The following was presented at DMT'08 (May 18-21, 2008).

The contents are provisional and will be superseded by a paper in the DMT'08 Proceedings.

See also earlier Proceedings (1997-2007) http://ngmdb.usgs.gov/info/dmt/

Washington Geological Survey GIS statewide landslide database - from design to implementation

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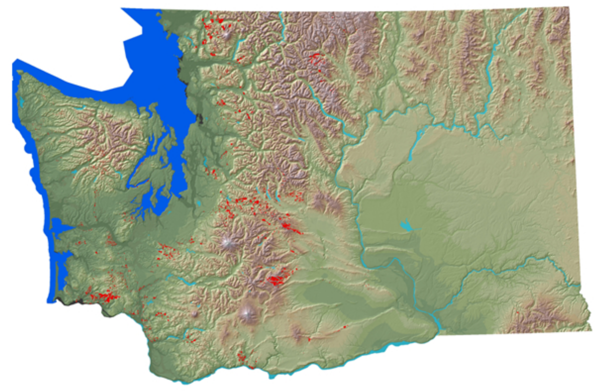
Introduction

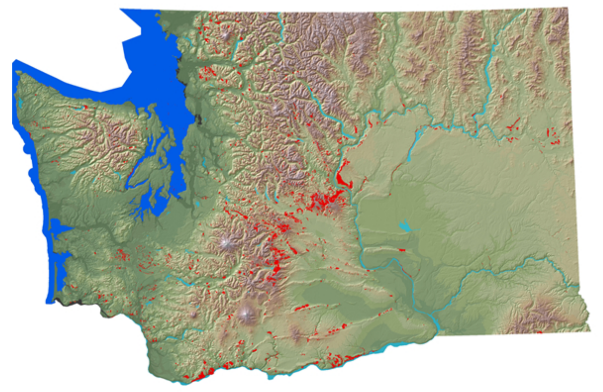
The Department of Natural Resources, Geology and Earth Resources Division (DGER), also known as the Washington Geological Survey, actively identify, assess, and map geologic hazards using modern geotechnical and geophysical methods. Our hazard maps are critical for land-use and emergency-management planning, disaster response, and building-code amendments. As our population grows, there is increasing pressure to develop in hazardous areas, thus delineating these areas is imperative. In response to the Growth Management Act's mandate to use the 'best available science', our geologists meet with local governments and citizens in at-risk communities to educate about geologic hazards and ensure these hazards are taken into account while planning for growth-management and disasters. The DGER is also first responders to natural disasters; helping staff the State Emergency Operations Center at Camp Murray and documenting damage in the field. Besides volcanic and earthquake hazards, Washington is also prone to landslides triggered by intense rainfall or earthquakes. Landslides kill more people and cost more overall each year than other natural disasters combined (Bell, 1999). Nationally, landslides account for over $2 billion dollars of loss annually and result in an estimated 25 to 50 deaths a year (Spiker and Gori, 2003; Schuster and Highland, 2001; Schuster, 1996). Additionally, according to Washington State legislative mandate RCW 43.92. ". . . the geological survey must conduct and maintain an assessment of seismic, landslide, and tsunami hazards in Washington. This assessment must include the identification and mapping of volcanic, seismic, landslide, and tsunami hazards, an estimation of potential consequences, and the likelihood of occurrence. The maintenance of this assessment must include technical assistance to state and local government agencies on the proper interpretation and application of the results of this assessment." DGER has designed and is implementing a GIS-based, statewide landslide database in both 24K and 100K scales, which will be accessible on our ArcIMS site for download as coverage files or as a KMZ file.

