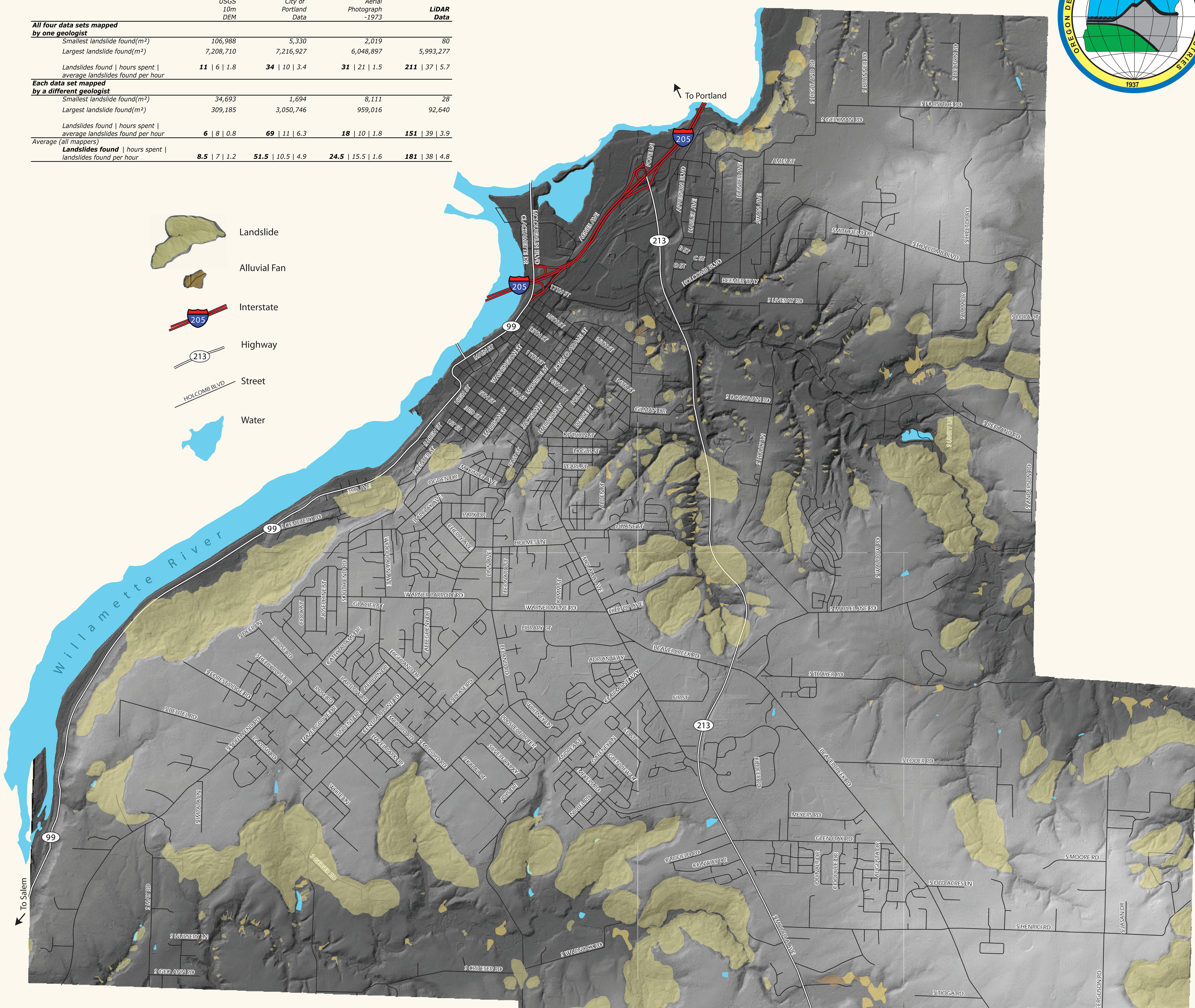
Landslide Mapping Using LiDAR Data Technology

