PIERCE COUNTY
HAZARD IDENTIFICATION & RISK ASSESSMENT

AVALANCHE HAZARD

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Identification Description

Definition

An avalanche is a mass of loosened snow or ice that suddenly, and usually swiftly, slides down a mountain, growing by collecting additional material as it descends. Avalanches can occur whenever snow falls on slopes steeper than approximately 20 to 30 degrees. In Washington State avalanches exist solely in mountainous areas.

Types

There are two basic types of avalanches, loose-snow avalanches and slab avalanches. Although the most dangerous avalanche is the slab avalanche, loose-snow slides can and do produce injury and death.

Loose-Snow Avalanche

Loose-snow avalanches occur when grains of snow on a slope greater than a critical angle of repose cannot hold onto a slope and begin sliding downhill picking up more snow and fanning out in an inverted V. The source of the slide could be set off by a piece of falling rock or ice or any sort of disruption at the point of origin.

A small loose-snow avalanche is frequently called a sluff. The largest and most destructive loose-snow avalanches are the large powder avalanches. The United States Department of Agriculture, Avalanche Handbook explains the process that creates loose-snow avalanches:

> *(1)* The layer is disturbed by any of several natural or artificial processes: overloading, from the added weight of newly fallen snow or a skier; vibration, from an earth tremor or explosive force; or, most important, internal changes such as the warming of the layer to a state of drastic loss of cohesion.
> *(2)* A small piece of the layer slips out; the piece can be as small as a single grain but is typically the size of a small snowball.
> *(3)* The loose piece either comes to rest at a new angle of repose or imparts enough energy to the snow in its track to cause an avalanche.[1]

Characteristics

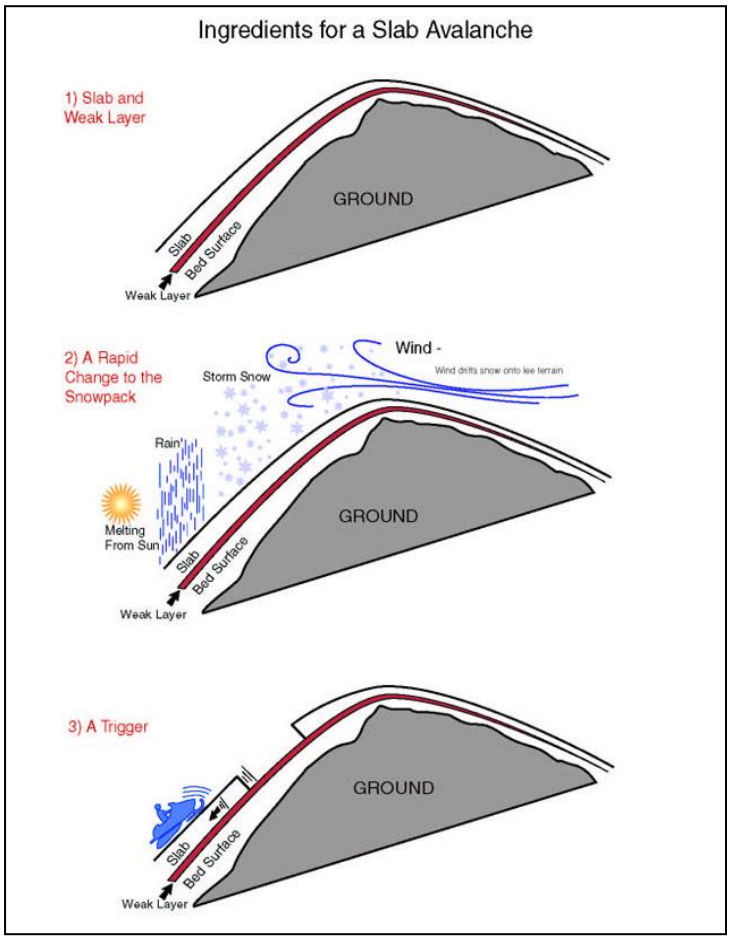
These avalanches may be either wet or dry. Since they are triggered at the surface it is largely dependent on the current weather. Cold weather not allowing melting close to the surface will result in dry loose-snow avalanches, while warm weather especially with intense sunshine will tend to melt the bonds between snow crystals within the upper layers of snow and create a wet avalanche.

