

# WASHINGTON STATE'S NEW LANDSLIDE INVENTORY MAPPING PROTOCOL

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1 Lidar image of a landslide in Pierce County, Washington.

## Project Summary

With the formation of the new Landslide Hazards Program at the Washington Geological Survey (WGS), landslide mapping efforts in Washington State have shifted from inventories in managed forest lands to assessments of where people live, work, and recreate. Due to this change of scope and the recent collection of high-resolution lidar, the WGS published the Protocol for Landslide Inventory Mapping from Lidar Data in Washington State (Slaughter and others, 2017) in April 2017. The objective of the inventory protocol is to establish a standard method for the production of a GIS-based landslide inventory. The protocol includes techniques describing how to create lidar derivatives to assist in the interpretation of landslides and contains an ESRI file geodatabase template with pull-down menus (domains) for ease and consistent data entry. The mapping procedures are similar to the landslide inventory protocol developed by the Oregon Department of Geology and Mineral Industries (Burns and Madin, 2009) and vary only slightly due to programmatic needs and regional differences. The data and attributes gathered from detailed landslide inventory mapping following this protocol are used to help generate regional landslide susceptibility maps.

## Potential Uses of the Landslide Inventory Data

- The metrics collected from detailed landslide inventory mapping are inputs for landslide susceptibility maps following Burns and others (2012) and Burns and Mickelson (2016). Susceptibility maps aid in estimating the potential for future landslides.
- Landslide inventory and susceptibility maps identify locations where the intersection of proposed land use and landslide hazards may trigger special planning considerations and additional geotechnical review. These maps will assist decision-makers by prioritizing mitigation measures to potentially reduce future losses due to landslides.
- These maps can aid in emergency management activities such as developing and refining emergency response plans and estimating resource impacts from future landslides.
- The landslide inventory can identify areas where repair of underground utilities or transportation networks may need additional review.
- Those purchasing or renting property or a home and (or) those who currently live on or adjacent to a landslide can be aware of the hazard and research the risk.

## Benefits of the Protocol

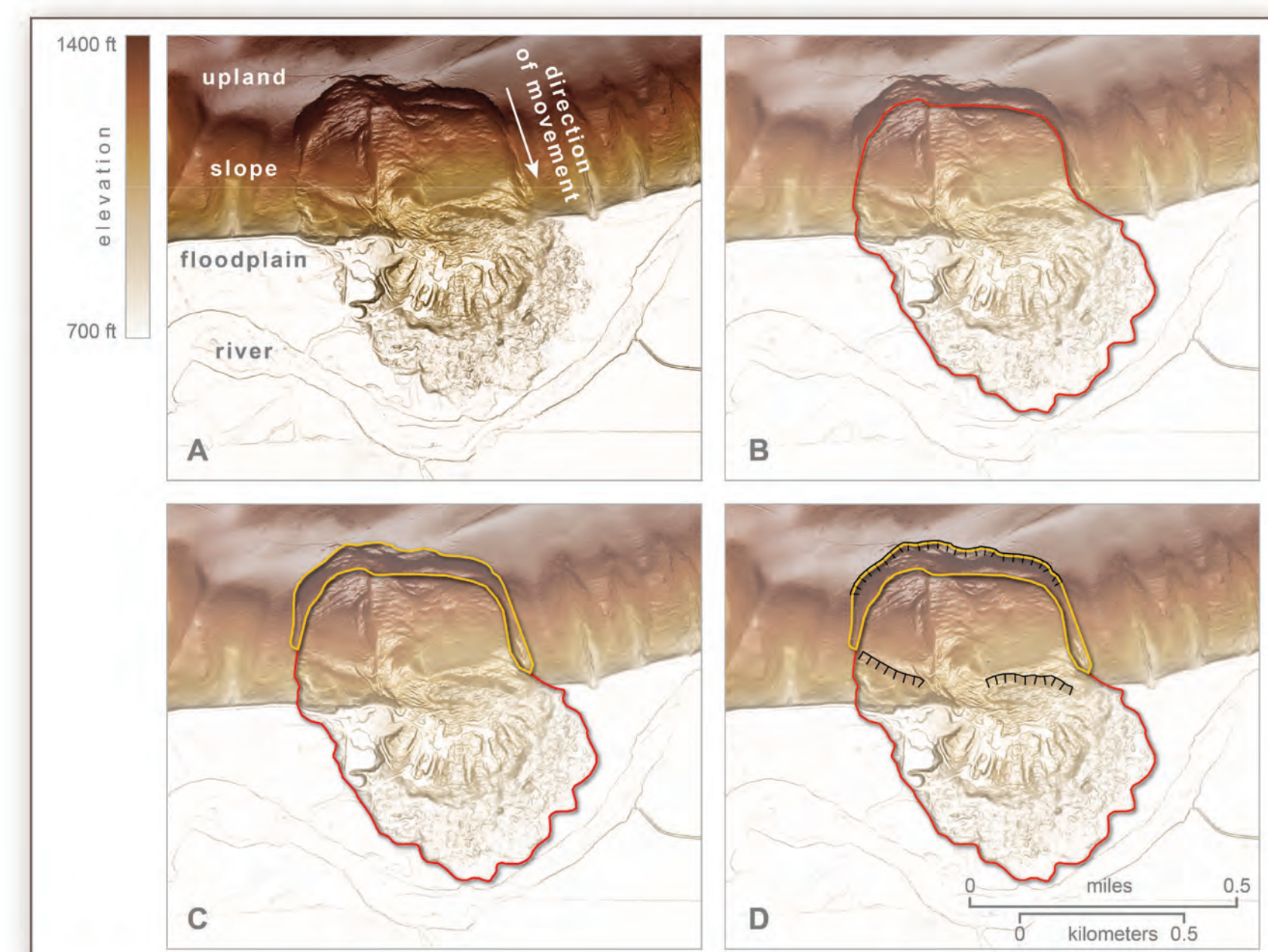
- Create a standardized method for the creation of a landslide inventory in a GIS to ensure that any and all data is inventoried in a consistent manner.
- Follows the well-established inventory protocol developed and currently used in Oregon.

