NATURAL RESOURCES

# ALLUVIAL FAN INVENTORY OF KLICKITAT COUNTY, WASHINGTON

by Katherine A. Mickelson, Trent Adams, and Crystal Lambert

WASHINGTON
GEOLOGICAL SURVEY
Report of Investigations 44
June 2023

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WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
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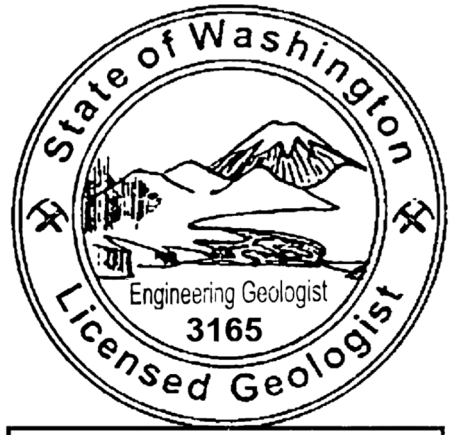


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# Alluvial Fan Inventory of Klickitat County, Washington

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## ABSTRACT

The Washington Geological Survey presents an inventory of 4,231 alluvial fans in Klickitat County mapped following published protocols for identifying features from lidar data. Alluvial fans are prone to flash floods and debris flows and therefore pose a significant hazard to public safety. This updated alluvial fan inventory intends to increase awareness of debris flow and flash flood hazards in Klickitat County and provide information for planners, emergency managers, public works departments, and those who live or work where these hazards could impact their daily lives. This inventory aims to assist local jurisdictions in making educated decisions about their assets, community safety, and growth management using the best-available science.

## INTRODUCTION

Alluvial fans are broad, gently sloping, fan-shaped landforms made of sediment and debris deposited when a stream emerges from steep hillslopes onto a wide, flat valley. Over tens to hundreds of years, the sediment carried by these streams builds up to form an alluvial fan.

Debris flows and flash floods can deposit large amounts of sediment and debris on an alluvial fan in a matter of hours. A flash flood is a rapid increase in flow along a stream channel that may allow the water to overflow channel banks and cause a flood. If a flood contains rocks, trees, and other debris, it is termed a debris flow. Debris flows can also travel a considerable distance from the uplands to the valley floor, where they can disrupt roadways and other infrastructure lifelines, destroy property, and cause flooding. Due to their speed and destructive capability, debris flows pose an immediate and critical threat to public safety.

Though streams feeding alluvial fans may be dry most of the year, they can quickly become flooded during rainstorms, especially following a wildfire. Wildfires dramatically change landscape and ground conditions, leading to an increased risk of flash floods and debris flows. High-intensity fires can cause soils to become temporarily water repellent after the fire. This lack of ability of the land to absorb water and the loss of vegetated cover can lead to unusually high runoff, which can trigger flash floods and (or) debris flows with even modest rainstorms. The risk of these hazards remains elevated for several years after a wildfire has been extinguished.

As populations grow and rural portions of Klickitat County are developed, and as the size, frequency, and severity of wildfires increase, a lack of awareness of unrecognized alluvial fans may pose an increased risk to lives and property. Those living on or adjacent to an existing alluvial fan are often unaware of the hazards and the potential consequences they pose.

Alluvial fan inventories identify areas that have likely had flash flooding and (or) debris flows in the past. Areas that have experienced these hazards are more susceptible to experiencing them in the future. Geologists trained in identifying alluvial fan hazards prepared this inventory publication using the best-available science.

This report provides a brief overview of the mapping methods and results for Klickitat County. The accompanying GIS data are available for viewing on the Washington Geologic Information Portal (geologyportal.dnr.wa.gov).

## INTENDED USE

Alluvial fan inventories assist planners, emergency managers, public works departments, and those who live and work where flooding or debris flows could impact their daily lives, by identifying areas that have likely experienced these hazards in the past. Examples of uses for this inventory include:

- Public works: An alluvial fan inventory can identify vulnerable areas where utilities or transportation networks may be impacted by flooding or debris flows.
- Planning: An alluvial fan inventory can identify areas where proposed land use intersects alluvial fans. These areas need additional geotechnical review to ensure that the proposed land use is not adversely impacted by flooding or debris flows.
- Emergency management: Access to alluvial fan inventories can help emergency managers assess the likelihood that a reported incident may be debris-flow-related. When planning evacuation routes, roads that cross existing alluvial fans should

