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The 3D Elevation Program—Supporting Washington's Economy

Introduction

Washington State has a geographically diverse and spectacular landscape that is divided to the east and west by the largely volcanic mountains of the Cascade Range. Approximately 88 percent of the population lives in western Washington, mostly in urban areas. The climate is varied, with high precipitation and seasonal flooding in the western part of the State, while drier conditions are found east of the Cascades. Where the terrain is mountainous, the dominant vegetation is coniferous forests, which are prone to frequent seasonal fires. The climate and land use in combination with a dynamic geology result in frequent landslides. Washington has the second highest risk, after California, of large and damaging earthquakes because of its geologic setting. Critical applications that meet the State's management needs depend on light detection and ranging (lidar) data that provide a highly detailed three-dimensional (3D) model of the Earth's surface and aboveground features.

The 3D Elevation Program (3DEP; see sidebar) is managed by the U.S. Geological Survey (USGS) in partnership with Federal, State, Tribal, U.S. territorial, and local agencies to acquire consistent lidar coverage at quality level 2 or better (table 1) to meet the many needs of the Nation and Washington. However, in some areas the emphasis is on acquisition of quality level 1 lidar. The status of available and in-progress 3DEP baseline lidar data in Washington is shown in figure 1. 3DEP baseline lidar data include quality level 2 or better, 1-meter or better digital elevation models, and lidar point clouds, and must meet the Lidar Base Specification version 1.2 (https://www.usgs.gov/3dep/lidarspec) or newer requirements. The National Enhanced Elevation Assessment (Dewberry, 2012) identified user requirements and conservatively estimated that availability of lidar data would result in at least $9 million in new benefits annually to the State. The top nine Washington business uses for 3D elevation data, based on the estimated annual conservative benefits of 3DEP, are shown in table 2.

Table 1. Data quality levels, pulse spacing, and pulse density. Quality level 2 or better lidar data meet 3DEP requirements.

[Specifications for quality level 0 (QL0) are from Heidemann (2014, p. 3 and table 1); for quality levels 1 and 2 they are from Sugarbaker and others (2014, table 1). In the quality level column, QL0 represents the highest level of quality. $RMSE_z$, root mean square error in the elevation (z) dimension; cm, centimeter; m, meter; pls/m^2, first return pulses per square meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	$RMSE_z$ (cm)	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m^2)
QL0	≤5	≤0.35	≥8.0
QL1	≤10	≤0.35	≥8.0
QL2	≤10	≤0.71	≥2.0

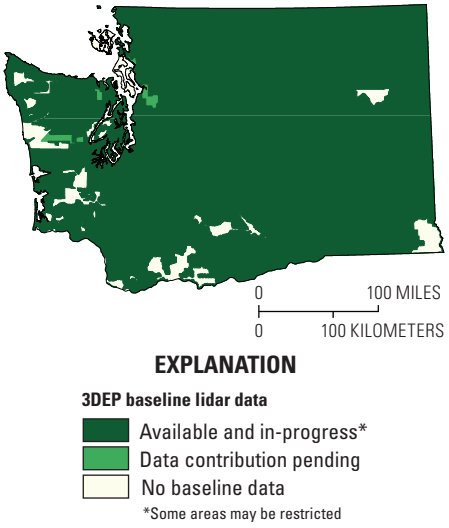

Figure 1. Map of Washington showing status of 3D Elevation Program (3DEP) baseline lidar data as of December 2022. Visit https://usgs.gov/NationalMap/LidarExplorer to see and download currently available data.

Geologic Resource Assessment and Hazard Mitigation

Geologic mapping, including the assessment of mineral deposits and geologic hazards, can be performed more efficiently and accurately using lidar data. The maps produced by the Washington Geological Survey (WGS) provide a base for further exploration and depict faults, folds, landslides, and cross sections of geologic units.

The Oso landslide on March 22, 2014, claimed 43 lives, and related reconstruction projects cost $43 million (Washington State Department of Transportation and Snohomish County Public Works, 2015). In response to the Oso landslide, the Washington State Legislature in 2015 tasked the WGS to provide a landslide inventory and acquire quality level 1 lidar data for hazards mapping of every county in the State. With the availability of lidar bare-earth digital elevation models derived from 3DEP data, a detailed view of the Earth's surface without vegetation (fig. 2) is possible, allowing for the identification and systematic mapping of features, which can support geologic risk assessment, hazard mitigation, and land-use planning (Washington Geological Survey, 2018).

> Dave Norman, former Washington State Geologist, said the importance of lidar hit home when geologic mappers told him they could produce higher quality maps with it.

