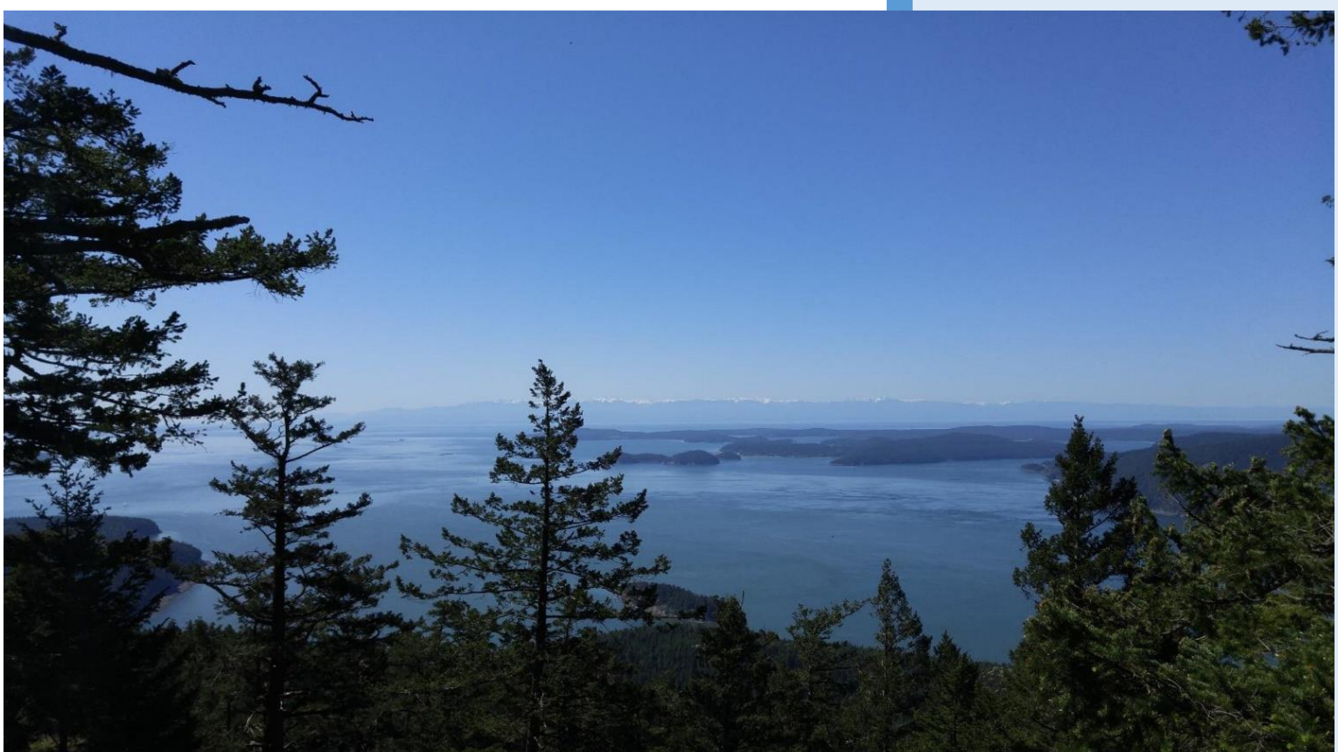
2021

Samish Indian Nation Hazard Mitigation Plan Update



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The Samish Indian Nation
HAZARD MITIGATION PLAN UPDATE

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Hazard Mitigation Plan
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HAZARD IDENTIFICATION AND RISK ASSESSMENT METHODOLOGY

5.1 OVERIEW

The DMA requires measuring potential losses to critical facilities and property resulting from natural hazards. A hazard is an act or phenomenon that has the potential to produce harm or other undesirable consequences to a person or thing. Natural hazards can exist with or without the presence of people and land development. However, hazards can be exacerbated by societal behavior and practice, such as building in a floodplain, along a sea cliff, or on an earthquake fault. Natural disasters are inevitable, but the impacts of natural hazards can, at a minimum, be mitigated or, in some instances, prevented entirely.

It should be noted that occurring simultaneous with this plan development is the COVID-19 Pandemic. Response to the Pandemic did impact the ability to develop this plan, with restrictions existing for meeting/gathering attendance. As such, more one-on-one telephonic meetings occurred, with the Samish Project Manager holding additional meetings / information gathering sessions in consideration of restrictions established by the Samish Indian Nation with respect to work-at-home orders, and the closing of facilities. The Samish primarily relied on the use of the internet, email distribution lists, use of its public relations consultants, and the one-on-one meetings to capture and disburse relevant data.

The goal of the risk assessment is to determine which hazards present the greatest risk and what areas are the most vulnerable to hazards. The Samish Indian Nation is exposed to many natural and other hazards. The risk assessment and vulnerability analysis helps identify where mitigation measures could reduce loss of life or damage to property in the planning region. Each hazard-specific risk assessment provides risk-based information to assist the Nation in determining priorities for implementing mitigation measures.

The risk assessment approach used for this plan entailed using geographic information system (GIS), Hazus hazard-modeling software, and hazard-impact data to develop vulnerability models for people, structures and critical facilities, and evaluating those vulnerabilities in relation to hazard profiles that model where hazards exist. This approach is dependent on the detail and accuracy of the data used. In all instances, this assessment used best available science and data to ensure the highest level of accuracy possible.

This risk assessment is broken down into three phases, as follows:

> The first phase, hazard identification, involves the identification of the geographic extent of a hazard, its intensity, and its probability of occurrence (discussed below). This level of assessment typically involves producing a map. The outputs from this phase can be used for land use planning, management, and development of regulatory authority; public awareness and education; identifying areas which require further study; and identifying properties or structures appropriate for mitigation efforts, such as acquisition or relocation.
>
> The second phase, the vulnerability assessment, combines the information from the hazard identification with an inventory of the existing (or planned) property and population exposed to the hazard. It then attempts to predict how different types of property and population groups will be impacted or affected by the hazard of concern. This step assists in justifying changes to building codes or regulatory authority, property acquisition programs, such as those available through

various granting opportunities; developing or modifying policies concerning critical or essential facilities; and public awareness and education.

The third phase, the risk analysis, involves estimating the damage, injuries, and costs likely to be incurred in the geographic area of concern over a period of time. Risk has two measurable components:

1. The magnitude of the harm that may result, defined through the vulnerability assessment; and
2. The likelihood or probability of harm occurring.

Utilizing those three phases of assessment, information was developed which identifies the hazards that affect the planning area, the likely location of natural hazard impact, the severity of the impact, previous occurrences, and the probability of future hazard events. That data, once complete, is utilized to complete the Risk Ranking process described in Chapter 13, which applies to all of the data captured.

The following is provided as the foundation for the standardized risk terminology utilized in this effort:

- Hazard: Natural, human caused or technological source or cause of harm or damage, demonstrated as actual (deterministic/historical events) or potential (probabilistic) events.
- Risk: The potential for an unwanted outcome resulting from a hazard event, as determined by its likelihood and associated consequences. For this plan, when possible, risk includes potential future losses based on probability, severity and vulnerability, expressed in dollar losses. In some instances, dollar losses are based on actual demonstrated impact, such as through the use of the Hazus model. In other cases, losses are demonstrated through exposure analysis due to the inability to determine the extent to which a structure is impacted.
- Extent and Location: The area of potential or demonstrated impact within the area in which the analysis is being conducted. In some instances, the area of impact is within a geographically defined area, such as a floodplain. In other instances, such as for severe weather, there is no established geographic boundary associated with the hazard, as it can impact the entire area.
- Severity/Magnitude: The extent or magnitude on which a hazard is ranked, demonstrated in various means, e.g., Richter Scale.
- Vulnerability: The degree of damage, e.g., building damage or the number of people injured.
- Probability of Occurrence and Return Intervals: These terms are used synonymous with likelihood, or the estimation of the potential of an incident to occur.

5.2 HAZARD IDENTIFICATION AND PROFILES

For this plan, the planning partners and stakeholders considered the full range of natural hazards that could impact the planning area. The process incorporated review of state and local hazard planning documents, as well as information on the frequency, magnitude and costs associated with hazards that have impacted or could impact the planning area. Anecdotal information regarding natural hazards and the perceived vulnerability of the planning area's assets to them was also used. Based on the review, the Planning Team, at its kick-off meeting, identified the following natural hazards that this plan addresses as the hazards of concern:

- Drought

- Earthquake
- Flood
- Landslide
- Severe Weather
- Tsunami
- Volcano
- Wildfire (through the 2020 Skagit County CWPP)

The list of hazards remain consistent with the previous plan, with slight modifications to expand Severe Weather, and to include discussion on Climate Change within each profile. Based on the full spectrum of hazards addressed, it is the intent of the Tribe to use this risk assessment in lieu of preparing a separate hazard identification and vulnerability assessment for other planning efforts which may require the same type of analysis.

The hazard profiles describe the risks associated with identified hazards of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and, when possible, probable event scenarios. The following steps were used to define the risk of each hazard:

Identify and profile the following information for each hazard:

- – General overview and description of hazard;
- – Identification of previous occurrences;
- – Geographic areas most affected by the hazard;
- – Event frequency estimates;
- – Severity estimates;
- – Warning time likely to be available for response;
- – Risk and vulnerability assessment, which includes identification of impact on people, property, economy, and the environment.

5.3 RISK ASSESSMENT PROCESS AND TOOLS

The hazard profiles and risk assessments describe the risks associated with each identified hazard of concern. Each chapter describes the hazard, the planning area's vulnerabilities, and probable event scenarios. Chapter 13 summarizes all analysis through completion of the Calculated Priority Risk Index (CPRI) for hazard ranking.

Once the profiles were completed, the following steps were used to define the risk vulnerability of each hazard:

- Determine exposure to each hazard—Exposure was determined by overlaying hazard maps with an inventory of structures, facilities, and systems to determine which of them would be exposed to each hazard.
- Assess the vulnerability of exposed facilities—Vulnerability of exposed structures and infrastructure was determined by interpreting the probability of occurrence of each event and

assessing structures, facilities, and systems that are exposed to each hazard. Tools such as GIS and Hazus (discussed below) were used in this assessment.

- Where specific quantitative assessments could not be completed, vulnerability was measured in general, qualitative terms, summarizing the potential impact based on past occurrences, spatial extent, and subjective damage and casualty potential. Those items were categorized utilizing the criteria established in the CPRI (see below).
- The final step in the process was to assign a significance level determined by review of the results of vulnerability based on the CPRI schedule, assigning a final qualitative assessment based on the following classifications:
    - Extremely Low—The occurrence and potential cost of damage to life and property is very minimal to nonexistent.
    - Low—Minimal potential impact. The occurrence and potential cost of damage to life and property is minimal.
    - Medium—Moderate potential impact. This ranking carries a moderate threat level to the general population and/or built environment. Here the potential damage is more isolated and less costly than a more widespread disaster.
    - High—Widespread potential impact. This ranking carries a high threat to the general population and/or built environment. The potential for damage is widespread. Hazards in this category may have occurred in the past.
    - Extremely High—Very widespread with catastrophic impact.

5.3.1 Calculated Priority Risk Index Scoring Criteria

For the 2021 update, the Planning Team utilized a Calculated Priority Risk Index Score for each hazard of concern. Vulnerabilities are focused on Samish-owned structures. Vulnerabilities are described in terms of critical facilities, structures, population, economic values, and functionality of government which can be affected by the hazard event as identified in the below tables. Hazard impact areas describe the geographic extent a hazard can impact the tribe and are uniquely defined on a hazard-by-hazard basis. Mapping of the hazards, where spatial differences exist, allows for hazard analysis by geographic location. Some hazards can have varying levels of risk based on location. Other hazards cover larger geographic areas and affect the area uniformly. Therefore, a system must be established which addresses all elements (people, property, economy, continuity of government) to rate each hazard consistently. The use of the Calculated Priority Risk Index allows such application, based on established criteria of application to determine the risk factor. For identification purposes, the six criteria on which the CPRI is based are probability, magnitude, geographic extent and location, warning time/speed of onset, and duration of the event. Those elements are further defined as follows:

Probability

Probability of a hazard event occurring in the future was assessed based on hazard frequency over a 100-year period (where available). Hazard frequency was based on the number of times the hazard event occurred divided by the period of record. If the hazard lacked a definitive historical record, the probability was assessed qualitatively based on regional history and other contributing factors. Probability of occurrence was assigned a 40% weighting factor, and was broken down as follows:

Rating	Likelihood	Frequency of Occurrence
1	Unlikely	Less than 1% probability in the next 100 years.
2	Possible	Between 1% and 10% probability in the next year, or at least one chance in the next 100 years.
3	Likely	Between 10% and 100% probability in next year, or at least one chance in the next 10 years.
4	Highly Likely	Greater than 1 event per year (frequency greater than 1).