Data assembly

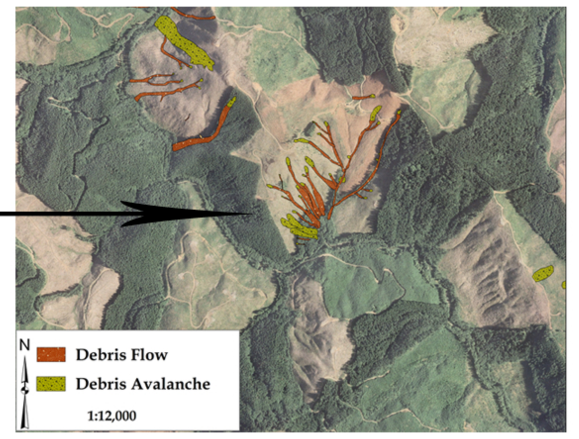
Through the years various landslide databases have been created in different divisions of the DNR to meet a variety of purposes. In 1999, the Division of Forest Practices created the first GIS statewide inventory of landslides (Boyd and Vaugeois, 2003). This database incorporated previously mapped landslides of all scales. The DGER has been involved in various projects, from mapping landslide hazards in Cowlitz County in response to the Aldercrest-Banyon landslide, to hazard response such as the Nisqually earthquake in 2001 and the December 3rd storm, 2007. However, each of these datasets and databases were intended to meet particular goals. The statewide database assesses the reliability of other database entries and uses the appropriate attributes from the previous databases to populate the statewide project, with a notation indicating where the data were obtained. An additional database is linked to the statewide database to provide information on the economic impact of landslides when that data is available. This secondary database is intended for mitigation and development planning purposes.



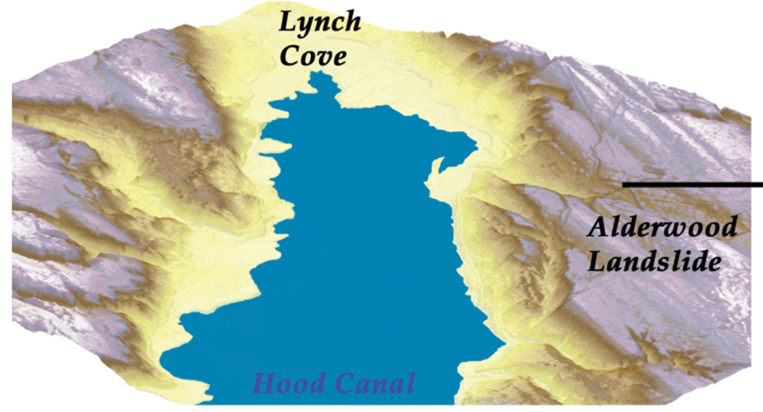
Statewide 1:24,000 landslide database

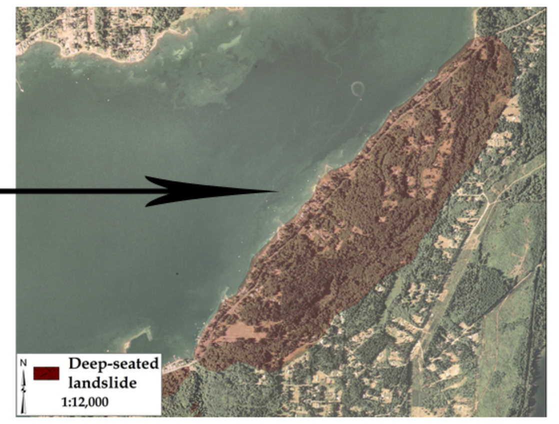


Statewide 1:100,000 landslide database



Landslides on the south side of Little Hill, Chehalis Headwaters, from the Dec. 3rd, 2007 storm
(photo by Trevor Contreras)





Alderwood landslide near Lynch Cove, Mason County, occured in 900AD and triggered a tsunami that inundated Lynch Cove. (imagery by Isabelle Sarikhan)

Landslide Processes and Attributes

Landslide Processes

Landslide processes were modified from the Washington Department of Natural Resources, Forest Practices Division, Landslide Hazard Zonation Project Protocol (LHZ, 2004). The changes reflect gaps in the LHZ protocol, such as the additions of hyperconcentrated flows and lateral spreads, which are critical in future land use planning. Landslide processes were grouped into two categories, shallow landslides and deep-seated landslides. Shallow landslides are differentiated to shallow undifferentiated (including shallow colluvial), debris flow, debris slide (which includes debris avalanches), hyperconcentrated flows and block falls and topples. Deep-seated landslides are differentiated to lateral spreads, general deep-seated, earthflows, translational, rotational, composite and megalandslides/sturzstroms.