A small slide composed of windblown snow cascading down a slope, but seldom accumulating much new snow as it goes, is often referred to as a spindrift avalanche. Spindrift avalanches are always dry.

Slab Avalanche

Slab avalanches occur when a cohesive mass of snow breaks away from the slope all at once. There is a fracture line entirely surrounding the mass of snow that forms almost instantaneously. Based on their different characteristics, slab avalanches can be divided into two main categories: soft slab and hard slab avalanches. In addition, these avalanches can be sub-characterized by the type of contact they have with the underlying layers, the amount of water content in the snow and the triggering method. In this case they can be distinguished as dry or wet slab avalanches.

Figure AV-1 Slab Avalanche



Slab avalanches occur when the stresses on a slab overcome the internal strength of the slab and its attachment to the underlying snow or ground. A decrease in strength may be produced through warming, melting snow, rain, the metamorphosis of snow crystals in a layer, an increase in stress produced by the weight of additional snowfall, or a break in the bonds holding the slope together, see Figure AV-1. These avalanches can be triggered spontaneously by natural triggers or by a skier or a snowmobiler.

Soft Slab

Soft slab avalanches are characterized by a lack of internal cohesion as they descend the slope. While the initial slab structure of a sequence of blocks is apparent when the slide begins the individual blocks rapidly break up into individual particles and the resulting mass may tend to resemble the consistency of a loose-snow avalanche.

Hard Slab

In contrast to soft slab avalanches, hard slab avalanches will continue to have a degree of cohesiveness throughout the descent. Sections will maintain themselves as independent blocks within the mass of moving snow. These could be small along the lines of a couple of feet up to some that may be several meters across.

Characteristics

Like loose snow avalanches the differing characteristics of slab avalanches have to do with the amount of free water content within the slab. However, there are distinct differences.

Dry slab avalanches tend to happen when there is a breakdown between bonds that are holding the layers of snow together. This can happen when extra weight is added to a slope, such as additional heavy snowfall. Skiers, snowmobilers, or a falling cornice can trigger this type of avalanche. The internal lack of cohesion in the snowpack may have a number of causes. These include the deposition of a layer of hoarfrost, or graupel, or the development of a layer of crystals that have metamorphosed into a layer with very weak bonds between the individual crystals. These layers may be so weak that they partially collapse creating a space in the snowpack between the different layers.

Wet slab avalanches occur when water percolating through the top slab finds a layer of discontinuity where it can flow along, weakening or dissolving the bond between the layers, decreasing the ability of the lower layer to hold on to the upper layer or slab. This layer of discontinuity can be between actual snow layers or even between the snowpack and the underlying ground surface. This water moving through the snowpack increases the density of the snow, breaks the bonds holding the snow crystals together, and lubricates the intersection between the layers. Combined, these factors increase the chances of an avalanche. This type of avalanche is most prevalent in the spring when extra sun on the snowpack allows free water to percolate throughout the snowpack.

Profile

Location and Extent

Avalanches directly affect only mountainous areas of Pierce County. Areas in Pierce County that have potential for avalanches include Mount Rainier National Park, Crystal Mountain and other slopes of the Cascade Mountain Range. Avalanche season begins in November and runs through early summer for all mountain areas of the state; in high alpine areas of the Cascade Range, the season is year-round. In Pierce County, this is limited to Mount Rainier. The low elevation of the majority of the county's mountainous terrain combined with dense forestation precludes a high probability of avalanches in most areas.