	USGS 10m DEM	City of Portland Data	Stereo-Pair Aerial Photograph -1973	**LiDAR Data**
All four data sets mapped by one geologist				
Smallest landslide found(m²)	106,988	5,330	2,019	80
Largest landslide found(m²)	7,208,710	7,216,927	6,048,897	5,993,277
Landslides found | hours spent | average landslides found per hour	**11** | 6 | 1.8	**34** | 10 | 3.4	**31** | 21 | 1.5	**211** | 37 | 5.7
Each data set mapped by a different geologist				
Smallest landslide found(m²)	34,693	1,694	8,111	28
Largest landslide found(m²)	309,185	3,050,746	959,016	92,640
Landslides found | hours spent | average landslides found per hour	**6** | 8 | 0.8	**69** | 11 | 6.3	**18** | 10 | 1.8	**151** | 39 | 3.9
Average (all mappers)				
***Landslides found** | hours spent | landslides found per hour*	**8.5** | 7 | 1.2	**51.5** | 10.5 | 4.9	**24.5** | 15.5 | 1.6	**181** | 38 | 4.8



Feet

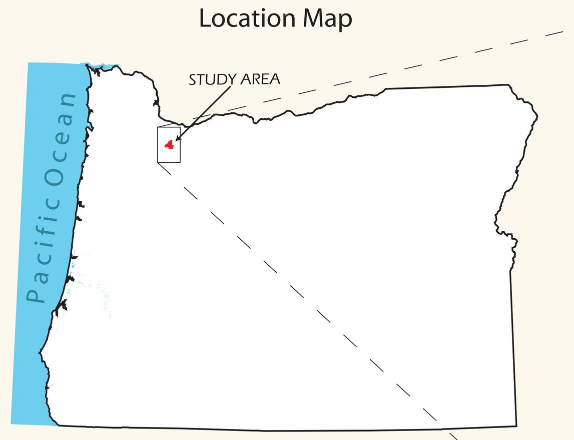
0 1,875 3,750 7,500 11,250 15,000

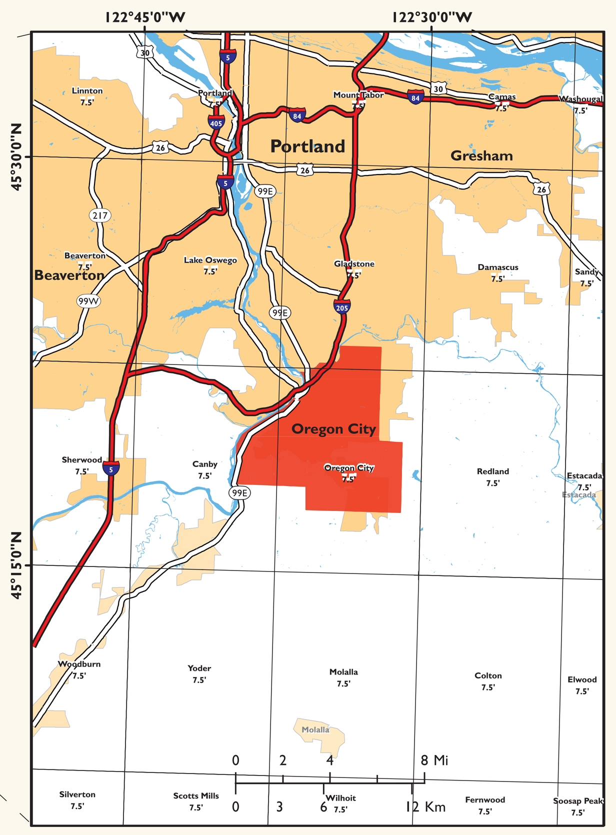
0 0.5 1 2 3 4

Kilometers

Map Scale 1:15,000

Location Map





Prepared by:
State of Oregon
Department of Geology and Mineral Industries
Vicki S. McConnell, State Geologist
800 NE Oregon St., Ste. 965
Portland, Oregon 97232
(971) 673-1555
http://www.oregongeology.com/

Landslides are a prominent hazard in the Oregon City area. Several landslide studies and maps exist for the area, for example, by Hammond and others (1974), Schlicker and Finlayson (1979), and recently Madin and Burns (2006).