Magnitude

The magnitude of potential hazard events was evaluated for each hazard. Magnitude is a measure of the strength of a hazard event and is usually determined using technical measures specific to the hazard. Magnitude was calculated for each hazard where property damage data was available and was assigned a 25% weighting factor. Magnitude calculation was determined using the following: *Property Damage / Number of Incidents) / $ of Building Stock Exposure = Magnitude.* In some cases, the Hazus model provided specific people/dollar impact data. For other hazards, a GIS exposure analysis was conducted. Magnitude was broken down as follows:

Rating	Magnitude	Percentage of People and Property Affected
1	Negligible	Less than 5% Very minor impact to people, property, economy, and continuity of government at 90%.
2	Limited	6% to 24% Injuries or illnesses minor in nature, with only slight property damage and minimal loss associated with economic impact; continuity of government only slightly impacted, with 80% functionality.
3	Critical	25% to 49% Injuries result in some permanent disability; 25-49% of population impacted; moderate property damage; moderate impact to economy, with loss of revenue and facility impact; government at 50% operational capacity with service disruption more than one week, but less than a month.
4	Catastrophic	More than 50% Injuries and illness resulting in permanent disability and death to more than 50% of the population; severe property damage greater than 50%; economy significantly impacted as a result of loss of buildings, content, inventory; government significantly impacted; limited services provided, with disruption anticipated to last beyond one month.

Extent and Location

The measure of the percentage of the people and property within the planning area impacted by the event, and the extent (degree) to which they are impacted. Extent and location were assigned a weighting factor of 20%, and broken down as follows:

Rating	Magnitude	Percentage of People and Property Affected
1	Negligible	Less than 10% Few if any injuries or illness. Minor quality of life lost with little or no property damage. Brief interruption of essential facilities and services for less than four hours.

Rating	Magnitude	Percentage of People and Property Affected
2	Limited	10% to 24% Minor injuries and illness. Minor, short term property damage that does not threaten structural stability. Shutdown of essential facilities and services for 4 to 24 hours.
3	Critical	25% to 49% Serious injury and illness. Major or long-term property damage, that threatens structural stability. Shutdown of essential facilities and services for 24 to 72 hours.
4	Catastrophic	More than 50% Multiple deaths Property destroyed or damaged beyond repair Complete shutdown of essential facilities and services for 3 days or more.

Warning Time/Speed of Onset

The rate at which a hazard occurs, or the time provided in advance of a situation occurring (e.g., notice of a cold front approaching or a potential hurricane, etc.) provides the time necessary to prepare for such an event. Sudden-impact hazards with no advanced warning are of greater concern. Warning Time/Speed of onset was assigned a 10% weighting factor, and broken down as follows:

Rating	Probable amount of warning time
1	More than 24 hours warning time.
2	12-24 hours warning time.
3	5-12 hours warning time.
4	Minimal or no warning time.

Duration

The time span associated with an event was also considered, the concept being the longer an event occurs, the greater the threat or potential for injuries and damages. Duration was assigned a weighting factor of 5%, and was broken down as follows:

Rating	Duration of Event
1	6-24 hours
2	More than 24 hours
3	Less than 1 week
4	More than 1 week

Chapter 13 summarizes the analysis conducted by way of completion of the Calculated Priority Risk Index (CPRI) for hazard ranking.

5.3.2 Hazus and GIS Applications

Earthquake and Flood Modeling Overview

In 1997, FEMA developed the standardized Hazards U.S., or Hazus model to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. Hazus was later expanded into a multi-hazard methodology, with new models for estimating potential losses from hurricanes, floods, and tsunami (although still limited in nature).

Hazus is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical facility, transportation and utility lifeline, and multiple models to estimate potential losses from natural disasters. The program maps and displays hazard data and the results of damage and economic loss estimates for buildings and infrastructure. Its advantages include the following:

- Provides a consistent methodology for assessing risk across geographic and political entities.
- Provides a way to save data so that it can readily be updated as population, inventory, and other factors change and as mitigation planning efforts evolve.
- Facilitates the review of mitigation plans because it helps to ensure that FEMA methodologies are incorporated.
- Supports grant applications by calculating benefits using FEMA definitions and terminology.
- Produces hazard data and loss estimates that can be used in communication with local stakeholders.
- Is administered by the tribal or local government and can be used to manage and update a hazard mitigation plan throughout its implementation.

Levels of Detail for Evaluation

HAZUS provides default data for inventory, vulnerability, and hazards; this default data can be supplemented with local data to provide a more refined analysis. The model can carry out three levels of analysis, depending on the format and level of detail of information about the planning area:

- **Level 1**—All of the information needed to produce an estimate of losses is included in the software's default data. This data is derived from national databases and describes in general terms the characteristic parameters of the planning area.
- **Level 2**—More accurate estimates of losses require more detailed information about the planning area. To produce Level 2 estimates of losses, detailed information is required about local geology, hydrology, hydraulics and building inventory, as well as data about utilities and critical facilities. This information is needed in a GIS format.
- **Level 3**—This level of analysis generates the most accurate estimate of losses. It requires detailed engineering and geotechnical information to customize it for the planning area.

Building Inventory

A User Defined Facility approach was used to model exposure and vulnerability to the critical infrastructure identified during this process. GIS building data utilizing detailed structure information for tribal facilities was loaded into the GIS and Hazus model. Building information was developed using best available Tribal data, including building address points, aerial imagery, and Samish staff resources. Building and content replacement values were estimated using values from various sources, including valuation by Samish staff.

Hazus Application for This Plan

The following methods were used to assess specific hazards for this plan:

- **Flood**—A Hazus Level 2 analysis was performed. Analysis was based on current FEMA regulatory 100- and 500-year flood hazard data. The 1989 Skagit County FIRM was utilized for this analysis. Based on review of that data, there are no Tribal owned structures within the 500-year floodplain.

- **Earthquake**—A Hazus Level 2 analysis was performed to assess earthquake risk and exposure. Earthquake shake maps prepared by the U.S. Geological Survey (USGS) were used for the analysis of this hazard. A modified version of the National Earthquake Hazard Reduction Program (NEHRP) soils inventory was used. One scenario event was modeled:
  - The scenario event utilized for this update was the Devils Mountain M7.5 Earthquake.

Drought, Landslide, Severe Weather, Tsunami and Volcano

For drought, landslide, severe weather, tsunami and volcano, historical data is not adequate to model future losses as no specific damage functions have been developed. However, GIS can map hazard areas and calculate exposure if geographic information is available with respect to the location of the hazard and inventory data. Areas and inventory susceptible to some of the hazards of concern were mapped and exposure was evaluated. For other hazards, a qualitative analysis was conducted using the best available data and professional judgment. Locally relevant information was gathered from a variety of sources. Frequency and severity indicators include past events and the expert opinions of geologists, Samish staff, emergency management personnel and others. The primary data source was Samish staff, including various GIS data sets, augmented with county, state, and federal datasets. Additional data sources for specific hazards were as follows:

Drought—The risk assessment methodologies used for this plan focus on damage to structures. Because drought does not impact structures, the risk assessment for drought was more limited and qualitative than the assessment for the other hazards of concern. The impact from drought also references fish loss associated with the negative impact of climate change on water levels, and sedimentation issues resulting from drought situations.

Landslide—Historic landslide hazard data was used to assess exposure to landslides using Washington State Department of Ecology Landslide Susceptibility data. This data depicts landslide susceptibility at a 10-meter resolution across the state of Washington. Utilizing elevation data and WA DNR identified slope susceptibility at anything greater than 40 percent slope, a 100' buffer was used to identify potential critical facilities falling within these potential landslide hazard areas. It should be noted that *this data is for mitigation planning purposes only, and should not be considered for life safety matters.* No landslide hazard analysis was conducted, but rather, only reprojection of existing data. Additional landslide data is available at: http://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/landslides

Severe Weather—Severe weather data was downloaded from various sources, including the Natural Resources Conservation Service and the National Climatic Data Center, PRISM, Tornado Project, and other sources as referenced. A lack of data separating severe weather damage from flooding, windstorms, and landslide damage prevented a detailed analysis for exposure and vulnerability, as well as the fact that there are no generally accepted damage functions for the hazard. For planning purposes, it is assumed that the entire planning area is exposed to some extent to severe weather. Certain areas are more exposed due to geographic location and local weather patterns, as well as the response capabilities of local first responders.

- **Tsunami** – Information for Tsunami was captured through FEMA's Risk Map project as a pilot project for the new Hazus 4.0 model, and various on-going studies for evacuation mapping.

Volcano - There are currently no generally accepted damage functions for volcanic hazards in risk assessment platforms such as Hazus or any GIS system for the ash fall associated with the hazard. There would also be too many variables to associate with any type of plume modeling for ash. No historical data was available specifically for the Samish with respect to impact and losses associated with the eruption of Mount St. Helens on which impact could be based. Therefore, for planning purposes, it is assumed that the entire planning area is exposed to some extent to ash accumulations from eruption of either Mt. Baker or Glacier Peak. Those structures would be vulnerable to the excessive weight of tephra and rainfall. Certain areas are more exposed to ash accumulations due to geographic location and local weather patterns, as well as the response capabilities of local first responders. In addition to the ashfall, Lahar inundation zones were also identified, with identification of the area and critical facilities impacted.

5.3.3 Probability of Occurrence and Return Intervals

Natural hazard events with relatively long return periods, such as a 100-year flood or a 500-year earthquake, are often thought to be very unlikely. In reality, the probability that such events occur over the next 30 or 50 years is relatively high.

Natural hazard events with very long return periods, such as 100 or 500 or 1,000 years, have significant probabilities of occurring during the lifetime of a building:

- Hazard events with return periods of 100 years have probabilities of occurring in the next 30 or 50 years of about 26 percent and about 40 percent, respectively.
- Hazard events with return periods of 500 years have about a 6 percent and about a 10 percent chance of occurring over the next 30 or 50 years, respectively.
- Hazard events with return periods of 1,000 years have about a 3 percent chance and about a 5 percent chance of occurring over the next 30 or 50 years, respectively.

For life safety considerations, even natural hazard events with return periods of more than 1,000 years are often deemed significant if the consequences of the event happening are very severe (extremely high damage and/or substantial loss of life). For example, the seismic design requirements for new construction are based on the level of ground shaking with a return period of 2,475 years (2 percent probability in 50 years). Providing life safety for this level of ground shaking is deemed necessary for seismic design of new buildings to minimize life safety risk. Of course, a hazard event with a relatively long return period may occur tomorrow, next year, or within a few years. Return periods of 100 years, 500 years or 1,000 years mean that such events have a 1 percent, a 0.2 percent or a 0.1 percent chance of occurring in any given year.

5.4 LIMITATIONS

Loss estimates, exposure assessments and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

- Approximations and simplifications necessary to conduct a study;
- Incomplete or outdated inventory, demographic or economic parameter data;
- The unique nature, geographic extent and severity of each hazard;
- Mitigation measures already employed; and

- The amount of advance notice residents have to prepare for a specific hazard event.

These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate. *The results do not predict precise results and should be used only to understand relative risk for planning purposes; not life-safety measures.*

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CHAPTER 6. DROUGHT

6.1 GENERAL BACKGROUND

DEFINITIONS

Drought—The cumulative impacts of several dry years on water users and agricultural producers. It can include deficiencies in surface and subsurface water supplies and cause impacts to health, well-being, and quality of life.

Hydrological Drought—Deficiencies in surface and subsurface water supplies.

Socioeconomic Drought—Drought impacts on health, well-being, and quality of life.

Droughts originate from a deficiency of precipitation resulting from an unusual weather pattern. If the weather pattern lasts a short time (a few weeks or a couple of months), the drought is considered short-term. If the weather pattern becomes entrenched and the precipitation deficits last for several months or years, the drought is considered long-term. It is possible for a region to experience a long-term circulation pattern that produces drought, and to have short-term changes in this long-term pattern that result in short-term wet spells. Likewise, it is possible for a long-term wet circulation pattern to be interrupted by short-term weather spells that result in short-term drought.