## What's in the Publication

- Detailed methods for producing raster derivatives, populating geodatabases, and remote collection of landslide metrics using step-by-step descriptions.
- Blank geodatabase with drop-down menus (domains) with accompanying spreadsheet describing all fields and domains.
- An example of a mapped landslide with attributes.

## Download the pub here:

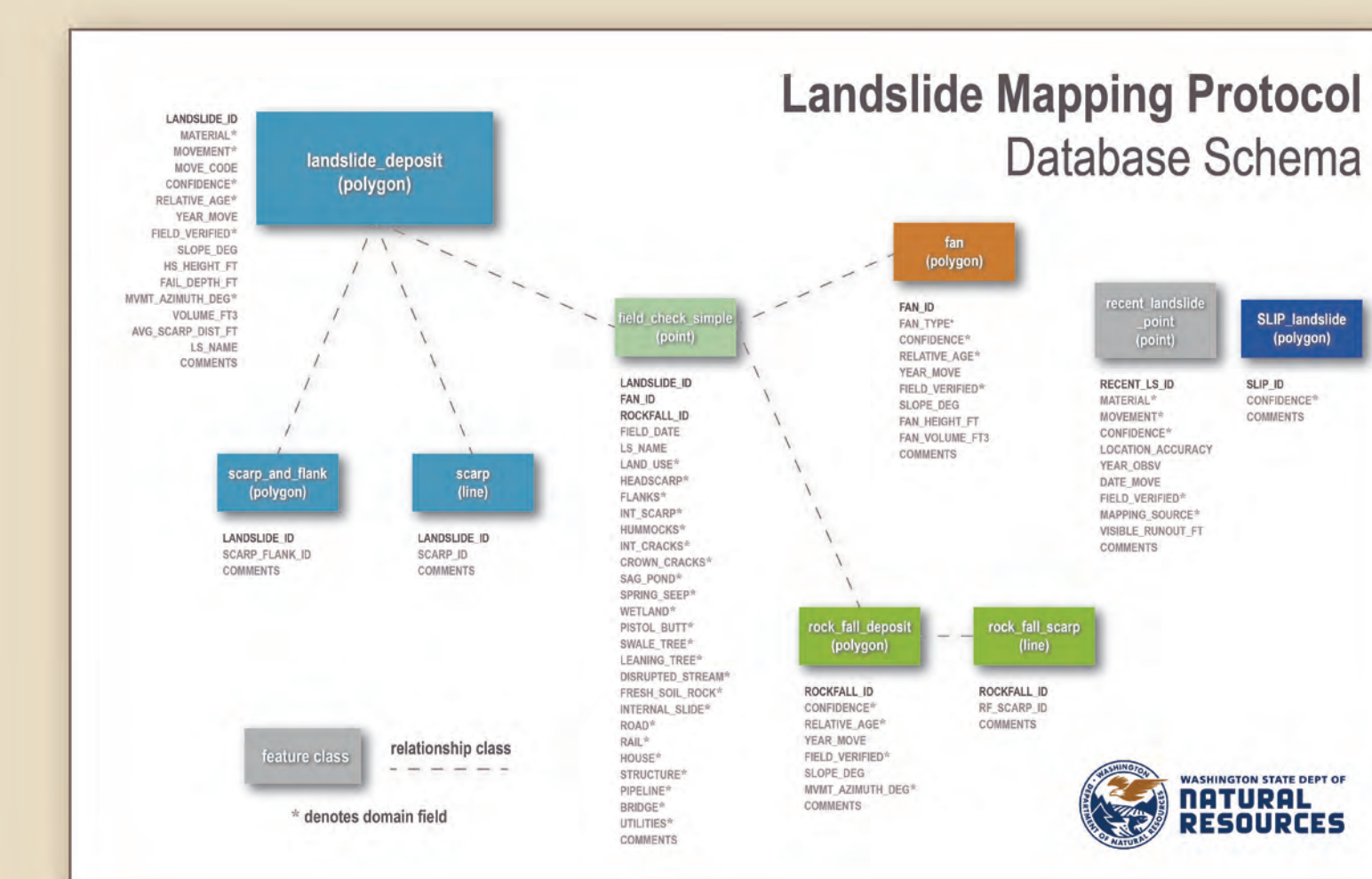
[http://www.dnr.wa.gov/Publications/ger\\_b82\\_landslide\\_inventory\\_mapping\\_protocol.zip](http://www.dnr.wa.gov/Publications/ger_b82_landslide_inventory_mapping_protocol.zip)



2 Components of digitizing a landslide deposit and associated landforms. Digitizing the landslide\_deposit (red), scarp\_and\_flank (yellow), and scarp (black).