During 1996 and 1997, heavier than normal rains in Oregon caused thousands of landslides. Over 700 of these landslides were mapped in the Portland metropolitan area (Burns et al., 1998). Some of these slides were the reactivation of ancient and historically active landslides, and some were new failures. Many of these slides occurred within the Oregon City area; an inventory of these landslides was prepared by Burns and others (1998) for the Portland METRO (Madin and Burns, 2006)

During the 2005-06 winter season, Portland and most of western Oregon again experienced heavier than normal rainfall, which resulted in hundreds of landslides. Again, many of the landslides were reactivation of older landslides, making the identification of these existing ancient and historic landslides an obvious priority in the attempt to begin the reduction of the risk from landslides. Several of these reactivated landslides occurred in the Oregon City area, impacting infrastructure as well as several residential homes and an apartment complex (Madin and Burns, 2006).

Photograph depicting scarps along the crest of the toe of the large Newell Creek Apartments landslide - 2007.

The two primary data sources used to make this map were serial stereo air photos of a variety of scales, and a LIDAR based DEM. Landslide geomorphology from both sets of imagery was compiled and then combined using geographic information system (GIS) software. The majority of landslide topography occurs in canyons that cut the Oregon City plateau. Slopes are typically forested, and topography is obscured when forest cover is intact. In an attempt to get around this problem, a time series of air photos was examined (1939, 1948, 1956, 1964, 1973, 1980, 1990, and 2000). For all of these photo series, stereo photo pairs were examined to look for topography characteristic of landslides such as steep arcuate scarps (cliffs), hummocky topography, and cracks and grabens (troughs or depressions) on the surfaces of slopes and irregular lobate toes. The outlines of areas of landslide topography were transferred from the stereo photos to the GIS by heads-up digitization on a georeferenced (UTM Zone 10, NAD 27) image of the USGS 1:24,000 scale topographic map (digital raster graphic: DRG). The transfer was accomplished with the DRG zoomed to scales between 1:12,000 and 1:6,000.

After the completion of the aerial photography analysis, high resolution bare earth LIDAR data became available from the City of Oregon City. LIDAR data are collected by scanning the ground with a laser range-finder flown in a precision navigated aircraft. The resultant cloud of elevation data is processed to remove laser returns from vegetation and structures, leaving an accurate and detailed model of the shape of the ground surface.

Initial processing of the Oregon City LIDAR data-points produced a DEM grid (Oregon State Plane N, 1983) with 5 ft by 5 ft cells, in addition enhancing that DEM with both relief shading and slope maps to highlight subtle topography. Also produced were elevation contours at 2 foot intervals to help visualize the data. We then digitized the areas of landslide topography directly from LIDAR imagery at a scale of 1:2400, again using topographic evidence such as scarps, hummocky terrain, and lobate toes. An additional advantage of the LIDAR data was that we could instantly produce topographic cross sections along a suspect slope. With the LIDAR data it was also possible to see subtle fan deposits at the mouths of small canyons that be interpreted as debris flow or earth flow deposits.

Areas of landslide topography mapped in this study were compared with those mapped in previous studies (Hammond and others, 1974; Schlicker and Finlayson, 1979; Burns, 1999). We found that previous maps identified most of the larger (greater than 5 acres) slide areas, but LIDAR data provided much more accurate delineation of the boundaries of the areas. Previous studies identified only a few of the smaller slide areas and in several cases identified areas which did not show any visible landslide features on the LIDAR DEM. Only the LIDAR DEM showed deposits of debris flows and earth flows. Our confidence in the existence, types, and boundaries of the larger slide areas identified on the LIDAR DEM is very high; we are less confident regarding the more numerous smaller slide areas.