Drought is a prolonged period of dryness severe enough to reduce soil moisture, water, and snow levels below the minimum necessary for sustaining plant, animal, and economic systems. Droughts are a natural part of the climate cycle. For this plan, the Samish Indian Nation has elected to use Washington's statutory definition of drought (RCW Chapter 43.83B.400), which is based on both of the following conditions occurring:

- The water supply for the area is below 75 percent of normal.
- Water uses and users in the area will likely incur undue hardships because of the water shortage.

6.2 HAZARD PROFILE

6.2.1 Extent and Location

Drought can have a widespread impact on the environment and the economy, depending upon its severity, although it typically does not result in loss of life or damage to property, as do other natural disasters. The National Drought Mitigation Center uses three categories to describe likely drought impacts:

- Agricultural—Drought threatens crops that rely on natural precipitation, while also increasing the potential for infestation.
- Water supply—Drought threatens supplies of water for irrigated crops, for communities and for fish and salmon and other species of wildlife.
- Fire hazard—Drought increases the threat of wildfires from dry conditions in forest and rangelands.

In Washington, where hydroelectric power plants generate nearly three-quarters of the electricity produced, drought also threatens the supply of electricity. Unlike most disasters, droughts normally occur slowly but last a long time. Drought conditions occur every few years in Washington. The droughts of 1977 and 2001 (discussed below), the worst and second worst in state history, provide good examples of how drought can affect the state.

On average, the nationwide annual impacts of drought are greater than the impacts of any other natural hazard. They are estimated to be between $6 billion and $8 billion annually in the United States and occur primarily in the agriculture, transportation, recreation and tourism, forestry, and energy sectors. Social and environmental impacts are also significant, although it is difficult to put a precise cost on these impacts.

Drought affects groundwater sources, but generally not as quickly as surface water supplies, although groundwater supplies generally take longer to recover. Reduced precipitation during a drought means that groundwater supplies are not replenished at a normal rate. This can lead to a reduction in groundwater levels and problems such as reduced pumping capacity or wells going dry. Shallow wells are more susceptible than deep wells. About 16,000 drinking water systems in Washington get water from the ground; these systems serve about 5.2 million people. Reduced replenishment of groundwater affects streams. Much of the flow in streams comes from groundwater, especially during the summer when there is less precipitation and after snowmelt ends. Reduced groundwater levels mean that even less water will enter streams when steam flows are lowest. Reduced water levels in wells also means that the wells are subject to saltwater intrusion.

The area's drinking water comes from the local watersheds and is provided primarily by the City of Anacortes, and in some areas, privately-owned wells. Drought conditions within the planning area may increase pressure on local aquifers, with increased pumping potentially resulting in saltwater intrusion into freshwater aquifers. This, in turn, could cause restrictions on economic growth and development, impacting the economy.

6.2.2 Previous Occurrences

In the past century, Washington has experienced several drought episodes, including several that lasted for more than a single season—1928 to 1932, 1992 to 1994, and 1996 to 1997. Table 6-1 identifies additional drought occurrences in the state. The 1977 drought was the worst on record, but the 2001 drought came close to surpassing it in some respects. Table 6-2 has data on how the two droughts affected Washington by late September of their respective years.

TABLE 6-1
DROUGHT OCCURRENCES

July-August 1902	No measurable rainfall in Western Washington
August 1919	Drought and hot weather occurred in Western Washington
July – August 1921	Drought in all agricultural sections.
June-August 1922	The statewide precipitation averaged 0.10 inches.
March – August 1924	Lack of soil moisture retarded germination of spring wheat.
July 1925	Drought occurred in Washington
July 21-August 25, 1926	Little or no rainfall was reported.
June 1928-March 1929	Most stations averaged less than 20 percent of normal rainfall for August and September and less than 60 percent for nine months.
July – August 1930	Drought affected the entire state. Most weather stations averaged 10 percent or less of normal precipitation.
April 1934-March 1937	The longest drought in the region's history – the driest periods were April-August 1934, September-December 1935, and July-January 1936-1937.
May – September 1938	Driest growing season in Western Washington.

TABLE 6-1 DROUGHT OCCURRENCES	
1952	Every month was below normal precipitation except June. The hardest hit areas were Puget Sound and the central Cascades.
January – May 1964	Drought covered the southwestern part of the state. Precipitation was less than 40 percent of normal.
Spring 1966	Drought throughout Washington
June – August 1967	Drought throughout Washington
January – August 1973	Dry in the Cascades.
October 1976 – September 1977	Worst drought in Pacific Northwest history. Below normal precipitation in Olympia, Seattle, and Yakima. Crop yields were below normal and ski resorts closed for much of the 1976-77 season. The 1977 drought led to widespread water shortages and severe water conservation measures throughout Washington. More than 70 public and private drinking-water operations reported water-supply problems. Wheat and cattle were the most seriously affected agricultural products in the state. The Federal Power Commission ordered public utilities on the Columbia River to release water to help fish survive. Agriculture experienced drought-related losses of more than $400 million.
2001	Governor declared statewide Stage 2 drought in response to severe dry spell.
June – September 2003	Federal disaster number 1499 assigned to 15 counties. The original disaster was for flooding, but several jurisdictions were included because of previous drought conditions. The 2001 drought came on rapidly. Between November 2000 and March 2001, most of the state's rainfall and snowpack totals were only about 60 percent of normal. The 2001 event was a result of warm weather melting snowpack into streams a month earlier than normal. Nine large utility companies statewide advised the Washington State Department of Health that they were highly vulnerable to the drought. Washington declared a statewide drought emergency on March 14, 2001. As a result of the 2001 drought, 90,000 acres of agricultural land were taken out of production; thousands of acres of orchards were unused, and the sugar beet industry was out of production.
March 10, 2005 Governor Declared Drought	Precipitation levels was below or much below the average from November through February, with extremely warm fall and winter months, adversely affecting the state's mountain snowpack. A warm mid-January removed much of the remaining snowpack, with March projections at 66 percent of normal, indicating that Washington might be facing a drought as bad as, or worse, than the 1977 drought. Late March rains filled reservoirs to about 95 percent. State legislature approved $12 million supplemental budget that provided funds to buy water, improve wells, and implement other emergency water supply projects. Wildfires numbers was about 75 percent of previous five years, but acreage burned was three times greater.

TABLE 6-1
DROUGHT OCCURRENCES

2015	2015 was the year of the "snowpack drought." Washington State had normal or near-normal precipitation over the 2014-2015 winter season. However, October through March the average statewide temperature was 40.5 degrees Fahrenheit, 4.7 degrees above the 20th century long-term average and ranking as the warmest October through March on record. Washington experienced record low snowpack because mountain precipitation that normally fell as snow instead fell as rain. The snowpack deficit then was compounded as precipitation began to lag behind normal levels in early spring and into the summer. With record spring and summer temperatures, and little to no precipitation over many parts of the state, the snowpack drought morphed into a traditional precipitation drought, causing injury to crop and aquatic species. Many rivers and streams experienced record low flows. (See Figure 6-1.)
2019	On May 20, 2019, Governor Jay Inslee issued an emergency drought declaration in 24 watersheds statewide (see Figure 6-2). According to the Washington State Department of Ecology, very dry conditions over several months and a diminished snowpack impacted streamflow, which were identified to be well below normal conditions across most of the state (see Figure 6-3).[1] Watersheds west of the Cascades crest, which are more rain dependent than rivers on the east side, flowed at much below normal levels. Some rivers set record daily lows for historic May flows. Statewide, at the time the declaration was ordered, only four (4) percent of rivers were flowing at levels above normal. Streamflows were strong in the southeast corner of the state. Twenty-seven out of 62 watersheds were declared for drought as of May 20, 2019. Skagit County and several of its watersheds were among the Counties identified as having a drought emergency. On August 29, 2019, the USDA designated Skagit County as one of the four areas identified as sustaining a natural disaster due to the drought.

[1] Source: https://waterwatch.usgs.gov/?m=real&r=wa

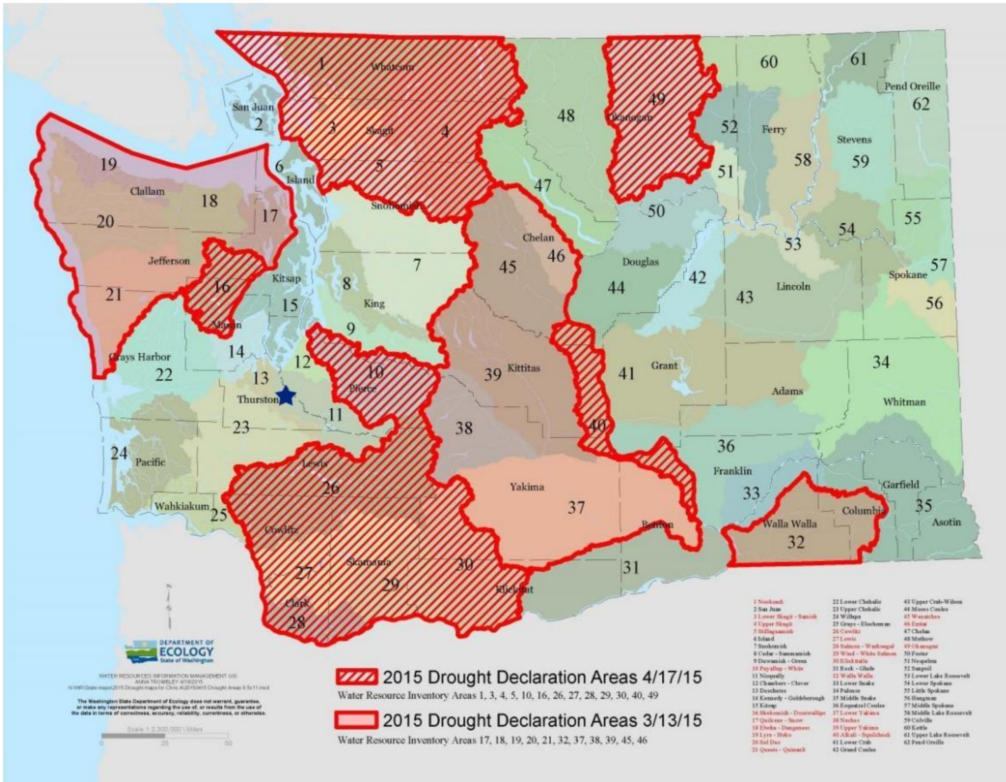


Figure 6-1 Washington State Department of Ecology 2015 Drought Map

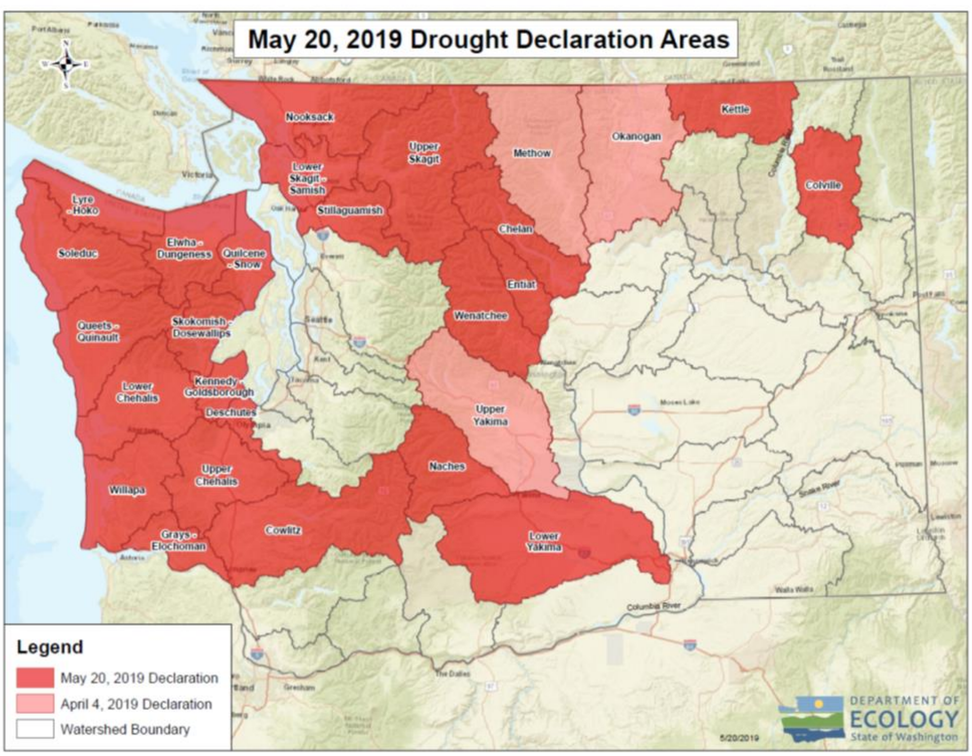


Figure 6-2 Washington State Department of Ecology May 2019 Drought Declaration Areas