## The Geodatabase

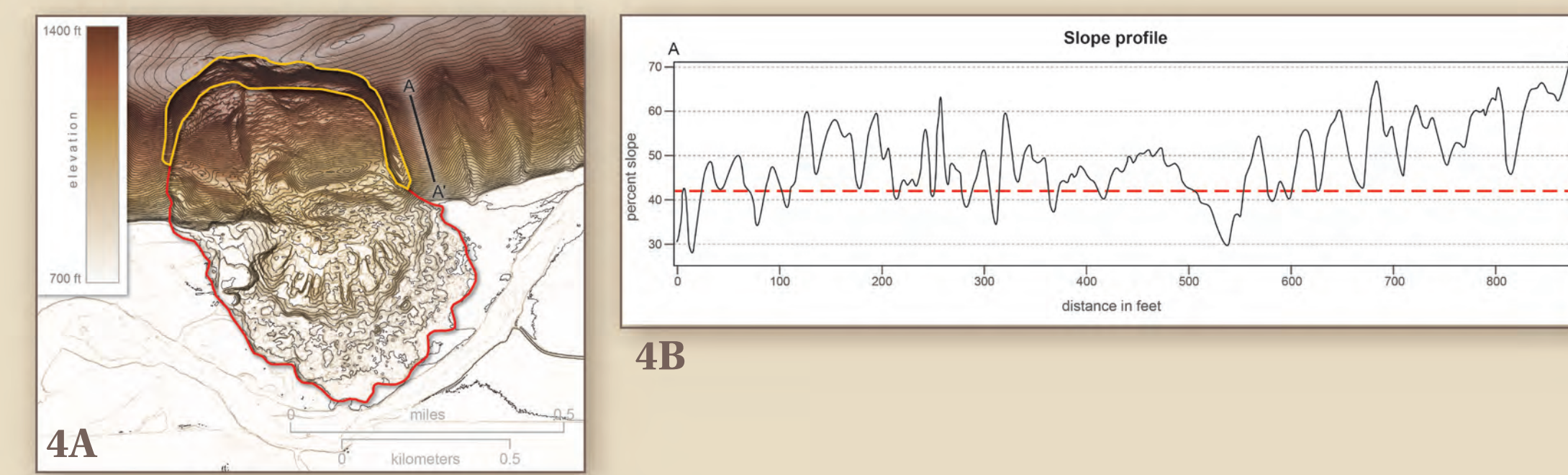
The landslide inventory database is structured such that specific feature classes are intended for different mapping techniques—each feature class contains attribute fields relevant to that particular mapping technique. For instance, when mapping landslide deposits in a GIS using lidar and orthoimagery, the feature class intended for remote mapping contains only attribute fields that can be populated from remotely sensed data. However, for on-the-ground mapping, a separate feature class contains attribute fields associated with data typically collected from field observations. The feature class for ground mapping (field\_check\_simple) can be linked to a mapped landslide deposit using the same primary key value associated with the feature.



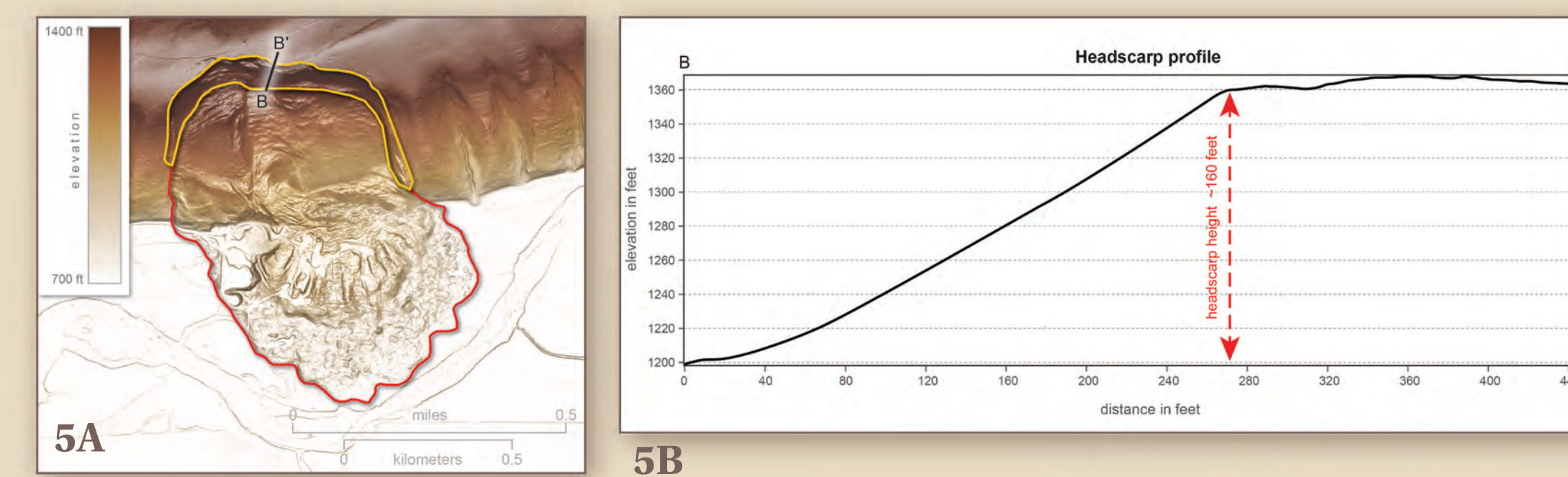
3A Database schema.