Attributes

Landslide attributes were modified from the Washington Department of Natural Resources (DNR), Forest Practices Division, Landslide Hazard Zonation Project Protocol (LHZ, 2004). Attributes were created for multiple reasons. The first was to establish a balance between critical information and attribute excessiveness. The second was to ensure critical information would be available for land use planning and hazard assessment, as well as for future research into landslide hazards. The third was to establish a basis by which to flag landslides that have caused or potentially could cause damage. Emphasis was placed on landslide triggers, such as slope, gradient, and structure. When available, landslides were hyperlinked to pictures and websites, allowing land managers and emergency responders to further assess future hazards. This will also allow the public to better understand landslide dangers within Washington State.

FEATURE_ID	DATABASE_SLIDEID	DATABASE_ID	LANDSLIDE_TYPE	DSLS_MORPHOLOGY	CERTAINTY	FAILURE_YEAR	DATE_ID	ASPECT	SLP_MORPHOLOY	GRADIENT	GRADIENT_ID
Unique ID to identify landslide	ID of the landslide in the original database	ID if available from another database	Landslide process	Distinctness of DSLS	Certainty that this is a landslide.	Year/month/day of landslide failure	Approximate date of landslide or when identified (this could be off by years, decades or centuries)	Aspect of the hill (direction) that the landslide is failing off of	Slope shape of where the landslide failed (limit to only shallow landslides)	Gradient at which the landslide failed	What was used to ID gradient?
			1 = Shallow undifferentiated	1 - Active, Reactivated, Recent	1 - Certain	Day/Month/Year	Day/Month/Year	Numerical degrees (360)	1 = concave	Numerical Degrees	1 - Field
			2 = Debris flow	2 - Dormant Distinct	2 - Probable				2 = concave-planar		2 - Lidar
			3 = Debris slide and avalanches	3 - Dormant Indistinct	3 - Questionable				3 = planar		3 - DEM (10m)
			4 = Lateral spreads	4 - Dormant Relict					4 = planar-convex		4 - DEM (30m)
			5 = Block fall or topple	5 - Stabilized/Abandoned					5 = convex, divergent		5 - Orthophoto
			6 = Deep-seated						6 = Other		
			7 = Deep-seated - earthflow								
			8 = Deep-seated - translational								
			9 = Deep-seated - rotational								
			10 = Deep-seated - composite								
			11 = Megalandslide/ Sturzstrom								
			12 - Hyperconcentrated Flows								

LANDUSE_TYPE	INFR_HAZ	TRIGGER_EVENT	GEOL_UNIT	GEOMAP_SOURCE	STRUCTURE	FIELD_CHECK	HYPERLINK	DATA_REFERENCE	DNR_Check
Was there any noted activity associated with the failure?	Is this a hazard to houses, roads, infrastructure?	Have these landslides been caused by a regional event?	Geologic Unit that the landslide initiated in.	Geologic map and date that was used to locate the geology.	What type of structure is the landslide associated with?	Was this landslide checked in the field?	Link to photo, report, or website	Reference of where data previously came from	Was this landslide evaluated by a DNR personnel?
1 - Harvest related (including yarding)	1 - Certain has damaged	Enter event with year (ie: Nisqually Earthquake of 2001; Rain-on-snow event of 1996)			1 - Anticline/ Monocline	1 - Field checked by DNR personnel			1- This event has been reviewed by a geologist
2 - Road/railroad/trail	2 - Probable has damaged				2 - Tilted Blocks/ Units	2- Field checked by previous individual			2 - This event hasn't been reviewed by a geologist
3 - Urban development/modifications (house; business, etc)	3- Questionable has damaged				3 - Fault	3- Field checked remotely (from a distance)			3 - This event has been omitted from the database by a geologist
4 - Agriculture/Ranging	4 - Certain poses a threat of damage				4 - Bedding Plane	4- Not checked in the field			4 - This event has been modified from the original data (to enhance accuracy)
5 - Undisturbed	5 - Probable poses a threat of damage				5 - Interbeds				
6- Forest Fire	6 - Questionable poses a threat of damage				6- Other				