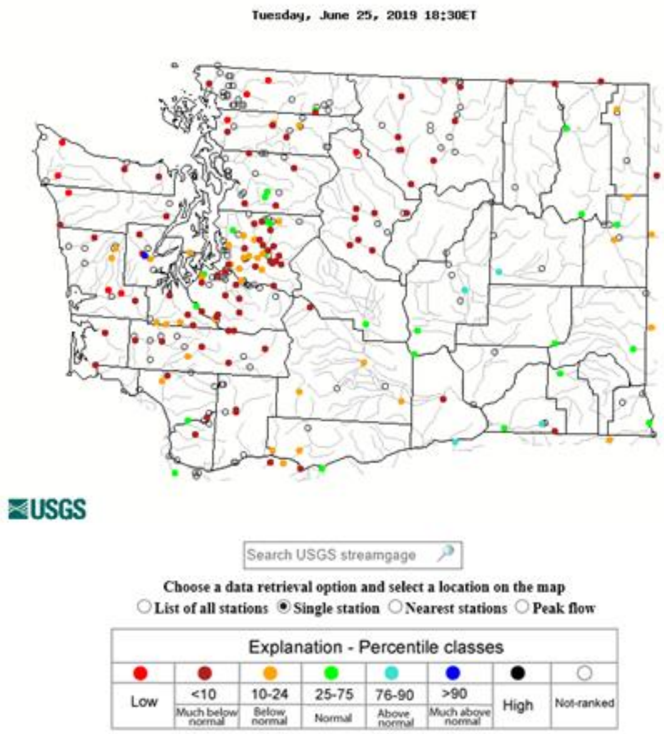


Figure 6-3 USGS Streamflow Comparison for Day of Year

TABLE 6-2
COMPARISON OF IMPACTS OF 1977 DROUGHT TO 2001 DROUGHT

Impact	1977 Drought	2001 Drought
Precipitation	Precipitation at most locations ranged from 50 to 75% of normal levels, and in parts of Eastern Washington as low as 42 to 45% of normal.	Precipitation was 56 to 74% of normal. U.S. Bureau of Reclamation – Yakima Project irrigators received only 37% of their normal entitlements. At the end of the irrigation season, the Bureau of Reclamation’s five reservoirs stored only 50,000 acre-feet of water compared with 300,000 acre-feet typically in storage.
Wildland Fire	1,319 wildland fires burned 10,800 acres. State fire-fighting activities involved more than 7,000 man-hours and cost more than $1.5 million.	1,162 wildland fires burned 223,857 acres. Firefighting efforts cost the state $38 million and various local, regional, and federal agencies another $100 million.
Fish	In August and September 1977, water levels at the Goldendale and Spokane trout hatcheries were down. Fish had difficulties passing through Kendall Creek, a tributary to the north fork of the Nooksack River in Whatcom County.	A dozen state hatcheries took a series of drought-related measures, including installing equipment at North Toutle and Puyallup hatcheries to address low water flow problems.

TABLE 6-2
COMPARISON OF IMPACTS OF 1977 DROUGHT TO 2001 DROUGHT

Impact	1977 Drought	2001 Drought
Emergency Water Permits	Department of Ecology issued 517 temporary groundwater permits to help farmers and communities drill more wells.	Department of Ecology issued 172 temporary emergency water-right permits and changes to existing water rights.
Economic Impacts	The state's economy lost an estimated $410 million over a two-year period. The drought hit the aluminum industry hardest. Major losses in agriculture and service industries included a $5 million loss in the ski industry. 13,000 jobs were lost because of layoffs in the aluminum industry and in agriculture.	The Bonneville Power Administration paid more than $400 million to electricity-intensive industries to shut down and remain closed for the duration of the drought. Thousands lost their jobs for months, including 2,000-3,000 workers at the Kaiser and Vanalco plants. Federal agencies provided more than $10.1 million in disaster aid to growers. More than $7.9 million in state funds paid for drought-related projects; these projects enabled the state to provide irrigation water to farmers with junior water rights and to increase water in fish-bearing streams.

6.2.3 Severity

In 1989, the Washington State Legislature gave permanent drought relief authority to the Department of Ecology and enabled them to issue orders declaring drought emergencies. (RCW 43.83B.400-430 and Chapter 173-166 WAC). In Washington State, the statutory criteria for drought is a water supply below 75% of normal and a shortage expected to create undue hardship for some water users.

While droughts customarily do not directly impact structures, droughts do impact individuals (farmers, laborers, etc.), the agricultural and natural resource industries, and other precipitation-dependent sectors. Lack of snowpack has forced ski resorts into bankruptcy. There is increased danger of forest /wildland fires. Millions of board feet of timber have been lost. Loss of forests and trees increases erosion, causing damage to aquatic life, irrigation, and power development by heavy silting of streams, reservoirs, and rivers. The health of forests is also a concern with respect to infestation associated with weakened trees due to drought.

Nearly all areas of Washington are vulnerable to drought. The coastal areas of Washington, the Olympic Peninsula, and areas in Central Washington just east of the Cascades are particularly vulnerable. High quality agricultural soils exist in Skagit County. These areas sustain crops that are dependent upon moisture through the winter and spring and dryer conditions in the summer.

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the duration of the drought and the larger the area impacted, the more severe the potential impacts. Droughts are not usually associated with direct impacts on people or property, but they can have significant impacts on agriculture, wildlife, and fishing, which can impact people indirectly. When measuring the severity of droughts, analysts typically look at economic impacts.

A drought lasting for more than one season would most likely reduce the annual snowpack accumulated at high elevations in the Cascade Mountains, thereby reducing normal stream flows in local rivers and creeks. Should an extreme, long-term drought occur, a large portion of the population of area would be impacted.

Customarily when such events occur, the initial response is to institute a voluntary water conservation measures, particularly in those communities which receive water supplies from the depleted watersheds. Such was the case with the 2019 drought.

The water supply for the planning area is obtained from the Skagit River, as well as large creeks with reliable, glacial sources. The effects of an extreme, long-term drought could result in inadequate stream flows and ground water recharge, thereby resulting in the implementation of strict water conservation measures.

A substantial reduction in stream flows could also severely impact the generation of electricity from the hydroelectric dams which are situated in Skagit County. A reduction in hydroelectric generation will result in increased electricity rates or could also result in brown outs.

The National Oceanic and Atmospheric Administration (NOAA) has developed several indices to measure drought impacts and severity to map their extent and locations. The Palmer Drought Severity Index (PDSI) and Crop Moisture Index (CMI) are indices of the relative dryness or wetness effecting water sensitive economies. The PDSI indicates the prolonged and abnormal moisture deficiency or excess. The CMI gives both short-term and the current status of the potential for an agricultural drought or moisture surplus, which can change rapidly from week to week. Both indices indicate general conditions and not local variations caused by isolated rain. Input to the calculations include the weekly precipitation total and average temperature, division constants (water capacity of the soil, etc.) and previous history of the indices.

The PDSI is an important climatological tool for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather. It can be used to help delineate disaster areas and indicate the availability of irrigation water supplies, reservoir levels, range conditions, amount of stock water, and potential intensity of forest fires. The CMI can be used to measure the status of dryness or wetness affecting warm season crops and field activities.

What follow are a series of maps indicating the existing conditions as they relate to Drought. These maps change very frequently and are intended to demonstrate information available to viewers. Additional information and current monthly data are available from the NOAA website at the following address:
https://www.cpc.ncep.noaa.gov/products/Drought/