## Attribute Collection Methods

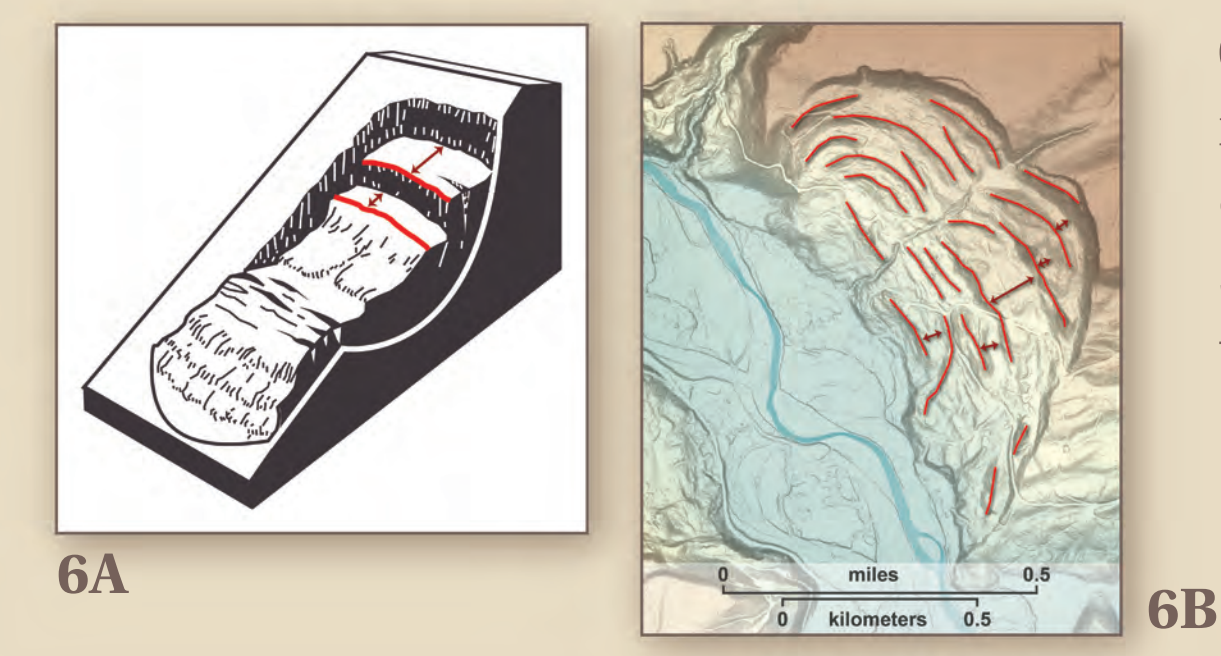
A primary goal of the protocol is consistency in landslide mapping from lidar. Below we illustrate how we collect some landslide metrics outlined in the protocol.



4A Measuring slope gradient. Line A-A' is an example of where to place the 3D Analyst toolbar Interpolate Line tool when measuring slope gradient. The line should be adjacent to the landslide deposit and outside of the landslide affected area. 4B Profile graph of the slope gradient and the estimated average slope illustrated by the red line, which is approximately 42 degrees.



5A Measuring headscarp height. Line B-B' marks where to measure headscarp height with the Interpolate Line tool in 3D Analyst toolbar. 5B Profile graph of headscarp elevation measured from line B-B' using the lidar DEM shown in 5A. The red line represents the headscarp height and is the difference between approximately 1,360 feet and 1,200 feet (160 feet).



6A, 6B Calculating the average horizontal distance between all identified landslide scarps, including the headscarp. The horizontal distance should always be measured from the top of one scarp to the base of the upslope scarp, as is illustrated by the red arrows, not from top of scarp to top of scarp. The sum of the horizontal distances is divided by the number of scarps to estimate the average scarp distance in feet. Adapted from Burns and Madin, 2009.

