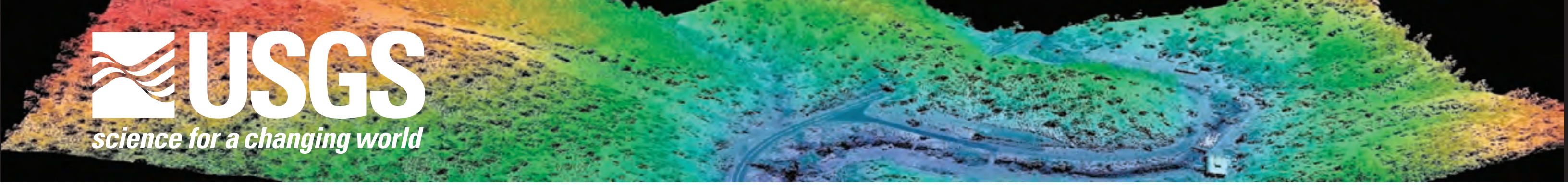

The 3D Elevation Program—Landslide Recognition, Hazard Assessment, and Mitigation Support

3D Elevation Information Underpins Our Understanding of Landslides

A core mission of the U.S. Geological Survey (USGS) is to provide information that leads to reduced loss of life and damage to property and infrastructure from landslides. Gathering this information relies on a detailed and accurate understanding of the landscape. The USGS Landslide Hazards Program (https://www.usgs.gov/science/mission-areas/natural-hazards/landslide-hazards) conducts landslide hazard assessments, pursues landslide investigations and forecasts, provides technical assistance to respond to landslide emergencies, and engages in outreach. All of these activities benefit from the availability of high-resolution, three-dimensional (3D) elevation information in the form of light detection and ranging (lidar) data and interferometric synthetic aperture radar (IfSAR) data.

Research on landslide processes addresses critical questions of where and when landslides are likely to occur as well as their size, speed, and effects (Schulz, 2005). This understanding informs the development of methods and tools for hazard assessment and situational awareness used to guide efforts to avoid or mitigate landslide impacts. Such research is essential for the USGS to provide improved information on landslide potential associated with severe storms, earthquakes, volcanic activity, coastal wave erosion, and wildfire burn areas. Decisionmakers in government and the private sector increasingly depend on information the USGS provides before, during, and following disasters so that communities can live, work, travel, and build safely. High-resolution 3D elevation data significantly aid in the refinement of assessments of where and when landslides will occur, improving information delivered to decisionmakers and the public (figs. 1 and 2). A nationwide program to provide a baseline of high-quality 3D elevation data is essential for supporting improved hazard assessments, response preparation, and effective response execution.

The 3D Elevation Program (3DEP) (Sugarbaker and others, 2014; see sidebar) is collecting 3D elevation data in response to a call for action to address landslide applications and a wide range of other urgent needs nationwide. 3DEP furnishes the programmatic infrastructure and provides data to users, reducing their costs and risks and allowing them to concentrate on their mission objectives. The programmatic infrastructure includes (1) data acquisition partnerships that leverage funding, (2) contracts with experienced private mapping firms, (3) technical expertise, standards, and specifications, and (4) most important, providing public access to high-quality 3D elevation data.

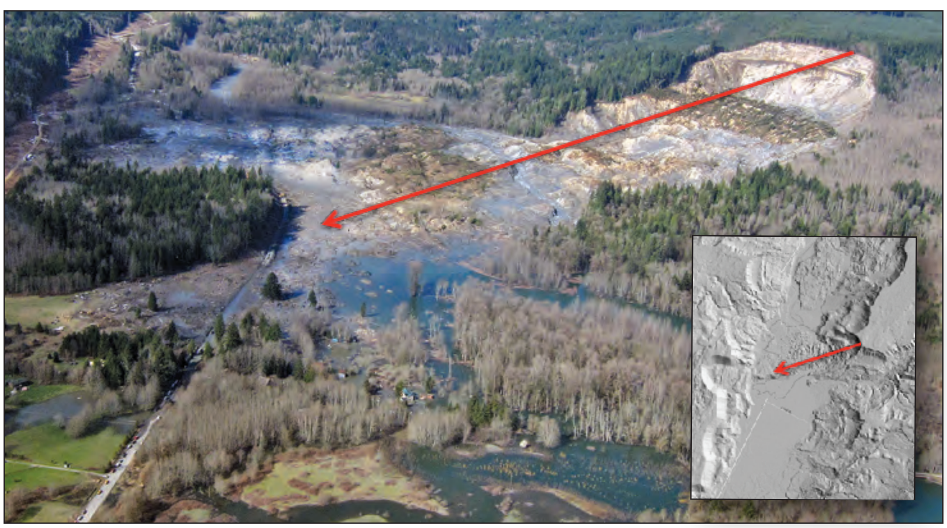

Figure 1. Oblique aerial view and smaller-scale lidar image (inset) of the Oso, Washington, landslide of March 22, 2014. Red arrows start at upper edge of scarp and show direction of material flow. Photograph taken on April 1, 2014, by Mark Reid (USGS). Lidar image derived from 3DEP data collected by the Washington Department of Transportation on March 24, 2014.