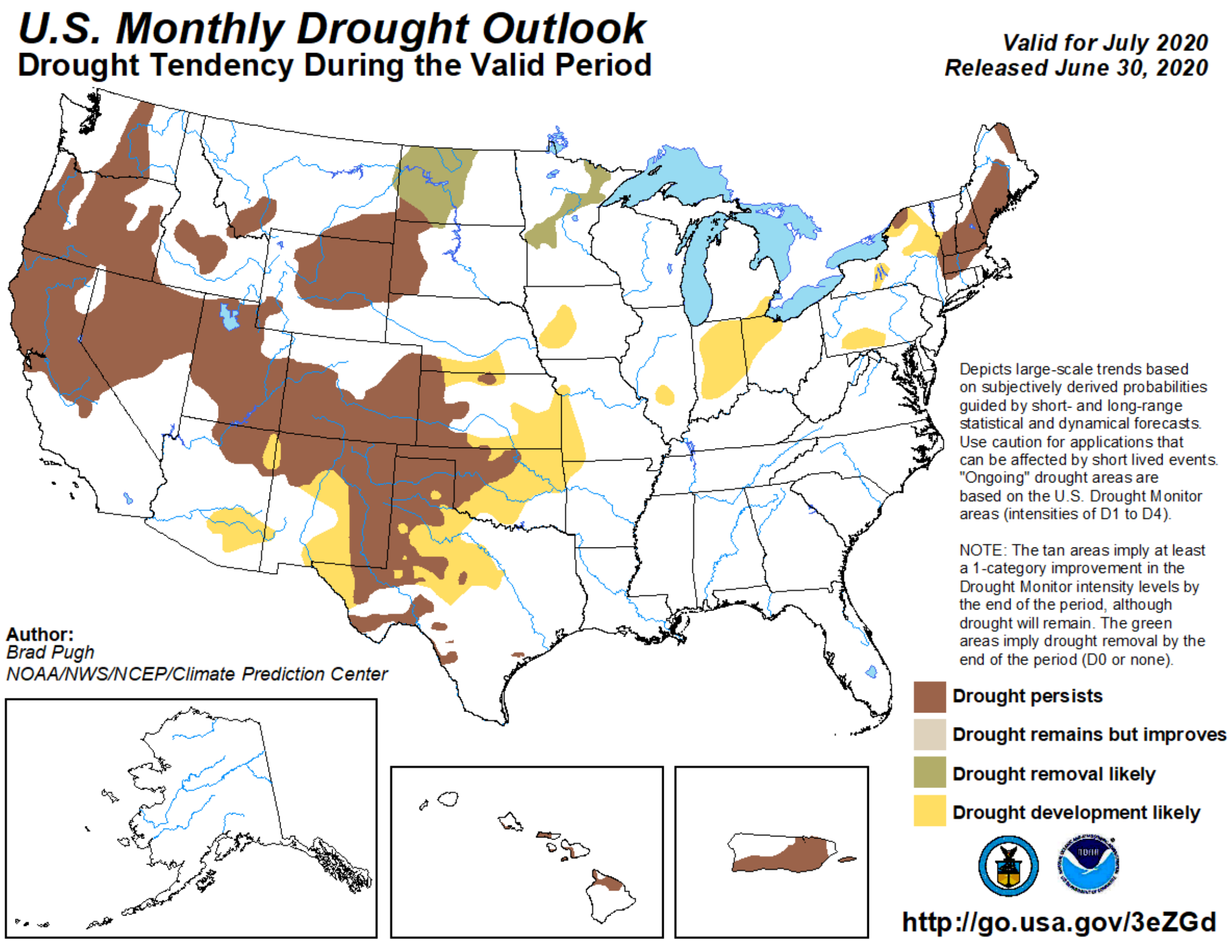


Figure 6-4 July 2020 Drought Monitor

Source: NOAA http://go.usa.gov/3eZGd

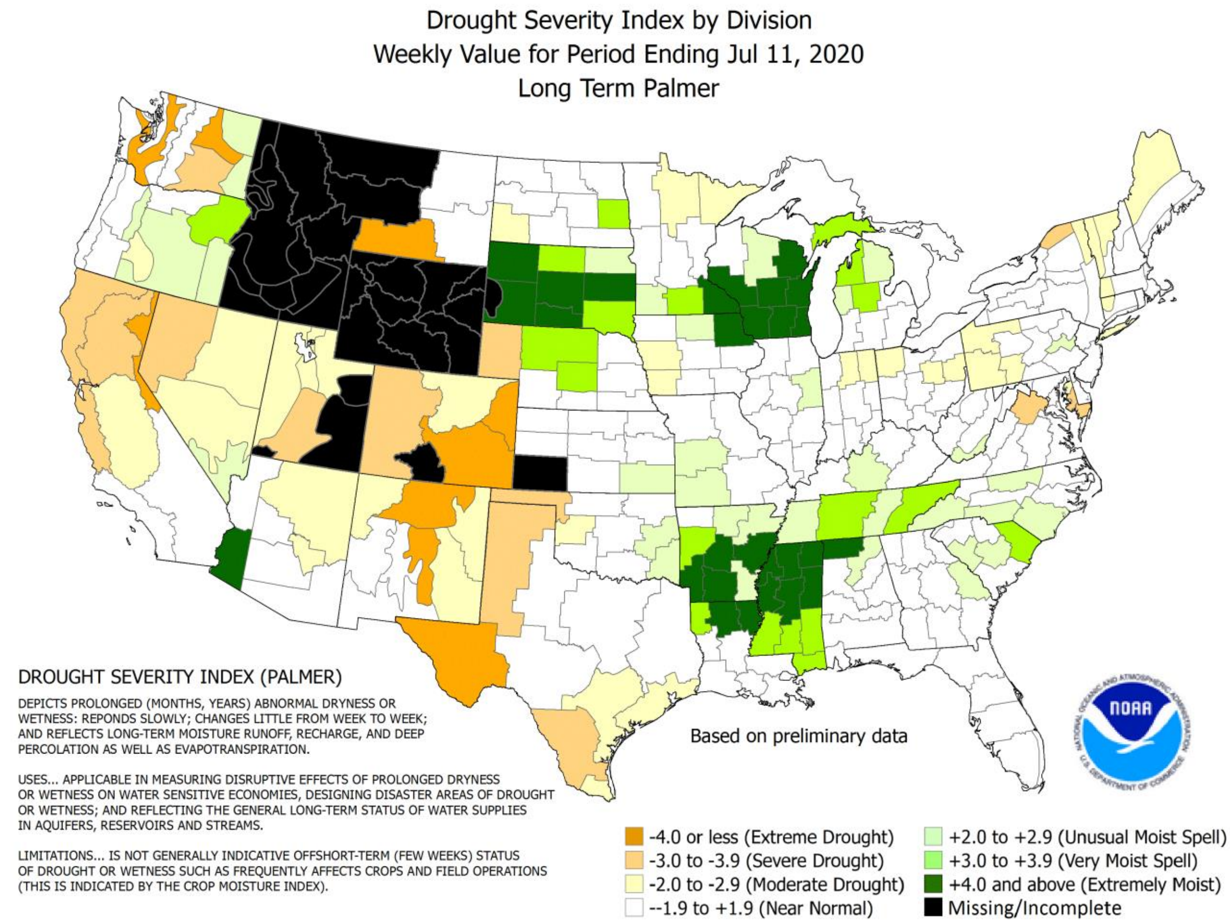


Figure 6-5 Palmer Drought Severity Index July 2020

Source: NOAA https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif

The ***Palmer Crop Moisture Index*** measures short-term drought on a weekly scale and is used to quantify drought's impacts on agriculture during the growing season. See figure below for the current information available as of this update.

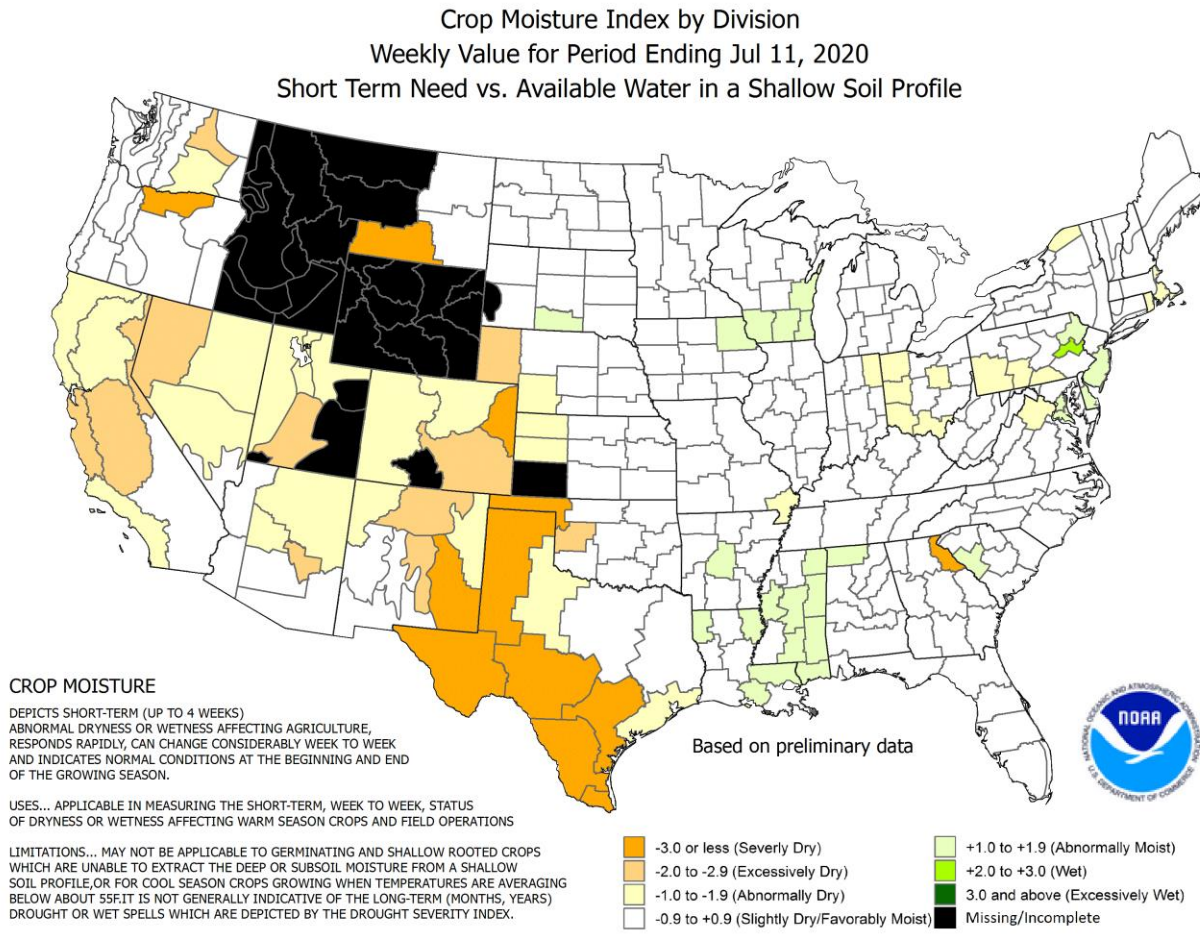


Figure 6-6 Crop Moisture Index

Source: NOAA https://www.weather.gov/ncrfc/LMI_WS_DroughtLinks

6.2.4 Frequency

Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause. It is the result of many causes, often synergistic in nature; these include global weather patterns that produce persistent, upper-level high-pressure systems along the West Coast with warm, dry air resulting in less precipitation.

In temperate regions, including Washington, long-range forecasts of drought have limited reliability. In the tropics, empirical relationships have been demonstrated between precipitation and El Niño events, but few such relationships have been demonstrated above 30º north latitude. Meteorologists do not believe that reliable forecasts are currently attainable one season or more in advance for temperate regions.

A great deal of research has been conducted in recent years on the role of interacting systems in explaining regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve the ability for long-range climate prediction. However, too many variables exist in determining the frequency with which a drought will occur.

According to the Washington State Hazard Mitigation Plan data (2013) "At this time, reliable forecasts of drought are not attainable for temperate regions of the world more than a season in advance. However, based on a 100-year history with drought, the state as a whole can expect severe or extreme drought at least 5 percent of the time in the future, with most of eastern Washington experiencing severe or extreme drought about 10 to 15 percent of the time." (WA EMD, 2013)

Below is the U.S. Seasonal Drought Outlook as predicted by NOAA for the period June 18, 2020 through September 30, 2020. Review of the data illustrates the continued drought within Eastern Washington, but no drought predicted during the period illustrated for Western Washington.

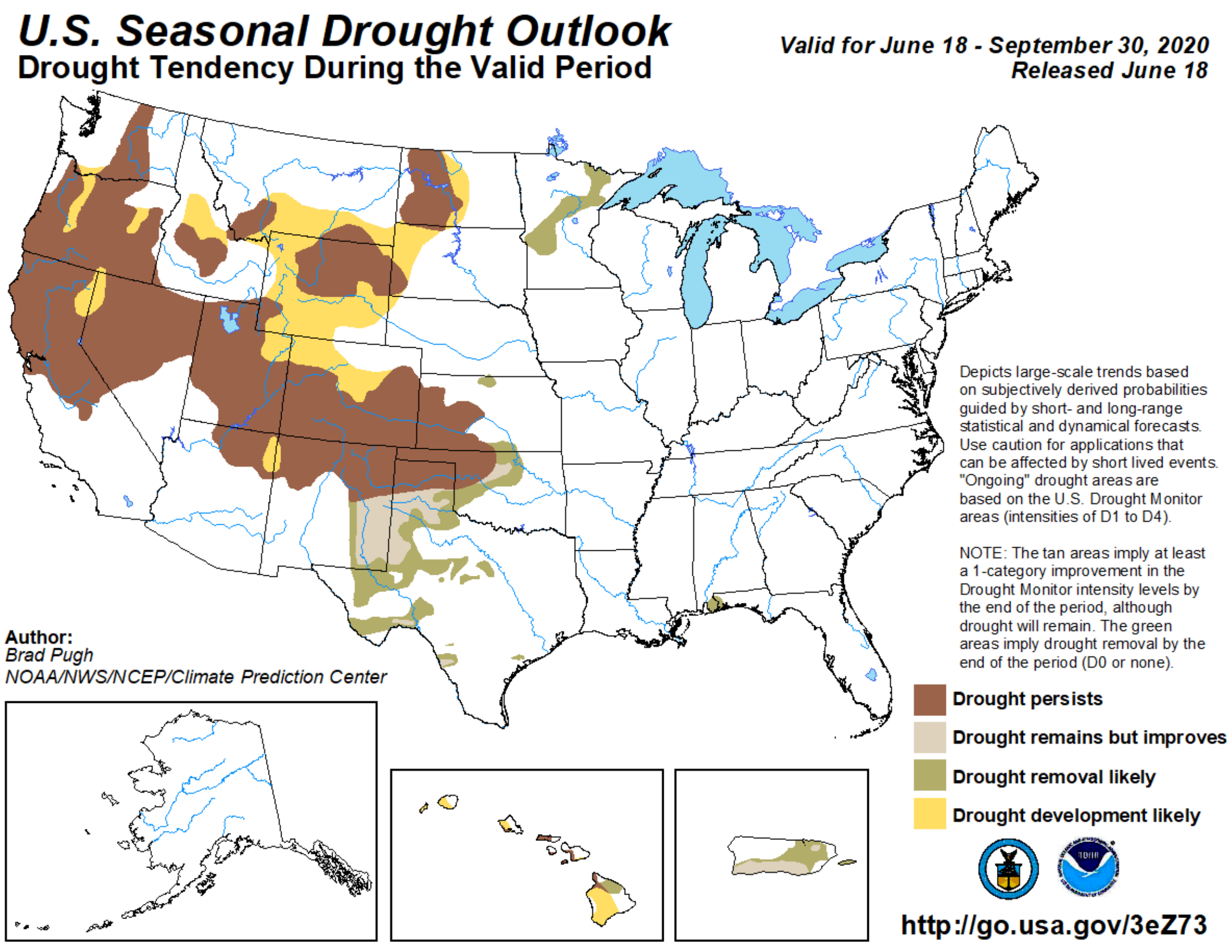


Figure 6-7 NOAA - US Seasonal Drought Outlook Prediction

Source: NOAA https://www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.php

6.3 VULNERABILITY ASSESSMENT

6.3.1 Overview

Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to the ability to produce goods and provide services. Drought can affect a wide range of economic, environmental, and social activities. The vulnerability of an activity associated with the effects of drought usually depends on its water demand, how the demand is met, and what water supplies are available to meet the demand.

All people, property and environments in the planning area could be exposed to some degree to the impacts of moderate to extreme drought. Areas densely wooded, especially areas in parks which host campers, increase the exposure to forest fires. Additional exposure comes in the form of economic impact should a prolonged drought occur that would impact fishing, fish rearing, recreation, agriculture, and timber harvesting—primary sources of income in the planning area. Prolonged drought would also decrease capacity within the watersheds, thereby reducing fish runs and, potentially, spawning areas.