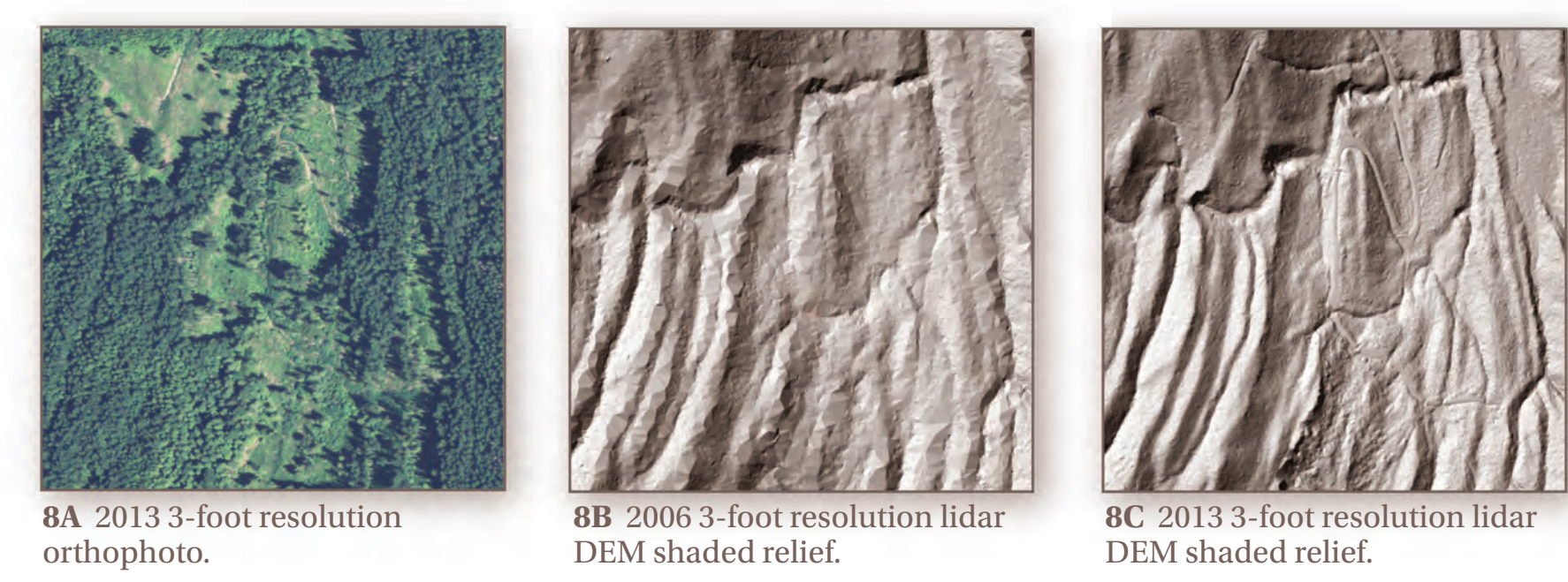
## Why do we need high-quality lidar?

Western Washington has very dense, temperate forests (7), so to collect sufficient ground returns lidar flown at >8 points/m<sup>2</sup> must be collected during leaf-off conditions. Figure 8 shows an orthoimage (8A) and two lidar hillshades from the same area (8B and 8C) with differing lidar quality near Bellingham, Washington. Areas that lack sufficient ground returns poorly model the Earth's surface and are called noisy, or TIN-y, and appear similar to a faceted mineral surface as in 8B. Note the significant detail missing between hillshades 8B and 8C, including the stream channels and forest road that is apparent in 8C.