3D Elevation Program (3DEP)

The 3D Elevation Program (3DEP) is a national program managed by the USGS to acquire high-resolution elevation data (Sugarbaker and others, 2014). It produces point clouds, bare-earth digital elevation models (DEMs), and other products.

3DEP is backed by a comprehensive assessment of lidar, interferometric synthetic aperture radar (IfSAR), and related elevation data requirements (Dewberry, 2012) and is now an operational program. The goal of this high-priority cooperative program is to have complete coverage of quality level 2 lidar data for the conterminous United States, Hawaii, and the U.S. territories, and IfSAR data for Alaska, by the end of 2023.

Reduced Acquisition Costs and Risks

A funded national program will provide:

- *Economy of scale* by acquiring data for larger areas and reducing acquisition costs by 25 percent.
- *Predictable, efficient, and flexible Federal investments* that reduce costs for and allow better planning by Federal, State, Tribal, U.S. territorial, and local government partners, including the option of "buying up" to acquire higher quality data.
- *Consistent, high-quality, national coverage* that (1) provides data ready for applications that span project, jurisdictional, and watershed boundaries, (2) meets multiple needs, and (3) increases benefits to citizens.
- *Simpler data acquisition* that provides contracts, published data-acquisition specifications, and specialized quality assurance and information technology expertise. Partners reduce their risks and can concentrate on their business activities.

3DEP can conservatively provide new benefits of $690 million per year and has the potential to generate $13 billion per year in new benefits through applications that span the economy (Dewberry, 2012). The shared lidar, IfSAR, and derived elevation datasets would foster cooperation and improve decisionmaking among all levels of government and other stakeholders.

High-Quality Data

For the conterminous United States, Hawaii, and the U.S. territories, the USGS and its partners acquire quality level 2 or better lidar data. Quality level 2 data have a minimum nominal pulse spacing of 0.7 meters

> "Landslide hazard assessment at local and regional scales contributes to mitigation of landslides in developing and densely populated areas by providing information for (1) land development and redevelopment plans and regulations, (2) emergency preparedness plans, and (3) economic analysis with the goal of (a) setting priorities for engineered mitigation projects and (b) defining areas of similar levels of hazard for insurance purposes."
>
> —Baum and others (2014)

Uses of 3D Elevation Data

The conservative annual benefit of 3D elevation data to landslide applications in the United States is estimated to be $20.2 million (Dewberry, 2012). Examples of landslide recognition, hazard assessment, and mitigation support activities using 3D elevation data include:

- Providing input data for slope-stability models used to identify locations where shallow landslides may mobilize into fast-moving, potentially damaging and deadly debris flows.
- Giving fundamental and highly detailed descriptions of boundary and initial conditions for landslide initiation and mobility models.
- Providing information helpful in planning for evacuations and staging areas.
- Creating accurate landslide inventory and deposits maps and estimating the shape and relative activity of landslides. According to Baum and others (2014), using 3DEP data identified 3 to 200 times the number of landslides located when mapping the same densely forested areas using other technologies.
- Providing baseline reference information needed for change-detection comparisons, such as estimating sediment transport rates following a wildfire.
- Developing novel approaches for estimating landslide thickness and relative and calibrated ages of landslide deposits.

References Cited

Baum, R.L., Schulz, W.H., Brian, D.L., Burns, W.J., Reid, M.E., and Godt, J.W., 2014, Progress in regional landslide assessment—Examples from U.S.A.: World Landslide Forum 3, June 2–6, 2014, Beijing, China, plenary lecture, 36 p.

Dewberry, 2012, Final report of the National Enhanced Elevation Assessment (revised March 29, 2012): Fairfax, Va., Dewberry, 84 p. plus appendixes, http://www.dewberry.com/Consultants/Geospatial-Mapping/FinalReport-NationalEnhancedElevation-Assessment.

Haugerud, R.A., 2014, Preliminary interpretation of pre-2014 landslide deposits in the vicinity of Oso, Washington: U.S. Geological Survey Open-File Report 2014–1065, 4 p. plus geodatabases, https://pubs.usgs.gov/of/2014/1065. [See especially figure 2 on page 4.]

Schulz, W.H., 2005, Landslide susceptibility estimated from mapping using light detection and ranging (lidar) imagery and historical landslide records, Seattle, Washington: U.S. Geological Survey Open-File Report 2005–1405, 13 p., 1 pl., scale 1:30,000, https://pubs.usgs.gov/of/2005/1405/.