References:

Hammond, P. E., Benson, G. T., Cash, D. J., Palmer, L. A., Donovan, J., and Gannon, B., 1974, A preliminary geological investigation of the ground effects of earthquakes in the Portland metropolitan area, Oregon, plate 5, Landslide map of the Portland area: Oregon Department of Geology and Mineral Industries Open-File Report 74-01, 40 p., 5 plates.

Schlicker, H. G., and Finlayson, C. T., 1979, Geology and geologic hazards of northwestern Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries, Bulletin 99, 79 p., 10 plates.

Burns, S. F., Burns, W. J., James, D. H., and Hinkle, J. C., 1998, Landslides in Portland, Oregon metropolitan area resulting from the storm of February 1996: Inventory map, database, and evaluation, METRO contract 905828 report, Portland State University.

Burns, W. J., 1999, Engineering geology and relative stability of the southern half of Newell Creek canyon, Oregon City, Oregon: Portland State University, Master's thesis, 147 p.

Hofmeister, R. J., 2000, Slope failures in Oregon: GIS inventory for three 1996/97 storm events: OregonDepartment of Geology and Mineral Industries Special Paper 34, 20 p., 1 compact disc.

Madin, I. P., in preparation, Geologic map of the Oregon City 7.5 minute quadrangle, Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries.

Data sources: City of Oregon City, DOGAMI, USGS, OR DOT, USGS
Projection: State Plane North Oregon 1983 HARN, International Ft
Cartography: Mark A. Sanchez, DOGAMI
Informational Text: DOGAMI OFR 06-27 and Don Lewis, DOGAMI

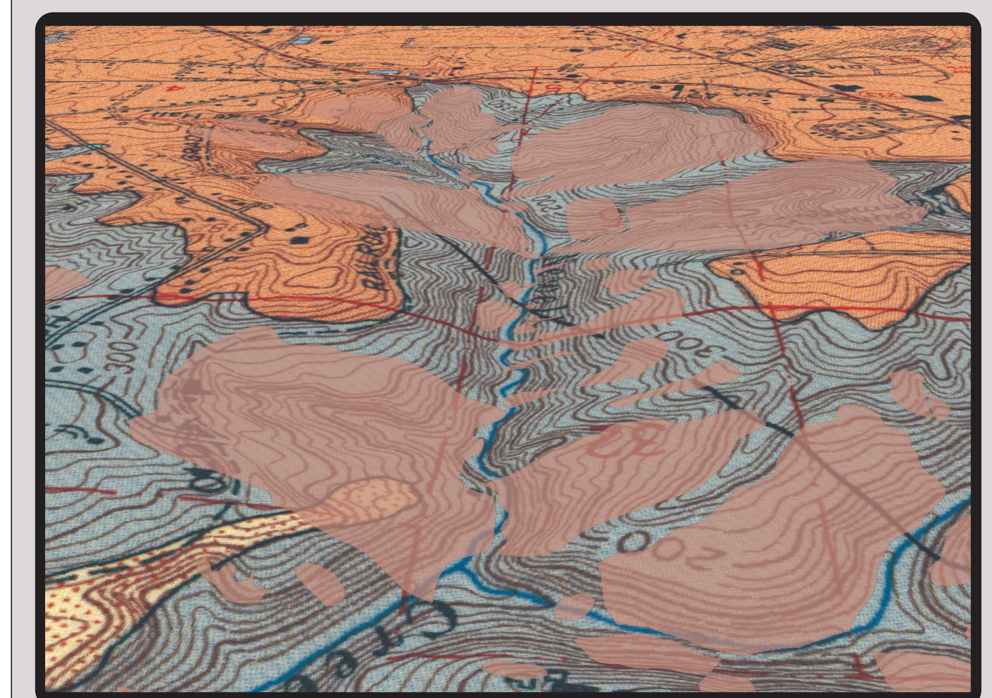
Dataset Comparisons

LiDAR is an inexpensive, fast and better way to obtain superior details of the true shape of the Earth's surface, as compared with existing decades-old topographic maps and the digital elevation models (DEMs) derived from them. DOGAMI uses LiDAR DEMs as an accurate and precise base for detailed geologic mapping and to radically improve our landslide, earthquake, coastal change and tsunami inundation hazard assessment maps.