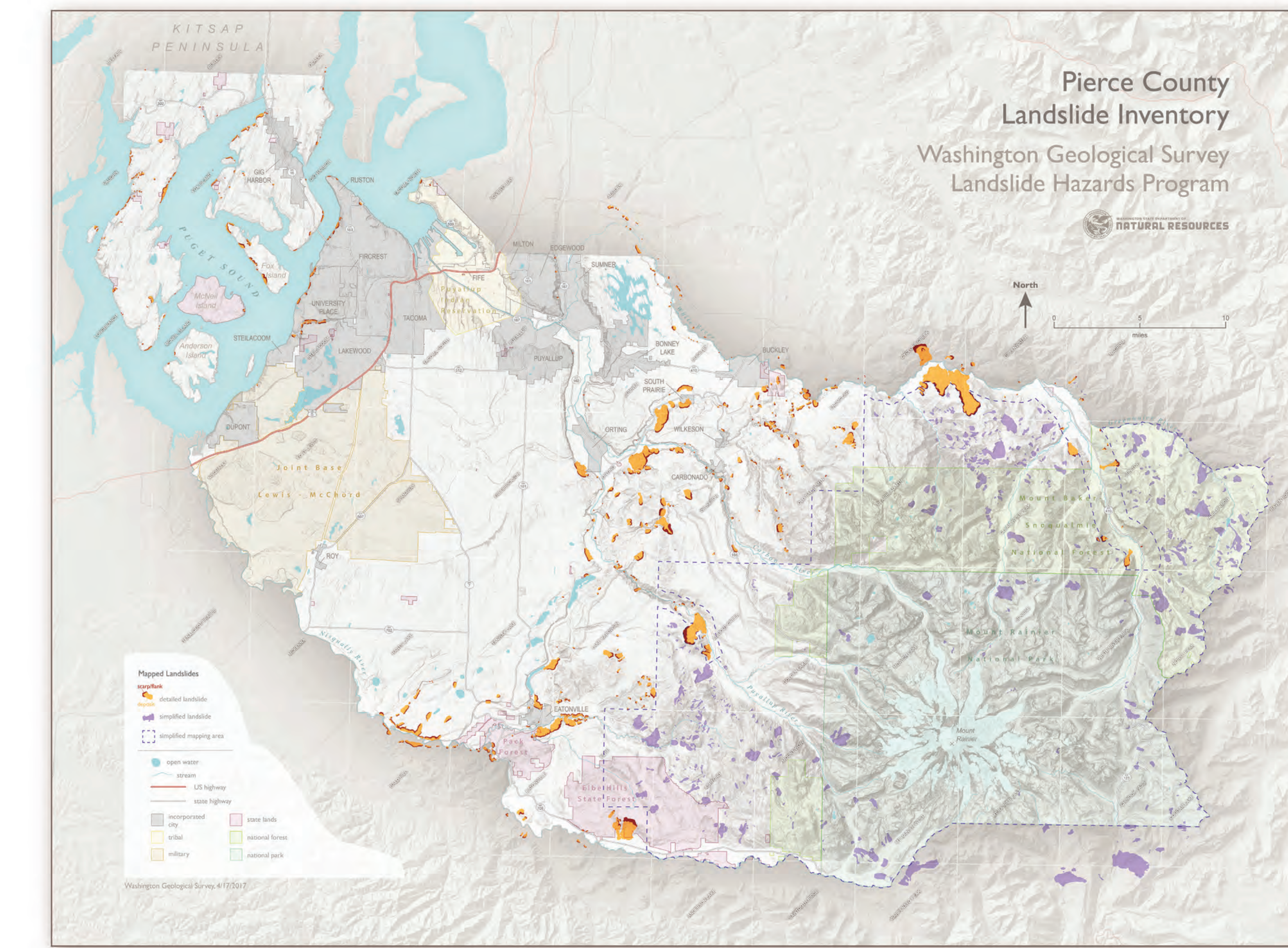
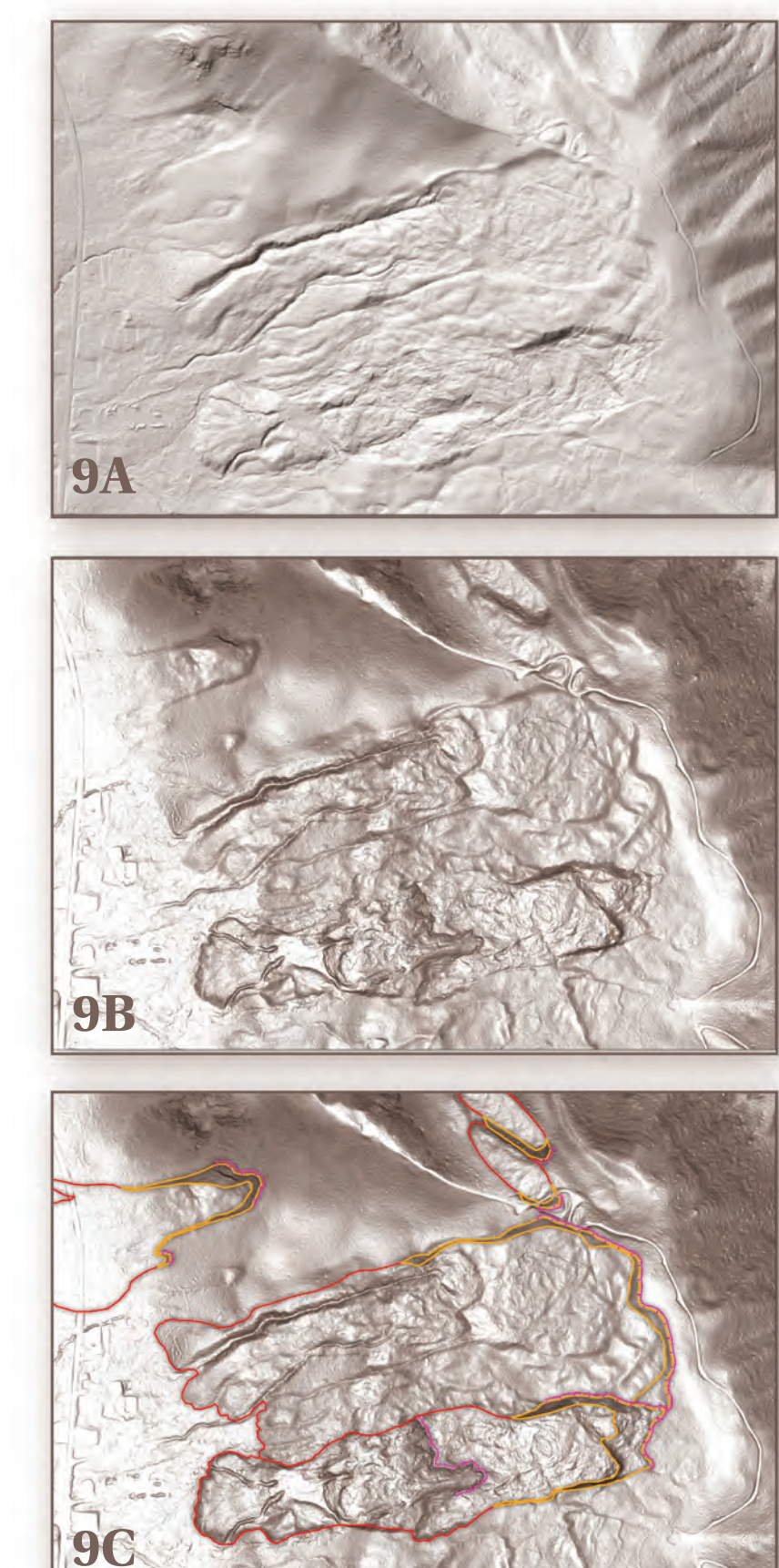
## Requirements

