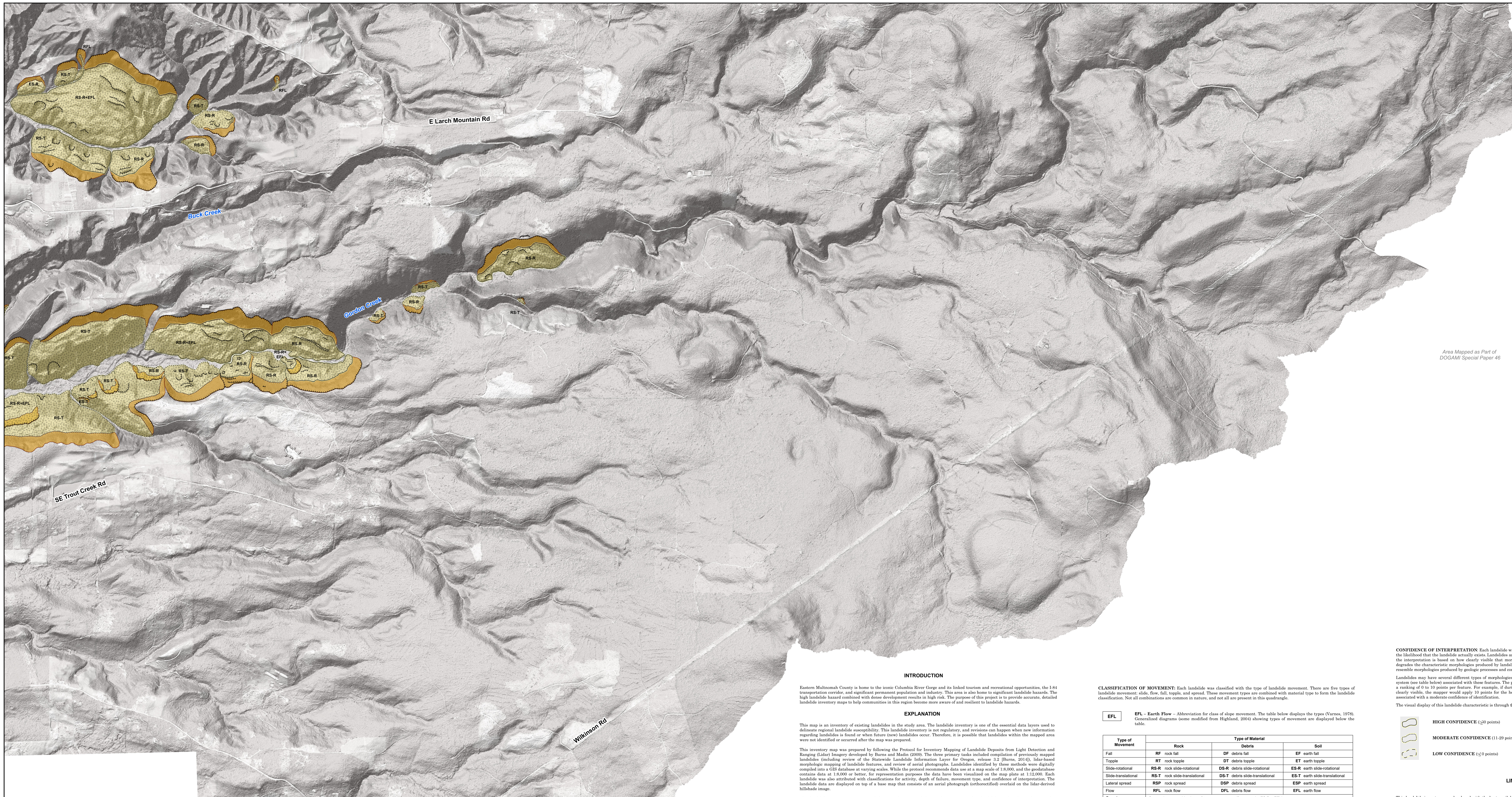
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
www.OregonGeology.org
Brad Avy, State Geologist

Southern Area—Landslide Inventory of Eastern Multnomah County, Oregon

2017

OPEN-FILE REPORT O-17-03
Landslide Inventory of Eastern Multnomah County, Oregon
by William J. Burns and Kassandra O. Lindsey
The project described in this publication was supported in part by FEMA through CTP EMW2014CA00289.

PLATE 2



INTRODUCTION

Eastern Multnomah County is home to the iconic Columbia River Gorge and its linked tourism and recreational opportunities, the I-84 transportation corridor, and significant permanent population and industry. This area is also home to significant landslide hazards. The high landslide hazard combined with dense development results in high risk. The purpose of this project is to provide accurate, detailed landslide inventory maps to help communities in this region become more aware of and resilient to landslide hazards.

EXPLANATION

This map is an inventory of existing landslides in the study area. 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 3.2 [Burns, 2014]), 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. While the protocol recommends data use at a map scale of 1:8,000, and the geodatabase contains data at 1:8,000 or better, for representation purposes the data have been visualized on the map plate at 1:12,000. 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 study area. 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 the data were 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 data base 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, confidence of landslide interpretation, and type of landslide movement. 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 relative age of 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).