Forest Resources Management

The Washington Department of Natural Resources and private timber companies use lidar to generate detailed bare-earth and tree canopy models of forested lands. Lidar data facilitate the estimating of forest volume, density, biomass, leaf area, canopy height, and growth rate. In 2021, the contribution of the forestry products industry to the State's economy was approximately $36 billion (Mason, Bruce & Girard, Inc., 2022, table 7). Wildfires, however, cause significant losses. Lidar is becoming important in its use in wildfire prevention by allowing foresters to estimate fuel loads and forest health in forested lands across the State.

Natural Resources Conservation

Lidar is seeing increasing use in Washington in habitat restoration to aid the recovery of endangered species. Large efforts are underway to restore salmon habitat, which includes upland streams, lakes, wetlands, river deltas, and shorelines. Lidar data are used to examine potential fish barriers such as culverts to determine a stream's fish-bearing potential, and also in pre- and post-dam-removal assessments.

3DEP by the Numbers: Washington

Expected annual benefits	$9.46 million
Estimated cost for quality level 2 completion[1]	$0.88 million
Payback	0.09 year

[1]Quality levels 0 and 1 collection is at additional cost.

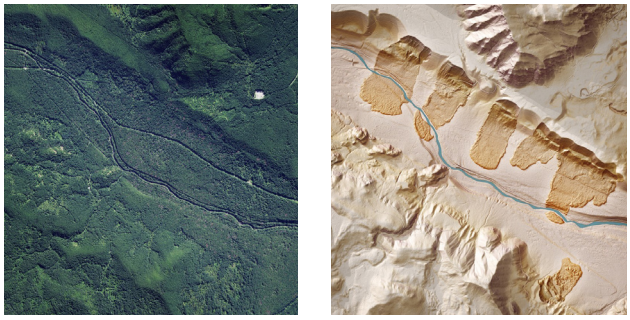

Figure 2. Comparison of aerial photograph (left) and lidar-derived image (right) of the Cedar River, King County, Washington. Landslide activity is not readily apparent in the former but is visible in the latter. At least six landslides can be seen in the lidar-derived image. Graphics courtesy of the Washington Geological Survey.

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Table 2. Conservative benefits estimates for the top nine Washington business uses of the proposed 3DEP data identified in the National Enhanced Elevation Assessment (Dewberry, 2012).

Rank	Business use	Annual benefits (millions)
1	Natural resources conservation	$2.21
2	Infrastructure and construction management	1.46
3	Agriculture and precision farming	1.52
4	Flood risk management	1.33
5	Geologic resource assessment and hazard mitigation	0.73
6	Water supply and quality	0.64
7	Coastal zone management	0.50
8	Sea-level rise and subsidence	0.48
9	Forest resources management	0.38
	Other	0.21
	Total	9.46

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3D Elevation Program (3DEP)

The 3D Elevation Program is managed by the U.S. Geological Survey (USGS) on behalf of the community of Federal, State, Tribal, local, and other partners and users of elevation data. In response to growing needs for high-quality elevation data, the goal of 3DEP is to complete acquisition of nationwide light detection and ranging (lidar) data (interferometric synthetic aperture radar [IfSAR] data in Alaska) to provide the first-ever national baseline of consistent, high-resolution topographic elevation data—both bare-earth digital elevation models and 3D point clouds.

Benefits

- Economies of scale by acquiring data for larger areas.
- Predictable and flexible Federal investments that reduce costs and allow better planning.
- Consistent national coverage that provides data for applications that span project, jurisdictional, and watershed boundaries.
- Simplified data acquisition that provides contracts, project management, quality assurance, and published data specifications.
- National benefits of $690 million per year conservatively, with the potential to generate $13 billion per year in additional benefits through applications that span the economy (Dewberry, 2012).

High-Quality Data and Products

3DEP lidar provides coverage with a minimum of two points per square meter and a vertical error not to exceed 10 centimeters, measured as root mean square error in the elevation (z) dimension ($RMSE_z$) (see table 1). 3DEP baseline lidar data products include all data points collected (point clouds) and bare-earth digital elevation models with a 1-meter or better resolution. The USGS integrates the elevation data into The National Map. Data are available free of charge and without use restrictions. To download 3DEP products visit https://apps.nationalmap.gov/downloader/.

Ways to Participate

3DEP participation is open to Federal, State, Tribal, U.S. territorial, and local government partners, as well as private sector partners, and offers the option to acquire higher quality data. Partners may contribute funds toward projects managed by the USGS, or they may receive cooperative funds to manage their own projects. An annual Broad Agency Announcement is the mechanism used to establish partner agreements. Organizations and the private sector may contribute existing data that meet 3DEP requirements. For more information see the 3DEP website at https://usgs.gov/3DEP/collaborate/.