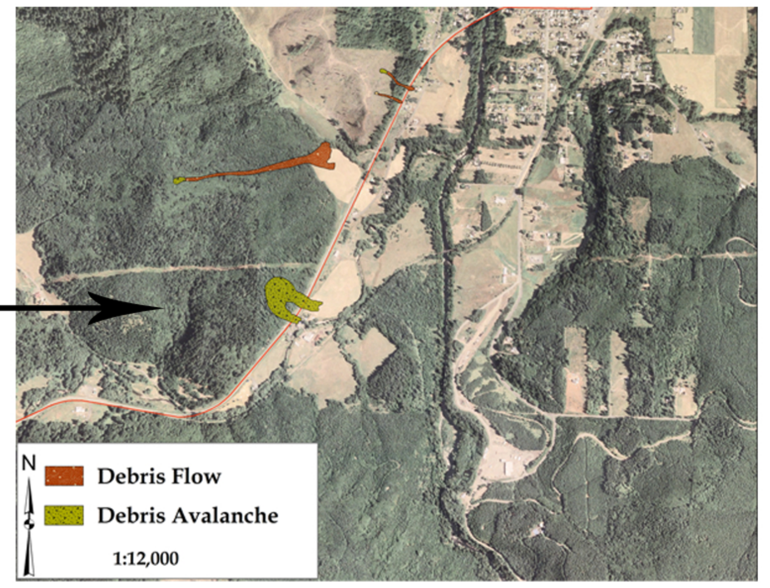
Converting Existing Data into a GIS Database

Existing

The inventory of existing landslide datasets and databases is sparse in Washington State. The most comprehensive landslide database is the 1999 Division of Forest Practices GIS statewide inventory of landslides (Boyd and Vaugeois, 2003). This database combines the 1:100,000 scale geologic mapped landslides with various other datasets, from scales at 1:24,000 to 1:12,000. The majority of datasets at a scale of 1:24,000 to 1:12,000 are from DNR studies of various departments. The rest of the datasets are from county or tribal records, or from independent mapping projects. Polygons were entered as a single layer (no overlapping polygons) and were sectioned to represent overlapping polygons. Every dataset has been converted, when possible, to the attribute-set within the Landslide Hazard Zonation Project Protocol.
The remaining inventoried landslide datasets are from various projects in the Washington Geological Survey. Each project is maintained in a GIS database with overlapping polygons and attributed for the specific project.

Converting Data

A dataset is converted into the Washington Geological Survey's landslide database by importing the polygons and relevant attributes into the database. In the case of the Division of Forest Practices Landslide Database, landslides of the scale of 1:100,000 were separated from the scale of 1:24,000 and 1:12,000. This was completed by overlaying the existing coverage of the 1:100,000 scale landslides and removing the polygons. The polygons were then hand-merged into single polygons and pasted into a new layer, allowing the polygons to be layered. Errors in attributes were noted in this process to insure quality of data. The layered polygons were then entered into the Washington Geological Survey's landslide database and relevant attributes were inserted into the database.
Original datasets will be preserved online for download, allowing the previous studies' unique attributes to be preserved. Each dataset within the Washington Geological Survey contains a unique code allowing the user to easily determine which dataset the landslide originated. This approach increases the usefulness of the database without allowing it to grow to unmanageable levels and by allowing the user to explore unique attributes of specific studies.