Sugarbaker, L.J., Constance, E.W., Heidemann, H.K., Jason, A.L., Lukas, Vicki, Saghy, D.L., and Stoker, J.M., 2014, The 3D Elevation Program initiative—A call for action: U.S. Geological Survey Circular 1399, 35 p., http://dx.doi.org/10.3133/cir1399.

By Vicki Lukas and William J. Carswell, Jr.

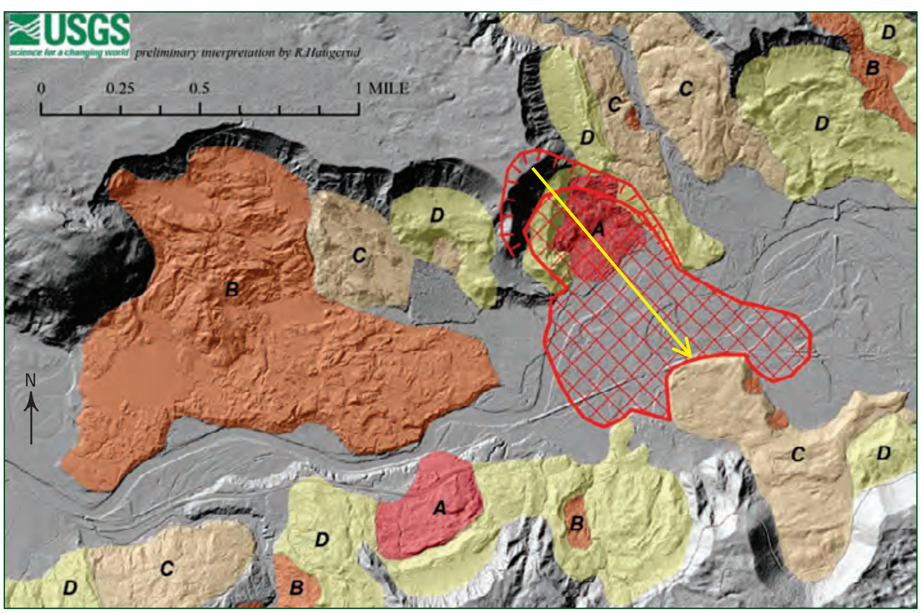

Figure 2. Shaded-relief image calculated from a 2013 high-resolution lidar survey of the North Fork Stillaguamish River valley, Washington. Red cross-hatched area marks the approximate extent of deposits (visible in figure 1) from the March 22, 2014, landslide near Oso. Colored areas show older landslide deposits, distinguished by their relative age: ***A***, youngest, to ***D***, oldest. Modified from Haugerud (2014). Yellow arrow (added) starts at the upper edge of the scarp and shows the direction of material flow as in figure 1.

3D Elevation Program—Continued

and a vertical error of 10 centimeters, measured as root mean square error in the elevation (z) dimension ($RMSE_z$). Statewide for Alaska, quality level 5 IfSAR data are acquired that have a vertical error of 185 centimeters $RMSE_z$.

The data must have been acquired during the previous eight years. For more information see the Lidar Base Specification available at http://pubs.usgs.gov/tm/11b4/.

Point Cloud and Derived Products

Lidar data products include the all-return classified point clouds and derived bare-earth DEMs. Each DEM dataset is identified by its horizontal resolution and is produced to a consistent set of specifications. All DEMs represent the topographic surface of the Earth and contain flattened water surfaces. Nationally seamless DEMs are produced by blending only the highest quality project data into a continuous terrain surface for the United States, and are published at resolutions of 1/3 arc-second, 1 arc-second, and 2 arc-seconds. The standard 1-meter DEM dataset is seamless within collection projects but not across projects.

IfSAR data in Alaska include digital surface models, orthorectified intensity images, and 5-meter-resolution hydro-flattened DEMs.

The USGS integrates the elevation model data into its national elevation data coverage, as a component of The National Map. All 3DEP products to include an elevation-point query service and bulk-point query service are components of The National Map. Data are available, free of charge and without use restrictions. To download 3DEP products visit http://viewer.nationalmap.gov/basic/.

Ways to Participate

Partners may contribute funds toward data acquisition projects managed by the USGS, or they may receive cooperative funds to manage their own acquisition projects. The Broad Agency Announcement process is the primary mechanism used to establish agreements between partners. For more information see the 3DEP Web site at http://nationalmap.gov/3DEP/index.html. Organizations may also access the geospatial products and services contracts and quality control services managed by the USGS to acquire 3DEP data. Organizations may contribute existing elevation data that meet 3DEP specifications. More information about using USGS contracts or about other ways to contribute is available by request through http://nationalmap.gov/3DEP/3dep_feedback.html.

Learn More About 3DEP

Please send questions to:
Michael A. Tischler, Director
USGS National Geospatial Program
12201 Sunrise Valley Drive, MS 511
Reston, VA 20192
Email: 3DEP@usgs.gov

ISSN 2327-6916 (print)
ISSN 2327-6932 (online)
https://doi.org/10.3133/fs20163094