The Washington State Enhanced Hazard Mitigation plan has established criteria on which it defines jurisdictions as being vulnerable to drought, changing the 2018 methodology from that in previous plan editions. To that degree, the State's plan identifies the tribal planning area among those areas referenced as being in a "medium-low" status with respect to vulnerability to drought in the Washington State Enhanced Hazard Mitigation Plan (see Figure 6-8).

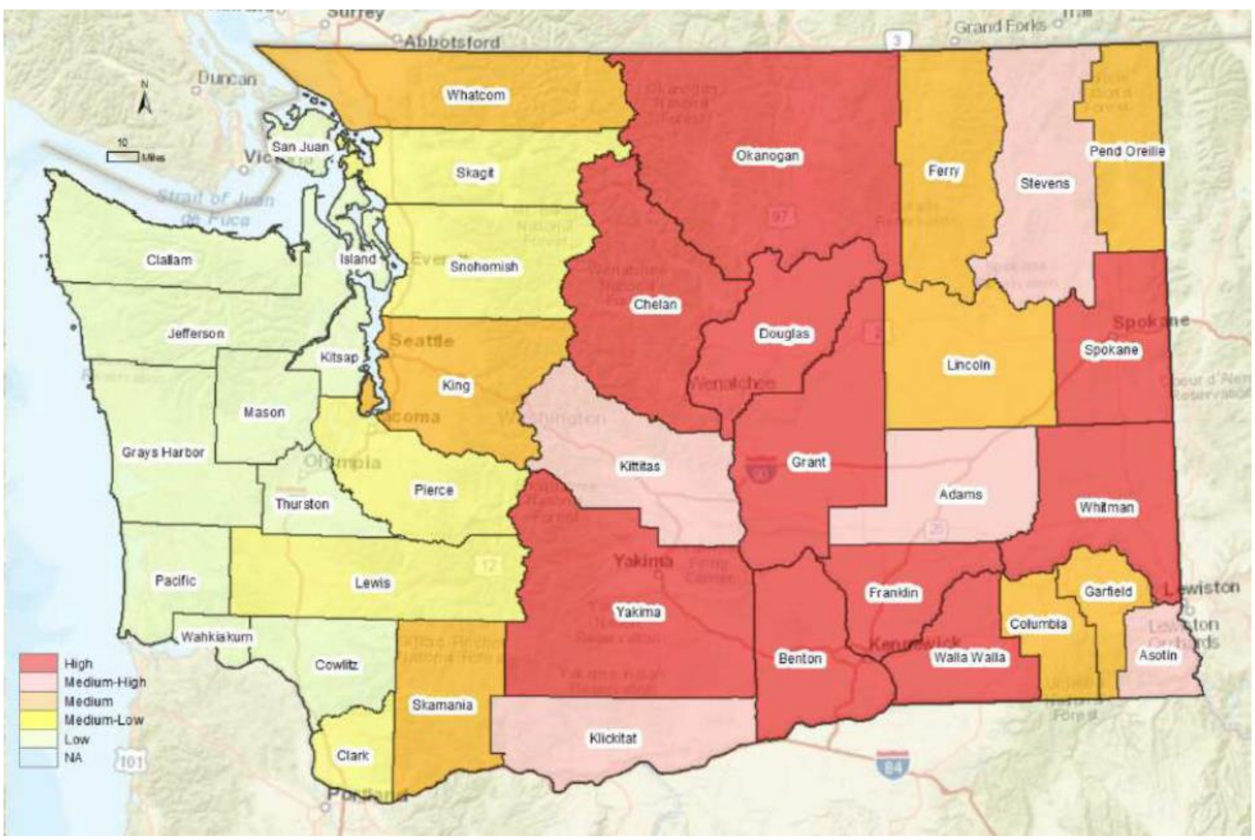


Figure 6-8 WA EMD Drought Risk Index (2018)

Warning Time

A drought is not a sudden-onset hazard. Droughts are climatic patterns that occur over long periods, providing for some advance notice. In many instances, annual situations of low water levels are identified months in advance (e.g., snowpack at lower levels are identified during winter months), allowing for advanced planning for water conservation.

Meteorological drought is the result of many causes, including global weather patterns that produce persistent, upper-level high-pressure systems along the West Coast resulting in less precipitation. Only general warning can take place, due to the numerous variables that scientists have not pieced together well enough to make accurate and precise predictions. It is often difficult to recognize a drought before being in the middle of it. Droughts do not occur spontaneously; they evolve over time as certain conditions are met.

Scientists do not know how to predict drought more than a few months in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Weather anomalies may last from several months to several decades. How long they last depend on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale. In temperate regions such as Washington, long-range forecasts of drought have limited reliability. Meteorologists do not believe that reliable forecasts are attainable at this time a season or more in advance for temperate regions.

6.3.2 Impact on Life, Health, and Safety

A drought directly or indirectly impacts all people in affected areas. Most notably, Skagit County has a fairly large number of privately owned wells, which may be impacted by reduced water flows and aquifer to supply drinking water. While the City of Anacortes provides water to some of the area in which the Samish owns structures, there are some areas which do rely on wells, which may be impacted by a drought. Likewise, as with the 2019 summertime season, the City did request voluntary conservation measures by residents to ensure an adequate water supply.

A drought can also result in farmers not being able to plant crops or the failure of planted crops, a significant level of the established economy in the region. This results in loss of work for farm workers and those in related food processing jobs. Other water- or electricity-dependent industries are commonly forced to shut down all or a portion of their facilities, resulting in further layoffs, impacting income. A drought can also harm recreational enterprises that use water (e.g., swimming pools, water parks, and river rafting companies) as well as landscape and nursery businesses. With much of Washington's energy coming from hydroelectric plants (including such plants within Skagit County), a drought means less inexpensive electricity coming from dams and probably higher electric bills. All people will pay more for water if utilities increase their rates. This has become an issue within Washington State previously, when a lack of snowpack has decreased hydroelectric generating capacity, and raised the electric prices, impacting residents.

Wildfires are often associated with drought. A prolonged lack of precipitation dries out vegetation, which becomes increasingly susceptible to ignition as the duration of the drought extends. This increases the risk to the health and safety of the residents within the planning area, especially those in wildland-urban interface areas. Smoke and particles embedded within the smoke are of significant concern for the elderly and very young, especially those with breathing problems.

6.3.3 Impact on Property

No structures will be directly affected by drought conditions, though some may become vulnerable to wildfires, which are more likely following years of drought. Droughts can also have significant impacts on landscapes, which could cause a financial burden to property owners. However, these impacts are not considered critical in planning for impacts from the drought hazard.

6.3.4 Impact on Critical Facilities and Infrastructure

Critical facilities will continue to be operational during a drought unless impacted by fire. Critical facility elements such as landscaping may not be maintained due to limited resources, but the risk to the planning area's critical facilities inventory will be largely aesthetic. For example, when water conservation measures are in place, landscaped areas will not be watered and may die. These aesthetic impacts are not considered significant.

6.3.5 Impact on Economy

As indicated above, economic impact from a drought is associated with different aspects, including, among others, the potential loss of agri- and aqua-cultural production and, of importance within the tribal planning area, tourism, and entertainment.

The area's agricultural producers are among the less than two percent of the population in the United States today that produce the food and fiber consumed by the remaining population and they do it more efficiently and at less cost to the consumer than any other industrialized country in the world. Loss of revenue to these producers would impact not only the owners, but the employees, and ultimately surrounding businesses and entertainment centers.

Additional economic impact stems from the potential loss of critical infrastructure due to fire damage and impacts on industries that depend on water for their business, such as aquaculture and fishing industries, and water-based recreational activities and areas. Samish relies heavily on the Fidalgo Bay Resort as an economic enterprise, which maintains camping facilities cabins and a Convention Center. Moreover, the Salish Landscape Services is a Samish-owned and operated landscape company that would be impacted by drought due to lack of business.

Problems of domestic and municipal water supplies have historically been corrected by building another reservoir, a larger pipeline, new well, or some other facility. The Samish are primarily reliant on public water sources for its water supply, with some of the tribal properties reliant on wells to supply water.

A drought impacting the watershed supply would be significant. With drought conditions increasing pressure on aquifers and increased pumping, which can result in saltwater intrusion into freshwater aquifers, resultant reductions or restrictions on economic growth and development could occur. Given this potential, a drought situation, if prolonged, could restrict building within specific areas due to lack of supporting infrastructure, thereby impacting the economy of the Samish and the region as a whole by limiting growth. In addition, impact to or the lack of hydroelectric generating capacity associated with drought conditions as a result of reduced precipitation levels could raise electric prices throughout the region.

A substantial reduction in streamflow could severely impact the generation of electricity from the hydro-electric dams located in the area. A reduction in hydro-electric generation will result in increased electricity rates for all residents and businesses in the area.

6.3.6 Impact on Environment

Environmental losses from drought are associated with aquatic life, plants, animals, wildlife habitat, air and water quality, forest fires, landscape quality, biodiversity, and soil erosion, among others.

Within Skagit County, the Skagit River and its watershed is the only river in Washington State that is home to five (5) species of salmon. The Skagit River supports some of the largest and healthiest Chinook runs and Pink salmon stock in Washington. (Ecology, 2014) A severe drought could cause reduced stream flows thereby creating a major environmental and economic impact on local salmon runs due to potentially warmer waters and low water levels.

Some effects are short-term, and conditions quickly return to normal after the drought. Other effects linger or even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes, and vegetation, but many species will eventually recover from this effect. Degraded landscape quality, including soil erosion, may lead to a more permanent loss of biological productivity. Lifecycles for fish spawning in the area would have environmental impacts years into the future. The Tribe does maintain two fish hatcheries, from which it annually releases stock.

In addition, the Samish Department of Natural Resources has expended considerable funds and staff time on various research projects such as Bull Kelp monitoring and Oregon Spotted Frog studies, (as well as others). A drought condition could negatively impact both Bull Kelp and the Oregon Spotted Frog, thereby rendering the research already completed potentially ineffective as conditions resulting from a drought could change the findings of the completed studies.

Public awareness and concern for environmental quality has led to greater attention to these effects. Drought conditions within the planning area could increase the demand for water supplies. Water shortages would have an adverse impact on the environment. If such conditions persisted for several years, the economy of the area could experience significant environmental setbacks.

6.3.7 Impact from Climate Change

The impact from climate change on drought will be significant. With historic records demonstrating increased temperature rise, the results will only further exacerbate drought stations. Drought plays a significant role in the wildfire system, fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildfire danger by warming and drying out vegetation. Climate change will further change the use of water available for fish spawning due to increased temperatures. It will also impact availability for agricultural growers for their crops; with decreased precipitation in the form of snow, water levels will fall, creating water shortages for use by consumers as drinking water, irrigation and watering of livestock, and firefighters to control and fight fires.

6.4 FUTURE DEVELOPMENT TRENDS

With an increase in population, there is also a propensity to increase water demands, as well as increase demands on other infrastructure, and increase the potential for wildfires. Practicing a low water-use lifestyle will increasingly become the norm for many as summer flows substantially reduce many of our rivers. Reducing water use will help meet future needs and result in cost savings and decrease energy use, helping preserve the environment.

The Samish continue to provide information, tools, and incentives to assist Tribal Citizens, local residents, businesses, other local governments, and water providers to design and implement comprehensive and proven conservation strategies. As the Samish continue to acquire lands within the planning area, in many instances, such is done with the intent to re-establish its natural environment. Such actions help to protect the area, and significantly reduce the impacts from drought.

6.5 ISSUES

Combinations of low precipitation and unusually high temperatures could occur over several consecutive years, especially in response to climate change. Intensified by such conditions, extreme wildfires could break out throughout the area, increasing the need for water. Surrounding communities, also in drought conditions, could increase their demand for water, causing social and political conflicts. Low water tables could increase issues of life, safety, and health, while also impacting the economy both for loss of potential agricultural income, but also with respect to decreased ability to construct new housing due to lack of ability to provide water. If such conditions persisted for several years, the economy of the region could experience setbacks, especially in water dependent industries.