Areas where avalanches are most likely to occur are:

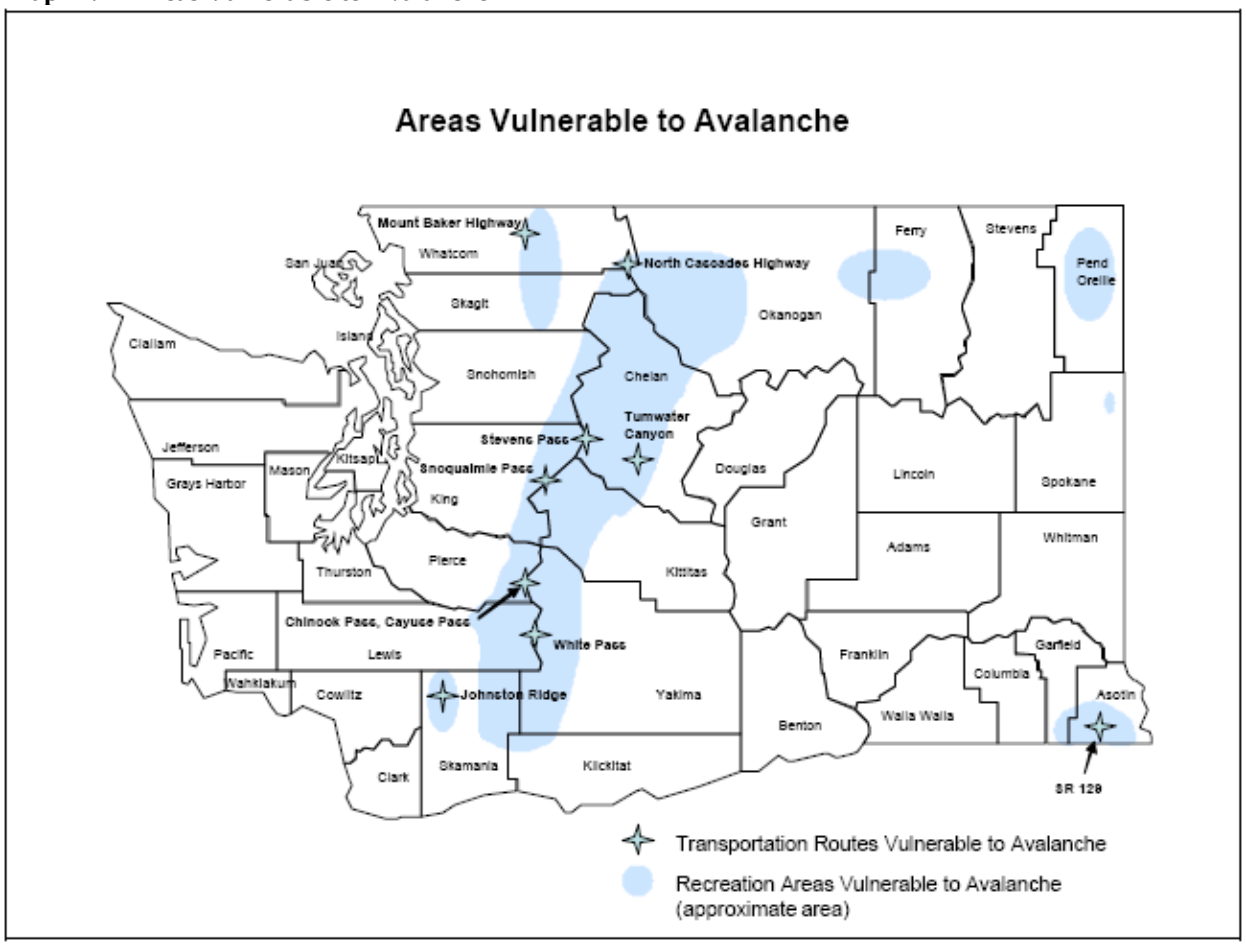
- Recreation areas in the Cascade Mountains,
- Slopes of Mount Rainier,
- Chinook Pass, SR 410 (closed to traffic in winter), and
- Cayuse Pass, SR 123 (closed to traffic in winter).

While not the case historically, most avalanche victims today are participating in recreational activities in the backcountry where there is no avalanche control. The

primary cause of these avalanches is the weight of the victim or someone in the victim's party on the slab of snow. Only one-tenth of one percent of avalanche fatalities occur on open runs at ski areas or on highways.[2]

Based on the location of key transportation routes and recreational areas threatened by avalanche, the Washington State Hazard Mitigation Plan identifies Pierce County as one of the counties in the state with areas at risk from avalanches; see Map AV-1 Areas Vulnerable to Avalanche. However, it should be pointed out that the only jurisdictions with infrastructure directly affected by avalanches in Pierce County are the County, Washington State, Puyallup Tribe of Indians, Muckleshoot Tribe of Indians, and the US Government. None of the others have any infrastructure or resident population located within the current avalanche hazard areas.