- High-quality lidar
- An experienced landslide hazards geologist
- Acceptance that more data isn't necessarily better

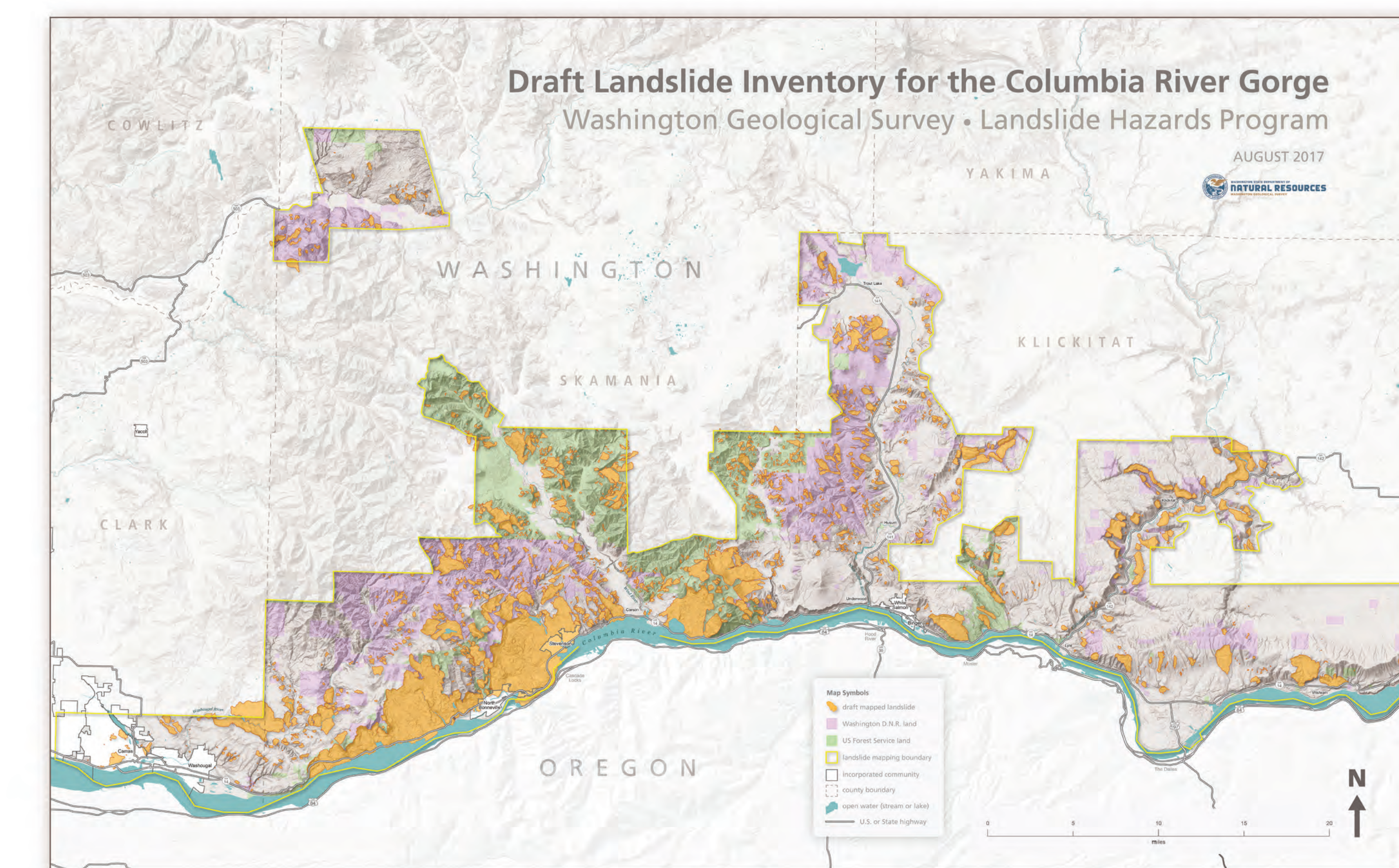


## Why we never digitize a landslide with a hillshade

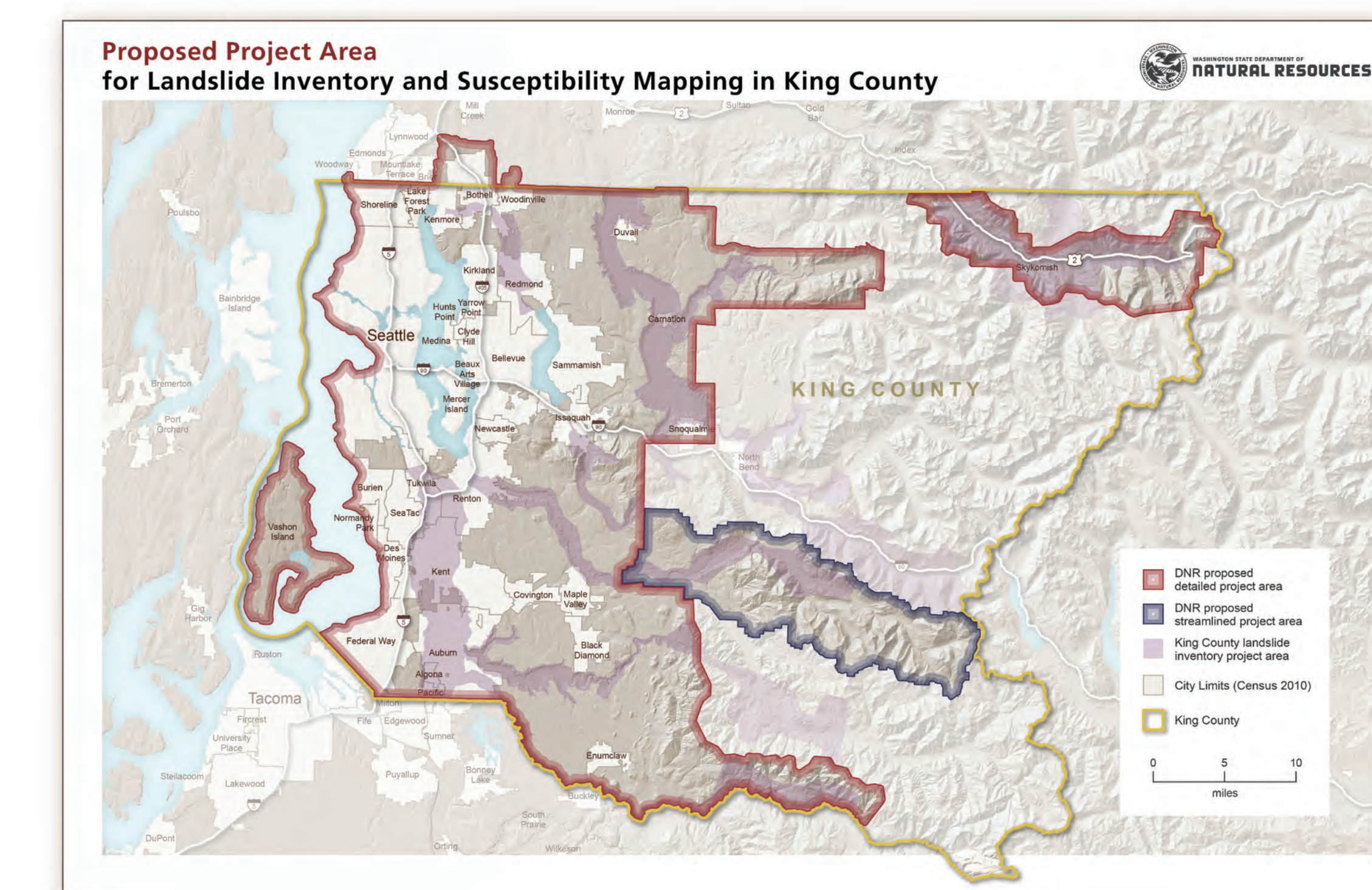
Slope maps are the most reliable method to accurately delineate a landslide deposit. A slope map depicts change in elevation and eliminates azimuthal bias from differing illumination angles represented by shaded relief rasters. 9A is a hillshade (shaded relief raster)(azimuth 315, altitude 45 degrees) and 9B is a slope map. Subtle features such as hummocky morphology, the extent of the toe and main scarp, and relative age are difficult to discern in 9A as compared to 9B. 9C shows our interpreted landslide landform features.



10 The first county-wide landslide inventory in Washington was completed in July 2017 for Pierce County, the second most populous county in the state. WGS mapped 1,800 mi<sup>2</sup> and 1,276 landslides within the county.



11 The WGS next focused on a 900 mi<sup>2</sup> project area in the Columbia River Gorge. More than 2,100 landslides have been mapped in this area; results will be published in early 2018.