6.6 IMPACT AND RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from Drought throughout the area is likely. The area has experienced drought conditions, with drought incidents occurring in 2015 and 2019. The State experienced one of its driest summers on record for the last 30 years in 2017, with several counties in the state also issuing declarations in April and June 2019. With anticipated increase in temperatures because of climate change, drought situations will only intensify. In addition, higher temperatures anticipated with climate change would increase vulnerability of the population due to excessive heat, while also potentially impacting power supplies at the hydro-dam in the area.

Current water supplies are relatively resistant to short-term drought episodes. Should a severe, long-term drought occur, it will be vital that local elected officials and governmental agencies work cooperatively to help ensure efforts are made to protect public water supplies, aid agriculture and local industry, and safeguard fish and stream flows.

Based on the potential impact, the Planning Team determined the CPRI score to be 2.35, with overall vulnerability determined to be a medium level.

CHAPTER 7.
EARTHQUAKE

An earthquake is the vibration of the earth's surface following a release of energy in the earth's crust. This energy can be generated by a sudden dislocation of the crust or by a volcanic eruption. Its epicenter is the point on the earth's surface directly above the hypocenter of an earthquake. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth. Earthquakes many times occur along a fault, which is a fracture in the earth's crust.

DEFINITIONS

Earthquake—The shaking of the ground caused by an abrupt shift of rock along a fracture in the earth or a contact zone between tectonic plates.

Epicenter—The point on the earth's surface directly above the hypocenter of an earthquake. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

Fault—A fracture in the earth's crust along which two blocks of the crust have slipped with respect to each other.

Focal Depth—The depth from the earth's surface to the hypocenter.

Hypocenter—The region underground where an earthquake's energy originates

Liquefaction— Loosely packed, water-logged sediments losing their strength in response to strong shaking, causing major damage during earthquakes.

7.1 GENERAL BACKGROUND

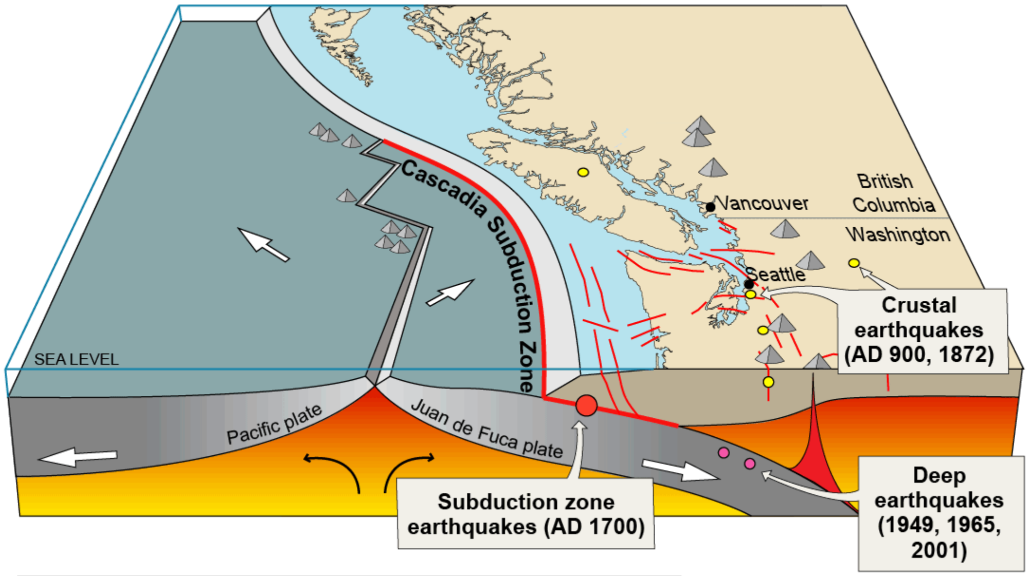
Most destructive quakes are caused by dislocations of the crust. The crust may first bend and then, when the stress exceeds the strength of the rocks, break and snap to a new position. In the process of breaking, vibrations called "seismic waves" are generated. These waves travel outward from the source of the earthquake at varying speeds.

Earthquakes tend to reoccur along faults, which are zones of weakness in the crust. Even if a fault zone has recently experienced an earthquake, there is no guarantee that all the stress has been relieved. Another earthquake could still occur.

Geologists classify faults by their relative hazards. Active faults, which represent the highest hazard, are those that have ruptured to the ground surface during the Holocene period (about the last 11,000 years). Potentially active faults are those that displaced layers of rock from the Quaternary period (the last 1,800,000 years). Determining if a fault is "active" or "potentially active" depends on geologic evidence, which may not be available for every fault.

Faults are more likely to have earthquakes on them if they have more rapid rates of movement, have had recent earthquakes along them, experience greater total displacements, and are aligned so that movement can relieve accumulating tectonic stresses. A direct relationship exists between a fault's length and location and its ability to generate damaging ground motion at a given site. In some areas, smaller, local faults produce lower magnitude quakes, but ground shaking can be strong, and damage can be significant because of the fault's proximity to the area. In contrast, large regional faults can generate great magnitudes but, because of their distance and depth, may result in only moderate shaking in the area.

It is generally agreed that three source zones exist for Pacific Northwest quakes: a shallow (crustal) zone; the Cascadia Subduction Zone; and a deep, intraplate "Benioff" zone. These are shown in Figure 7-1. More than 90 percent of Pacific Northwest earthquakes occur along the boundary between the Juan de Fuca plate and the North American plate.



Source	Max. Size	Recurrence
Subduction zone	M 9+	200–600 years
Deep Juan de Fuca plate	M 7+	30–50 years
Crustal faults	M 7+	Hundreds of years?

Volcano
Active crustal fault
Active plate boundary fault

*figure modified from USGS Cascadia earthquake graphics at http://geomaps.wr.usgs.gov/pacnw/pacnweq/index.html

Figure 7-1 Earthquake Types in the Pacific Northwest and Recurrence Intervals

An earthquake will generally produce the strongest ground motions near the epicenter (the point on the ground above where the earthquake initiated) with the intensity of ground motions diminishing with increasing distance from the epicenter. The intensity of ground shaking at a given site depends on four main factors:

- Earthquake magnitude
- Earthquake epicenter
- Earthquake depth
- Soil or rock conditions at the site, which may amplify or de-amplify earthquake ground motions.

For any given earthquake, there will be contours of varying intensity of ground shaking with distance from the epicenter. The intensity will generally decrease with distance from the epicenter, and often in an irregular pattern, not simply in concentric circles. The irregularity is caused by soil conditions, the complexity of earthquake fault rupture patterns, and directionality in the dispersion of earthquake energy.

7.1.1 Earthquake Classifications

Earthquakes are typically classified in one of two ways: By the amount of energy released, measured as *magnitude* (size or power based on the Richter Scale); or by the impact on people and structures, measured as *intensity* (based on the Mercalli Scale). Magnitude is related to the amount of seismic energy released at the hypocenter of an earthquake. It is determined by the amplitude of the earthquake waves recorded on instruments. Magnitude is represented by a single, instrumentally determined value for each earthquake event. Intensity indicates how the earthquake is felt at various distances from the earthquake epicenter. Table 7-1 presents a classification of earthquakes according to their magnitude.

TABLE 7-1
EARTHQUAKE MAGNITUDE CLASSES

Magnitude Class	Magnitude Range (M = magnitude)
Great	M > 8
Major	7 <= M < 7.9
Strong	6 <= M < 6.9
Moderate	5 <= M < 5.9
Light	4 <= M < 4.9
Minor	3 <= M < 3.9
Micro	M < 3

Estimates of moment magnitude roughly match the local magnitude scale (ML) commonly called the Richter scale. One advantage of the moment magnitude scale is that, unlike other magnitude scales, it does not saturate at the upper end. That is, there is no value beyond which all large earthquakes have about the same magnitude. For this reason, moment magnitude is now the most often used estimate of large earthquake magnitudes.

Intensity

There are many measures of the severity or intensity of earthquake ground motions. The Modified Mercalli Intensity scale (MMI) was widely used beginning in the early 1900s. MMI is a descriptive, qualitative scale that relates severity of ground motions to the types of damage experienced. MMI values range from I to XII (USGS, 1989). Table 7-2 compares the moment magnitude scale to the modified Mercalli intensity scale.

TABLE 7-2
EARTHQUAKE MAGNITUDE AND INTENSITY

Magnitude (Mw)	Intensity (Modified Mercalli)	Description
1.0—3.0	I	I. Not felt except by a very few under especially favorable conditions
3.0—3.9	II—III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0—4.9	IV—V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
5.0—5.9	VI—VII	VI. Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
6.0—6.9	VII—IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	VIII and higher	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

More accurate, quantitative measures of the intensity of ground shaking have largely replaced the MMI and are used in this mitigation plan. These scales use terms that can be physically measured with seismometers, such as the acceleration, velocity, or displacement (movement) of the ground. The intensity may also be measured as a function of the frequency of earthquake waves propagating through the earth. In the same way that sound waves contain a mix of low-, moderate- and high-frequency sound waves, earthquake waves contain ground motions of various frequencies. The behavior of buildings and other structures depends substantially on the vibration frequencies of the building or structure versus the frequency of earthquake waves. Earthquake ground motions also include both horizontal and vertical components.

Ground Motion

Earthquake hazard assessment is also based on expected ground motion. This involves determining the probability that certain ground motion accelerations will be exceeded over a time period of interest. A common physical measure of the intensity of earthquake ground shaking, and the one used in this mitigation plan, is peak ground acceleration (PGA). PGA is a measure of the intensity of shaking relative to the acceleration of gravity (g). For example, an acceleration of 1.0 g PGA is an extremely strong ground motion, which does occur near the epicenter of large earthquakes. With a vertical acceleration of 1.0 g, objects are thrown into the air. With a horizontal acceleration of 1.0 g, objects accelerate sideways at the same rate as if they had been dropped from the ceiling. A PGA equal to 10% g means that the ground acceleration is 10 percent that of gravity, and so on (see Figure 7-2).[2]

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. The following generalized observations provide qualitative statements about the likely extent of damage for earthquakes with various levels of ground shaking (PGA) at a given site:

- Ground motions of only 1% g or 2% g are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
- Ground motions below about 10% g usually cause only slight damage.
- Ground motions between about 10% g and 30% g may cause minor to moderate damage in well-designed buildings, with higher levels of damage in more vulnerable buildings. At this level of ground shaking, some poorly built buildings may be subject to collapse.
- Ground motions above about 30% g may cause significant damage in well-designed buildings and very high levels of damage (including collapse) in poorly designed buildings.
- Ground motions above about 50% g may cause significant damage in most buildings, even those designed to resist seismic forces.

[2] USGS. Accessed 7/20/20. Available at: https://earthquake.usgs.gov/earthquakes/byregion/washington.php

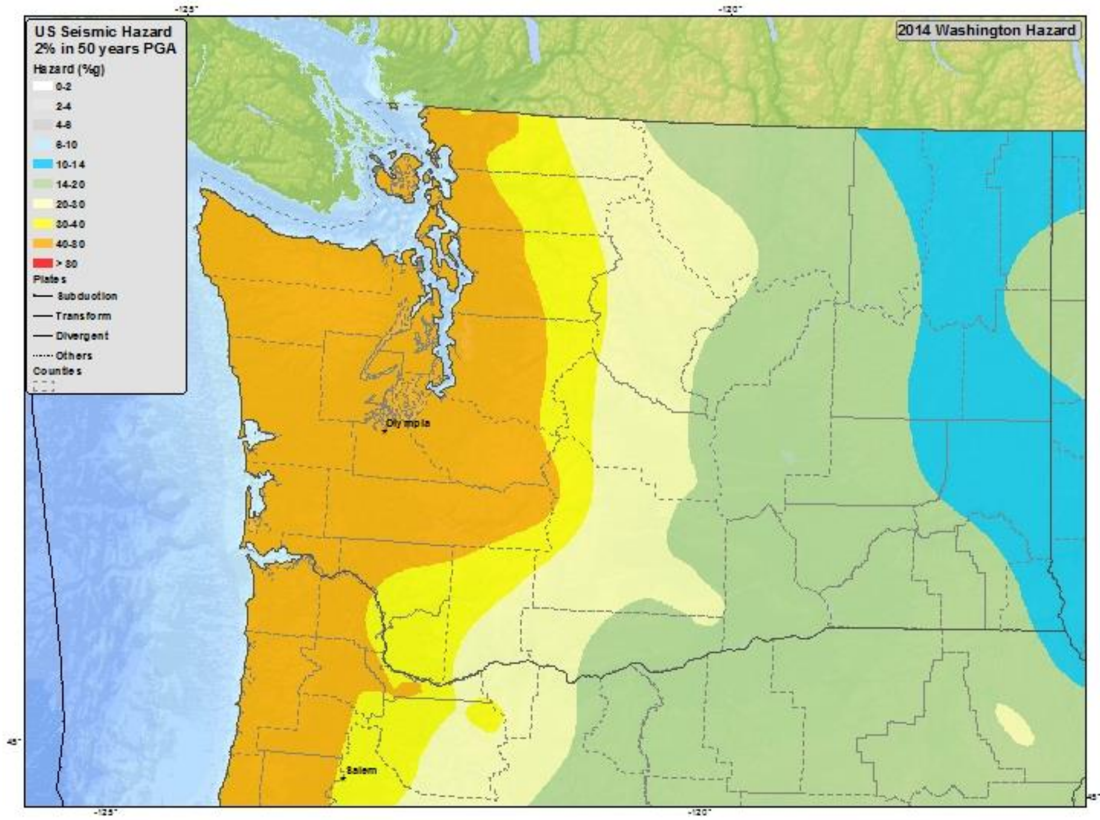


Figure 7-2 USGS PGA for Washington State (2014)

PGA is the basis of seismic zone maps that are included in building codes such as the International Building Code. Washington State DNR's Seismic Zone Map is illustrated in Figure 7-3.[3] Building codes that include seismic provisions specify the horizontal force due to lateral acceleration that a building should be able to withstand during an earthquake.

