewed to minimize these problems.
6. Earthwork related to development on hillsides can remove the geomorphic expressions of past landsliding. This can result in landslides being missed in the inventory. Earthwork on hillsides can also create geomorphic expressions that mimic past landsliding; for example, a cut and fill can look like a landslide scarp and toe. This limitation can sometimes be addressed by viewing aerial photographs that predate development in the area being mapped. Therefore, to ensure that past landslides have been adequately identified, if a landslide was identified on the predevelopment air photos, it was included in the landslide inventory, whether or not surface expression was located in the lidar-derived mapping.
7. Some landslides have been mitigated. Because it is not feasible to collect detailed site-specific information on every landslide, for example if it has been mitigated and what level of mitigation was implemented, mitigation has been omitted. Again, because of these limitations this map is intended for regional purposes only and cannot replace site-specific investigations. However, the map can serve as a useful tool for estimating the regional landslide hazard and as a starting place for future detailed landslide site-specific maps.

Please contact DOGAMI if errors and/or omissions are found so that they can be corrected in future versions of this map.

ACKNOWLEDGMENTS

We thank the people at the U.S. Geological Survey Landslide Hazard Program who contributed to the protocol and map template through discussions and suggestions, especially Jeff Coe, who provided a detailed review that significantly improved the protocol used to map this quarter quadrangle. We also thank DOGAMI staff who helped with this project through technical assistance, review, and general support, especially Rob Witter, Yumei Wang, and Deb Schueller.

REFERENCES

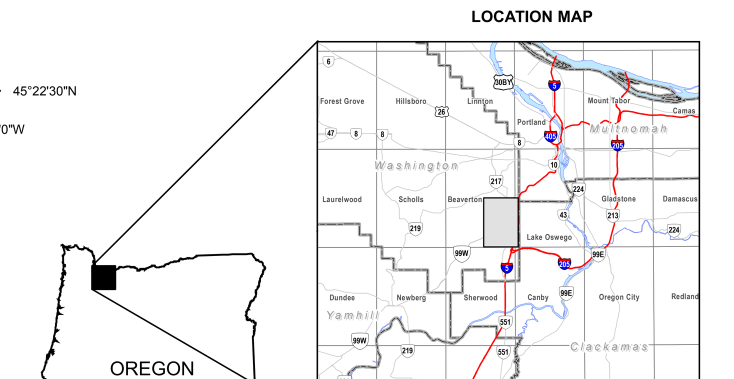
Burns, W. J., and Madin, I. P., 2009, Protocol for inventory mapping of landslide deposits from light detection and ranging (lidar) imagery: Portland, Oreg., Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p.

Burns, W. J., Mickelson, K.A., and Saint-Pierre, E.C., 2011, Statewide landslide information layer for Oregon (SLIDO), release 2: Portland, Oreg., Oregon Department of Geology and Mineral Industries Digital Data Series SLIDO-2, 41 p., 1 pl., scale 1:750,000.

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

Varnes, D. J., 1978, Slope movement types and processes, *in* Schuster, R. L., and Krizek, R. J., eds., Landslides—Analysis and control: Washington, D. C., Transportation Research Board Special Report 176, p. 11–33.

LOCATION MAP



U.S. Geological Survey 7.5-minute quadrangles and counties are labeled. This map extent shown as gray rectangle.

Base Map:

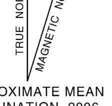
Lidar data from DOGAMI Lidar Data Quadrangle LDQ-2009-45122D7-Beaverton and the Puget Sound Lidar Consortium (2005). Digital elevation model (DEM) consists of a 3-foot square elevation grid that was converted into a hillshade image with sun angle at 315 degrees at a 60 degree angle from horizontal. The DEM is multiplied by 5 (vertical exaggeration) to enhance slope areas.

Orthophoto is from Oregon Geospatial Enterprise Office, 2005 and consists of 2005 orthophoto draped over DEM with transparency.

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

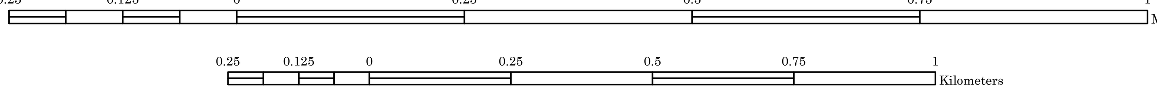
Software: Esri ArcMap 10, Adobe Illustrator CS2.

Source File: Rocks\Publications\Beaverton.mxd.



APPROXIMATE MEAN DECLINATION, 2006

SCALE 1:8,000



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

This map benefited from comments by Paul Schaefer, Senior Planner, Washington County, and other Washington County staff and Jim Duggan, Senior Engineer, city of Beaverton and other city of Beaverton staff. This map also benefited from internal review and comments by Ian Madin, Chief Scientist at DOGAMI.

IMPORTANT NOTICE

This map depicts an inventory of existing landslides based on published and unpublished reports and interpretation of topography derived from lidar data and air photos. The inventory was created following the protocol defined by Burns and Madin (2009). This map cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on this map.

For copies of this publication contact:
Nature of the Northwest Information Center
800 NE Oregon Street, #28, Ste. 965
Portland, Oregon 97232
telephone (971) 673-2331
http://www.naturenw.org