Landslide covering SR 6 east of Pe Ell, from the Dec. 3rd, 2007 storm. (photo by Kelsay M.D. Stanton)

Emergency Response

An important aspect of landslide hazard reduction is real-time monitoring and emergency response (Spiker and Gori, 2003). In addition to hazard response, DGER intends to provide an on-line data collection form to encourage Washington citizens to document all sizes of landslides to keep the database up to date and detailed. This form will request information regarding the size and type of landslide, material type, economic damage, etc. While not all citizens will be able to assess all aspects of landslides, this form will help keep DGER geologists informed about potentially very large or very damaging events which would require field assessment. A landslide database form will require DGER geologists to participate in educational forums for Washington citizens, according to legislative mandate RCW 43.92.900 which states, "It is the intent of the legislature that there be an effective State Geological Survey that can produce essential information that provides for the health, safety, and economic well-being of the citizens."

Landslide from December 3rd storm in the Chehalis headwaters.

Washington State Geological Survey Landslide Database form

Date of Landslide	Name of person	Location (Address, GPS location, or lat/long coordinates)
12/03/07	Isabelle Sarikhan	123.89.29W; 46.29.38N

Landslide Type (check box): [ ] Shallow Undiff.; [ ] Debris Flow; [X] Debris Slide; [ ] Lateral Spread; [ ] Falls or Topples; [ ] Deep-seated; [ ] Sturzstrom/Mega

Deep-Seated Landslide Type: [ ] Earthflow; [X] Translational; [ ] Rotational; [ ] Composite; [ ] Unknown/Other

Deep-Seated Landslide Morphology: [X] Active, recent, or reactivated; [ ] Dormant Distinct; [ ] Dormant Indistinct; [ ] Dormant Relict; [ ] Stabilized or Abandoned

Land-use Contributions: [X] Harvest related; [ ] Road, trail, rail; [ ] Urban area; [ ] Agriculture; [ ] Undisturbed

Infrastructure Hazard (is this a hazard to infrastructure)
Damaged: [ ] Certain; [X] Probable; [ ] Questionable
Threat of damage: [ ] Certain; [X] Probable; [ ] Questionable

Approximate slope of ground before landslide (degrees): [ ]

Certainty: [X] Certain; [ ] Probable; [ ] Questionable

Landslide dimensions: Length (ft); Width (ft); Depth (ft); Volume (ft); Area (ft)

Structural Contribution: [ ] Anti/monocline; [ ] Tilted blocks/units; [ ] Faults; [ ] Bedding planes; [ ] Interbeds; [ ] Other (state below)

Comments: From the December 3rd storm event

References

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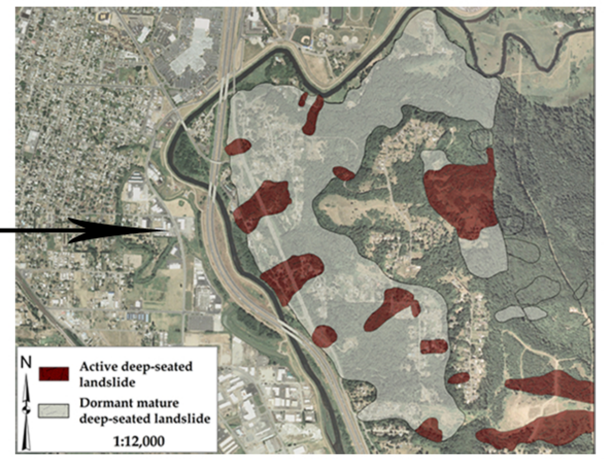
Deep-seated landslide along coastal bluff in Mason County, 2006. (photo by Isabelle Sarikhan)



Reactivation of portion of larger slide #271. Declared federal landslide disaster area in 1998. 138 homes affected, 128 total or partial losses. (photo by Karl Wegmann)