Map AV-1 Areas Vulnerable to Avalanche



A number of weather and terrain factors determine avalanche danger:

Weather

- Storms – A vast majority of all snow avalanches occur during or shortly after storm periods.[3]
- Wind – Wind is a redistributor of snow, creating some areas with a thin snow pack and others with a deep snow pack. Snow is picked up from windward slopes and redeposited on leeward slopes. Snow is carried from areas with strong wind to areas of little wind by three methods; rolling, saltation, or turbulent suspension. Rolling them along the ground, picking them up and bouncing them along (saltation) or picking them up and carrying them along in turbulent suspension tends to break down or pulverize the individual crystals into smaller particles. When this happens, the deposition creates a much denser mass that tends to solidify quickly into a slab.
- Rate of snowfall – Snow falling at a rate of one inch or more per hour rapidly increases avalanche danger.
- Temperature – Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
- Wet snow – Rainstorms or spring weather with warm, moist winds and cloudy nights can warm the snow cover resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.

Terrain

- Ground cover – Large rocks, trees and heavy shrubs help anchor snow.
- Slope profile – Dangerous slab avalanches are more likely to occur on convex slopes, however they can occur on concave slopes.
- Slope aspect – Leeward slopes are dangerous because windblown snow adds depth and creates dense slabs. In the Cascades, these tend to be the north and east facing slopes. Due to the large amount of solar radiation increasing the percentage of free water in the snowpack, south facing slopes become more dangerous in the springtime.
- Slope steepness – Snow avalanches are most common on slopes of 30 to 45 degrees.

Occurrences

Avalanches occur frequently in the backcountry of the Cascade Range, often without any impact to people, transportation routes, other infrastructure or development. Some slopes are prone to avalanche every year there is a significant snowfall. Others only do so when there is an unusual amount of snow combined with other weather variables and a trigger of some sort, like a skier crossing the slope. Crystal Mountain Ski Resort will also purposely trigger avalanches on the slopes controlled by the resort before the snow load gets large enough and unstable enough to threaten skiers or others spending time in the mountains.

Mount Rainier is the primary location for avalanches in Pierce County. Since record keeping began in 1887, avalanches in Mount Rainier National Park have claimed approximately 95 lives. Recorded information (see Table AV-1 Pierce County Avalanches of Record) shows the more recent avalanches in Pierce County that resulted in fatalities.

Table AV-1 Pierce County Fatal Avalanches of Record[45]

DATE	LOCATION	FATALITY/CASUALTY
5/30/2014	Mt. Rainier	6 fatalities
06/06/2010	Mt. Rainier – Ingraham	1 fatality
12/18/2007	Mount Rainer - Edith Creek Basin	1 fatality
05/02/2007	Crystal Mountain	1 fatality
02/24/2007	Mount Rainier, Park Place near Crystal Mountain	1 fatality
10/24/2004	Mount Rainier – Ingraham Glacier	1 fatality
06/13/2004	Mount. Rainier – Liberty Ridge	2 fatalities
01/16/2000	Crystal Mountain	1 fatality
06/11/1998	Mount Rainier	1 fatality, several injured
1992	Mount Rainier	2 fatalities
1988	Mount Rainier	3 fatalities
06/21/1981	Mount Rainier – Ingraham Glacier	11 fatalities, serac collapse[6]
12/31/1977	Mount Rainier – Panorama Point	1 fatality
11/18/1973	Mt. Rainier – Success Cleaver	1 fatality
03/04/1969	Mt. Rainier – Cadaver Gap	2 fatalities
1958	Silver Creek	1 fatality

Recurrence Rate

The recurrence rate for avalanches in Pierce County is yearly. Most of those that will cause fatalities, injuries or other damage happen within Mount Rainier National Park. There is some potential for slides to happen in the areas around Crystal Mountain. Outside of these two areas, Pierce County does not have roads that are open into avalanche terrain during the winter. As such, the potential for impact to a developed area or major road is extremely limited. Skiers, snowmobilers, snowshoers, climbers and other back country travelers, or those who access the roads which are closed in the winter will continue to be the individuals involved in avalanche incidents in the future. This is based on information from past avalanche occurrences, and a review of Pierce County topography and road infrastructure.