PRE-HISTORIC 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: The head scarp or upper most 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: Upper most 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).

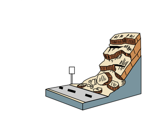
DEEP-SEATED LANDSLIDE: Estimated failure plane depth is greater than 4.5 m (15 ft).

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.

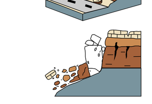
EFL

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.

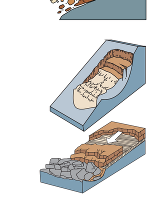
Type of Movement	Type of Material		
	Rock	Debris	Soil
Fall	**RF** rock fall	**DF** debris fall	**EF** earth fall
Topple	**RT** rock topple	**DT** debris topple	**ET** earth topple
Slide-rotational	**RS-R** rock slide-rotational	**DS-R** debris slide-rotational	**ES-R** earth slide-rotational
Slide-translational	**RS-T** rock slide-translational	**DS-T** debris slide-translational	**ES-T** earth slide-translational
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.

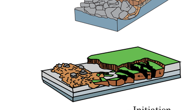


Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.

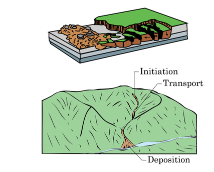


Slides are downslope movements of soil or rock on a surface of rupture (failure plane or shear zone).

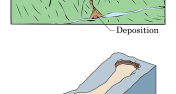
- Rotational slides move along a surface of rupture that is curved and concave.
- Translational slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.



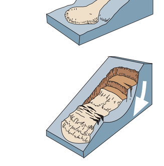
Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.



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.

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.

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 of the original input data.
2. Burns and Madin (2009) recommended 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, and this improvement will likely result in the identification of more landslides with greater accuracy and confidence. Because of 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, the 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 or future (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. Sometimes, small landslides are included if they are reported by a local governmental agency, a site-specific study, 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 was prepared in accordance with a published protocol (Burns and Madin, 2008) and 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.

REFERENCES

Burns, W.J., 2014, Statewide Landslide Information Database for Oregon, release 3.2: Oregon Department of Geology and Mineral Industries, Web: http://www.oregongeology.org/sub/slido/

Burns, W. J., Mickelson, K. A., Jones, C. B., Tilman, M. A., and Coe, D., 2015, Surficial and bedrock engineering geology, landslide inventory and susceptibility, and surface hydrography of the Bull Run Watershed, Clackamas and Multnomah Counties, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 46, 59 p., 5 pl., scales 1:24,000; 1:5,000, geodatabase.

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., geodatabase template.

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:

Base Map:

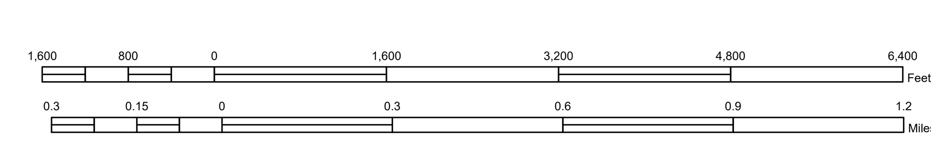
Lidar data for all four plates from DOGAMI Lidar Data Quadrangles LDQ-2010-45122-E2-Bridal Veil, LDQ-2010-45122-E1-Multnomah Falls, LDQ-2010-45121-E8-Bonneville Dam, LDQ-2010-45121-E8-Tanner Butte, and LDQ-2010-45122-D2-Bull Run.

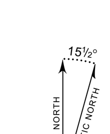
Digital elevation model (DEM) consists of a 3-foot-square elevation grid that was converted into a hillshade image with sun angle at 315 degrees at a 60-degree angle from horizontal. The DEM was multiplied by 5 (vertical exaggeration) to enhance slope areas.

2009 orthophoto imagery is from Oregon Geospatial Enterprise Office and is draped over the hillshade image with transparency.

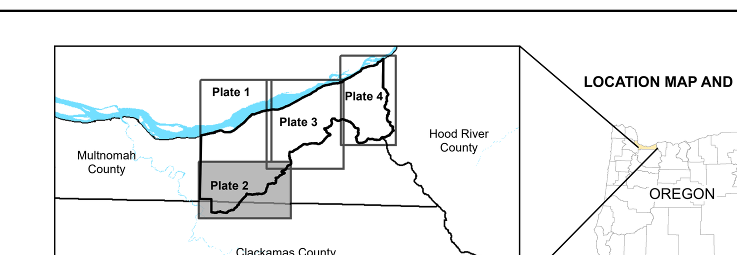
Projection: North American Datum 1983, UTM zone 10.
Source File: Project\PDX_Landslide_Risk\East Multnomah County.mxd

SCALE 1:12,000





APPROXIMATE MEAN DECLINATION, 2009



LOCATION MAP AND INDEX

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

This map benefited from a draft geological map provided by Russell C. Evarts, U.S. Geological Survey, and from reviews by Russ Evarts and Jason McClaughry and Nancy Calhoun, Oregon Department of Geology and Mineral Industries.