12 The WGS is currently mapping a 1,300 mi<sup>2</sup> area in King County, focusing on the most populous areas that are also covered by high-quality lidar.

References:  
Burns, W. J.; Mickelson, K. A., 2016. Protocol for deep landslide susceptibility mapping: Oregon Department of Geology and Mineral Industries, Special Paper 48, 69 p. <http://www.oregongeology.org/pubs/sp-48.pdf>  
Burns, W. J.; Madin, J. P.; Mickelson, K. A., 2012. Protocol for shallow-landslide susceptibility mapping: Oregon Department of Geology and Mineral Industries Special Paper 45, 32 p. <http://www.oregongeology.org/pubs/sp/p-SP-45.htm>  
Burns, W. J.; Madin, J. 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.  
Slaughter, S. L.; Burns, W. J.; Mickelson, K. A.; Jacobacci, K. E.; Biel, Alyssa; Contreras, T. A., 2017. Protocol for landslide inventory mapping from lidar data in Washington State: Washington Geological Survey Bulletin 82, 27 p. text with 2 accompanying ESRI file geodatabases and 1 Microsoft Excel file. [http://www.dnr.wa.gov/Publications/ger\\_b82\\_landslide\\_inventory\\_mapping\\_protocol.zip](http://www.dnr.wa.gov/Publications/ger_b82_landslide_inventory_mapping_protocol.zip)