Impacts

Health and Safety of Persons in the Affected Area at the Time of the Incident

The impacts include the injury and possible death to persons in the affected area. Death may result from suffocation, hypothermia, or traumatic injury. Injury may result either from impact with objects in the avalanche path, tumbling, or burial in the snow for a period of time. Those who survive the initial slide could suffer mental impairment from oxygen deprivation, hypothermia and/or frostbite prior to being rescued. There should be little, if any, long term effects to anyone not directly impacted by the avalanche.

Health and Safety of Personnel Responding to the Incident

The impacts to response personnel include the possibility of secondary avalanches in the response area causing injury or death, as well as cold weather injuries like hypothermia and frostbite.

Continuity of Operations and Delivery of Services

Due to the very limited nature of avalanches in Pierce County there should be no impact to the continuity of operations for any jurisdiction within the County.

Roads impacted by the avalanche hazard within Pierce County are either within Mount Rainier National Park or closed during most of the avalanche season. None of those impacted roads affect the delivery of services to citizens of the County. Other infrastructure is not affected by the threat of avalanches.

Property, Facilities, and Infrastructure

Due to the very limited nature of avalanches in Pierce County, and the closure of roads in the high avalanche areas, there should be no impact to the property, facilities and infrastructure of any jurisdiction within Pierce County.

The Environment

Most avalanches follow the same paths that they have in the past, beginning high on mountain sides and descending slopes, frequently funneling into gullies. Impacts to the environment include damage to hillsides, an increase in erosion potential, death and injury to local animals, and in some cases the actual destruction of forested areas.

Economic and Financial Condition

Economically, avalanches in Pierce County may impact logging revenues. The downing of trees could damage or close roads that lead to logging areas on Crystal Mountain or by damaging facilities at the Crystal Mountain Ski Resort. While this may impact individual businesses for a short period of time, avalanches should not cause a major economic impact to any jurisdiction within Pierce County.

Public Confidence in the Jurisdiction's Governance

Due to the prevention of damage from avalanches either by control activities at the ski resorts or by the closing of roads, there should be no major avalanche impacts on citizens of Pierce County. The result is that public confidence in the governance of the County and other jurisdictions within it should not be dampened by the occasional avalanche injury or fatality due to the person being in the wrong place at the wrong time. These are all due to individual choice: the choice to climb, ski, snowmobile or snowshoe in areas that have an avalanche potential.

Resource Directory

Regional

- **Pierce County Department of Emergency Management**
  https://www.co.pierce.wa.us/6481/Know-Your-Hazards
- **Tacoma Mountain Rescue**
  http://www.tmru.org
- **Washington State Hazard Inventory and Vulnerability Analysis**
  https://mil.wa.gov/enhanced-hazard-mitigation-plan

National

- **The Northwest Avalanche Center**
  http://www.nwac.noaa.gov
- **USGS Natural Hazards**
  http://www.usgs.gov/hazards/
- **United States Forest Service Avalanche Center**
  http://www.fsavalanche.org/

Endnotes

[1] Avalanche Handbook, Avalanche Handbook 489, U.S. Department of Agriculture, Ronald I. Perla and M. Martinelli, Jr., pp. 67-68.
[2] Friends of Utah Avalanche Center, www.avalanche.org~uac/med-quick-facts.htm
[3] Ibid. p. 35.
[4] Northwest Weather and Avalanche Center, http://www.nwac.us/accidents/
[5] U.S. Department of the Interior, NPS, Fatalities at Mt. Rainier National Park, http://www.mountrainierclimbing.us/sar/queryfatalities.php?activity=Climbing%20(Summit)
[6] This particular incident does not involve a normal avalanche that a backcountry traveler might run into. In this case a climbing party on Mt. Rainier had a large block of ice and snow on the Ingraham Glacier, called a serac, collapse, and sweep down the mountain, push the climbers into a crevasse, and bury them. Their bodies are still on the mountain.