Current efforts in identifying hazardous areas are, by default, "blurry", as the underlying topographic resolution itself is poor. Existing topographic maps were interpreted manually from aerial photos taken decades ago. They are outdated and there are myriad errors, especially in highly forested areas where the map makers could not see through the forest canopy. As a result, slopes are smoothed out and stream gradient detail is absent. This existing topographic base is frequently incomplete, artificial and simply wrong. High quality hazard assessment maps cannot be generated from low quality topographic data. With accurate, precise and high resolution DEMs, such as those based on LiDAR data, we achieve superb hazard assessment. When combined with wise planning, we sharpen the focus on truly dangerous locations for landslides, floods, coastal erosion, tsunami inundation and seismic activity.

The following are examples of varying datasets throughout the years available to geologists and engineers for the detection of geohazards. LiDAR data detected landslides are symbolized by transparent red polygons.

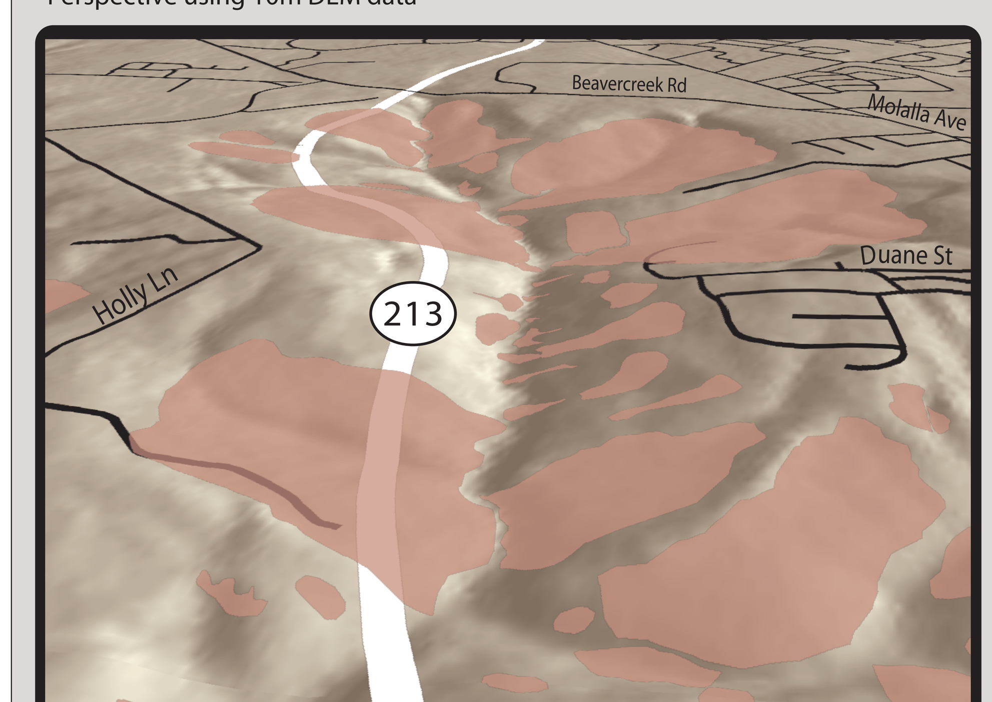
Perspective using Geologic map



DOGAMI Bulletin 99 - Geology and Geologic Hazards of Northwestern Clackamas County, Oregon - 1979

Perspective using 1m Orthophotography

Perspective using 10m DEM data



Perspective using 5' LiDAR data