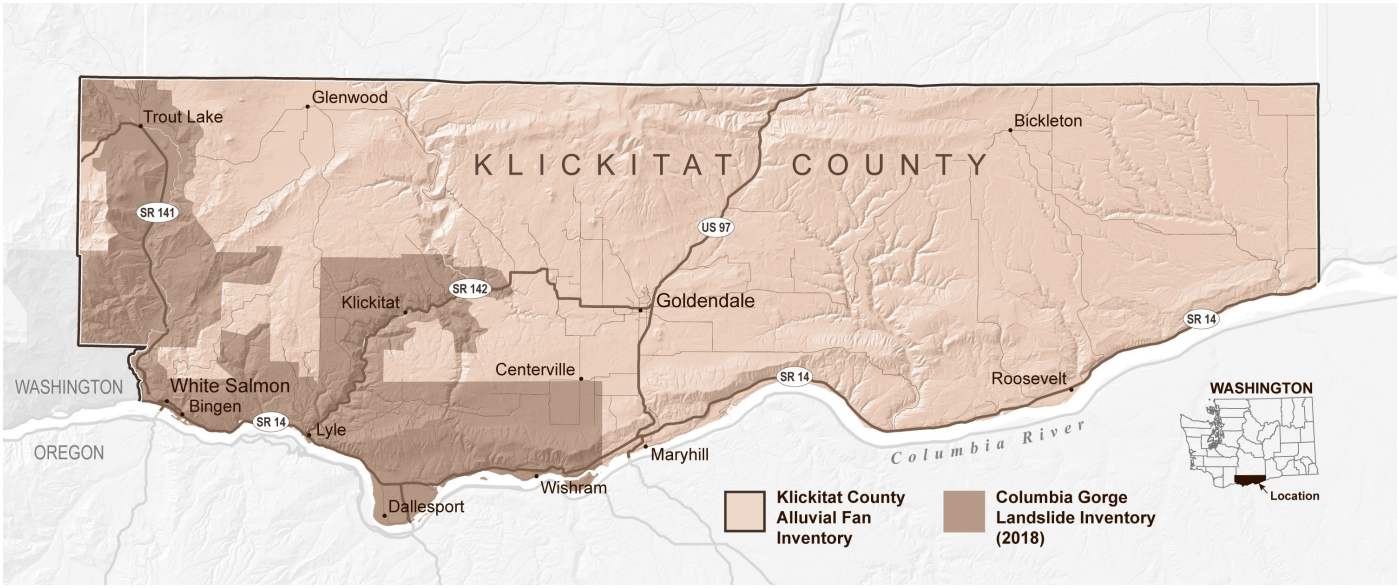


**Figure 1**. Study area for the Klickitat County alluvial fan mapping project.

be avoided due to the increased likelihood of flooding, which may block or hinder emergency response and (or) evacuation routes. During intense precipitation events, roads that cross alluvial fans may be impassable due to flooding and debris on the roadway.

- Public: Individuals purchasing or renting property or a home, or currently living on or near an alluvial fan, should be aware of the possibility of flash flooding or debris flows. During intense or prolonged precipitation events, homes and roads on alluvial fans may be impacted by flooding and debris. Alluvial fans located downstream of areas impacted by wildfires may also have temporarily increased risk of flash flooding or debris flows for several years following a wildfire.

In Washington, city or county governments regulate land-use planning. While the Washington Geological Survey (WGS) updates landslide and alluvial fan inventories to ensure that city and county planners have the best data available to them, WGS does not revise building codes or evaluate development permits. Those decisions are controlled by county- and city-level governments.

## STUDY AREA

Klickitat County is located in southern Washington, bordering on the Columbia River Gorge. The study area covers all of Klickitat County, an area of over 1,900 mi$^2$ (Fig. 1). The study area includes the cities of Bingen, Goldendale, and White Salmon. Four major highways run through Klickitat County—U.S. Route 97 and State Routes 14, 141, and 142.

## METHODS

### Lidar and Imagery

Lidar collected between 2010–2019 covers the entire study area. Table 1 lists the lidar datasets used and their specifications. Geologists created slope gradient maps and other lidar derivatives from each lidar-derived Digital Elevation Model (DEM) dataset. Orthoimages taken between 1990–2021 (NAIP: 2009, 2011, 2013, 2017, 2021; HXIP: 2015, 2017, 2019; Washington Department of Natural Resources: 1990–2000, 2002), aerial photos taken between 1960–1961 (Central Washington University, 2023), and oblique air photos taken between 1976–1977 and 2016–2017 (Washington Department of Ecology, 2023) also aided in interpretation of lidar data and in identifying recent alluvial fan activity.

### Alluvial Fan Mapping

Following the protocol of Slaughter and others (2017), geologists trained in identifying alluvial fan hazards used available lidar data and derivatives to interpret and delineate alluvial fans. Geologists mapped alluvial fans where cone-shaped deposits existed at the mouth of a drainage (Fig. 2). They then assigned unique identification numbers along with attributes, including identification confidence, age, year of movement (if known), field verification, slope degrees, fan height, area, and volume to each mapped alluvial fan. For more information about these attributes, refer to Slaughter and others (2017).

Field verification, performed on approximately nine percent of mapped alluvial fans, focused on landforms that were difficult to interpret from lidar and that were located in, or around, populated areas or infrastructure.

After the completion of mapping, a licensed engineering geologist provided quality control by reviewing the entire alluvial fan inventory and associated attributes.

## RESULTS

The new alluvial fan inventory contains 4,231 fans. Of these alluvial fans, 54 (1%) are historical, meaning that all or portions of the alluvial fan reactivated in the past 150 years. Alluvial fans are concentrated along river corridors with the highest concentrations along Rattlesnake Creek, Major Creek, Rock Creek, Wood Creek, Alder Creek, Spring Canyon, Tule Canyon, and the Klickitat and Columbia Rivers. Multiple alluvial fans lie within 100 ft of the four major highways that run through Klickitat

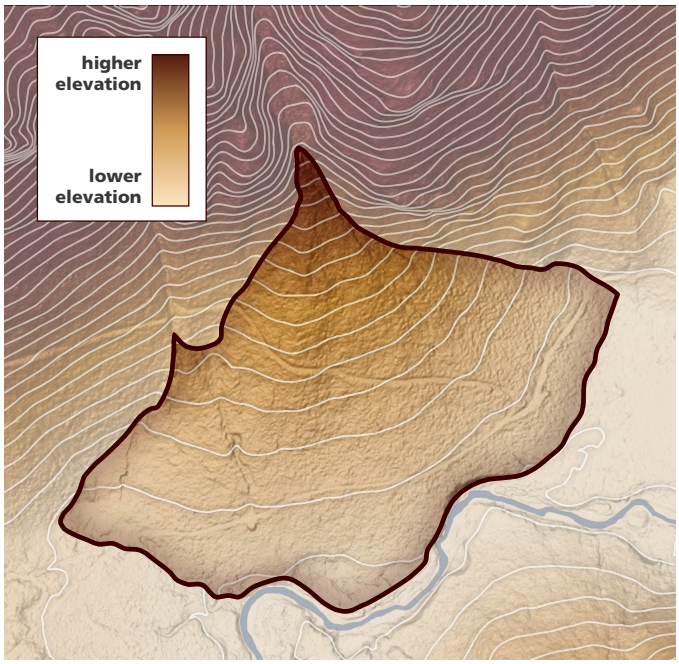


**Figure 2**. An example of a mapped alluvial fan deposit (dark brown line) with 40-ft contours to better distinguish the depositional surface from the valley bottom.

County—13 along U.S. Route 97, 13 along State Route 141, 39 along State Route 142, and 129 along State Route 14.

## CONCLUSIONS

WGS mapped alluvial fans using lidar in Klickitat County to assist the county in planning, mitigation, and emergency preparedness. This mapping enables counties and cities to make educated decisions about their assets, community safety, and growth management using the best-available science. Potential mitigation actions could include moving essential facilities out of hazard zones, restricting development within hazard zones, and promoting public education and outreach in affected areas so that losses can be prevented or minimized. This updated alluvial fan inventory also will help inform communities in Klickitat County about alluvial fan hazards, like flash floods and debris flows, so they may become more resilient to these events.

Additionally, this inventory highlights areas to avoid during precipitation events, especially after a wildfire. By mapping existing alluvial fans in the county prior to any future fires, we can identify areas where property and lives may be at increased risk of future debris flows and flash floods. Not all alluvial fans mapped in this inventory are at risk of debris flows or flash floods. A site-specific analysis by a licensed practitioner can help determine if an area is at risk. For more information on wildfires and alluvial fans in Klickitat County please consult our Esri Experience (https://experience.arcgis.com/experience/9202f7d5e81c427a85fdbc019bdfc0df/).

WGS has incorporated the alluvial fan inventory into the Washington State Landslide Inventory Database (WASLID) (Appendix A). This dataset can be viewed through the Washington Geologic Information Portal (geologyportal.dnr.wa.gov). For more information about downloading the data, see Appendix A.

**Table 1**. Lidar projects used for alluvial fan interpretation. All lidar data were obtained from the Washington Lidar Portal (lidarportal.dnr.wa.gov).

| Lidar Project | Year Collected | Lidar Ground Returns (Pulses/m$^2$) | Raster Resolution (ft) |
|---|---|---|---|
| Columbia | 2010 | unknown | 3 |
| Klickitat | 2015 | 20.11 | 3 |
| Klickitat 3dep | 2019 | 3.82 | 3 |
| Mount Adams | 2016 | 17.42 | 3 |
| Wasco B | 2015 | 15.09 | 3 |
| Wasco Del4 | 2014 | 13.77 | 3 |
| Yakima Basin | 2018 | unknown | 3 |

## ACKNOWLEDGMENTS

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# Appendix A. Alluvial Fan Inventory Data

An Esri file geodatabase containing the mapped alluvial fans is available for download from the Washington Geological Survey website (www.dnr.wa.gov/programs-and-services/geology/publications-and-data/gis-data-and-databases). It is also viewable on the interactive Washington Geologic Information Portal (geologyportal.dnr.wa.gov). Note that this geodatabase is a combined dataset. It contains landslide data for all the counties in Washington that have already been inventoried. The combined inventory is known as the Washington State Landslide Inventory Database (WASLID). WASLID contains two types of data: (1) detailed mapping conducted using the protocol of Slaughter and others (2017), referred to in this publication; and (2) a compilation of other landslides mapped by various groups and for various purposes over the past few decades, not using the protocol of Slaughter and others (2017).