PGA values are directly related to these lateral forces that could damage "short period structures" (e.g. single-family dwellings). Longer period response components determine the lateral forces that damage larger structures with longer natural periods (apartment buildings, factories, high-rises, bridges). The amount of earthquake damage and the size of the geographic area affected generally increase with earthquake magnitude:

- Earthquakes below M5 are not likely to cause significant damage, even near the epicenter.
- Earthquakes between about M5 and M6 are likely to cause moderate damage near the epicenter.
- Earthquakes of about M6.5 or greater (e.g., the 2001 Nisqually earthquake in Washington) can cause major damage, with damage usually concentrated fairly near the epicenter.

[3] Washington State Department of Natural Resources (2007). Accessed 07/20/20. Available at: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/geologic-hazard-maps#seismic-design-categories

- Larger earthquakes of M7+ cause damage over increasingly wider geographic areas with the potential for very high levels of damage near the epicenter.

- Great earthquakes with M8+ can cause major damage over wide geographic areas.

- A M9 mega-quake on the Cascadia Subduction Zone could affect the entire Pacific Northwest from British Columbia, through Washington and Oregon, and as far south as Northern California, with the highest levels of damage nearest the coast.

Table 7-3 identifies damage potential and perceived shaking by PGA factors, compared to the Mercalli scale.

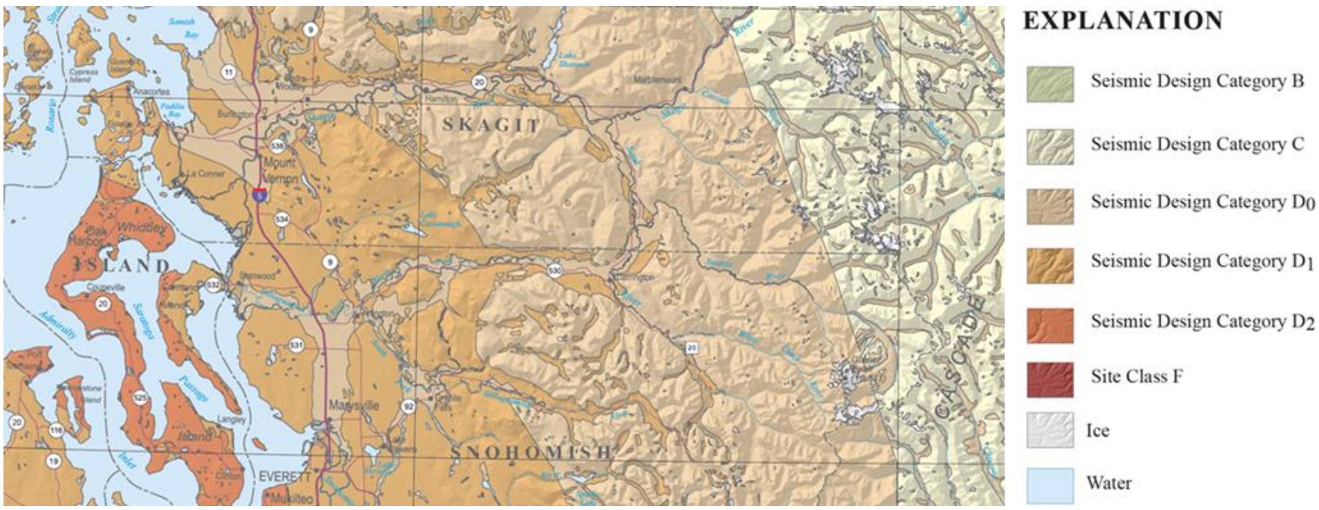


Figure 7-3 Seismic Design Codes

TABLE 7-3
COMPARISON OF MERCALLI SCALE AND PEAK GROUND ACCELERATION

Modified Mercalli Scale	Perceived Shaking	Potential Structure Damage: Resistant Buildings	Potential Structure Damage: Vulnerable Buildings	Estimated PGA[a] (%g)
I	Not Felt	None	None	<0.17%
II-III	Weak	None	None	0.17%—1.4%
IV	Light	None	None	1.4%—3.9%
V	Moderate	Very Light	Light	3.9%—9.2%
VI	Strong	Light	Moderate	9.2%—18%
VII	Very Strong	Moderate	Moderate/Heavy	18%—34%
VIII	Severe	Moderate/Heavy	Heavy	34%—65%
IX	Violent	Heavy	Very Heavy	65%—124%
X—XII	Extreme	Very Heavy	Very Heavy	>124%

a. PGA measured in percent of g, where g is the acceleration of gravity
Sources: USGS, 2008; USGS, 2010

7.1.2 Effect of Soil Types

Liquefaction is a secondary effect of an earthquake in which soils lose their shear strength and flow or behave as liquid, thereby damaging structures that derive their support from the soil. Liquefaction generally occurs in soft, unconsolidated sedimentary soils. The National Earthquake Hazard Reduction Program (NEHRP) creates maps based on soil characteristics to help identify locations subject to liquefaction. Figure 7-4 identifies the soils classifications for the Samish Indian Nation.

Table 7-4 summarizes NEHRP soil classifications. NEHRP Soils B and C typically can sustain ground shaking without much effect, dependent on the earthquake magnitude. Areas that are commonly most affected by ground shaking and susceptible to liquefaction have NEHRP Soils D, E and F.

Review of the existing data identifies that the area is variable in its soils type, with Tribal structures located on C, C-D, D, D-E, and E soils. The majority of those structures assessed (29 of the 32), fall within Soils Class C (six), Soils Class D, D-E (22), and E (one), meaning that the liquefaction factor for the assessed structures fall within the very low, low-to-moderate, and moderate-heavy soils type based NEHRP soils classifications. This should not be construed to mean that no impact will be sustained, as this data is for planning purposes only, and should not be utilized for determining life-safety measures. Such assessments would require engineered analysis and is far beyond the scope of this project.

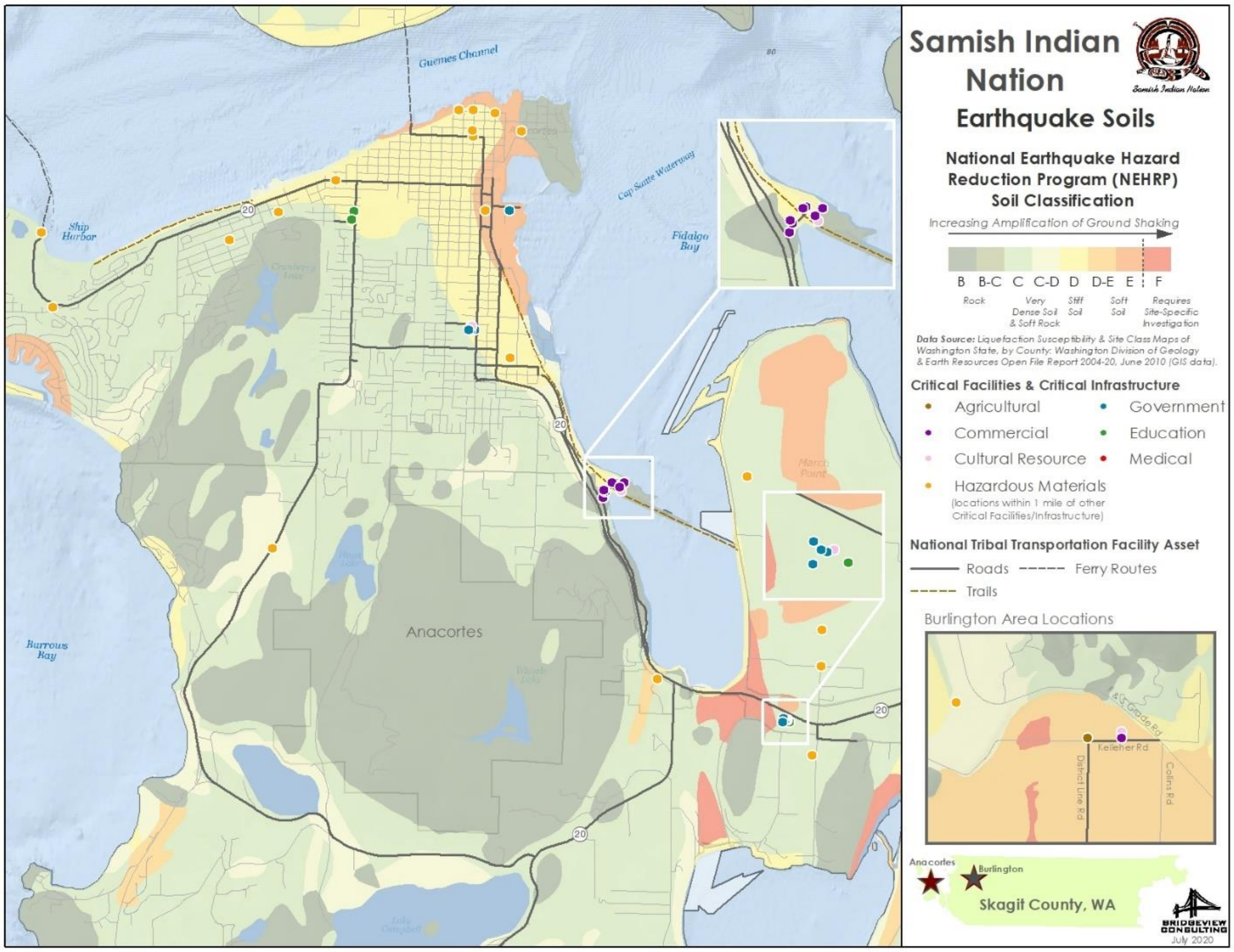


Figure 7-4 NEHRP Soils Classifications

TABLE 7-4 NEHRP SOIL CLASSIFICATION SYSTEM		
NEHRP Soil Type	**Description**	**Mean Shear Velocity to 30 Meters (m/s)**
A	Hard Rock	1,500
B	Firm to Hard Rock	760-1,500
C	Dense Soil/Soft Rock	360-760
D	Stiff Soil	180-360
E	Soft Clays	< 180
F	Special Study Soils (liquefiable soils, sensitive clays, organic soils, soft clays >36 m thick)	

7.1.3 Fault Classification

The U.S. Geologic Survey defines four fault classes based on evidence of tectonic movement associated with large-magnitude earthquakes during the Quaternary period, which is the period from about 1.6 million years ago to the present:

- Class A—Geologic evidence demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed by mapping or inferred from liquefaction or other deformational features.
- Class B—Geologic evidence demonstrates the existence of Quaternary deformation, but either (1) the fault might not extend deep enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A.
- Class C—Geologic evidence is insufficient to demonstrate (1) the existence of tectonic faulting, or (2) Quaternary slip or deformation associated with the feature.
- Class D—Geologic evidence demonstrates that the feature is not a tectonic fault or feature; this category includes features such as joints, landslides, erosional or fluvial scarps, or other landforms resembling fault scarps but of demonstrable non-tectonic origin.

Review of fault data for the immediate area of Tribal structures indicates the closest fault being an unnamed fault (Fault ID 55) located in the Strait of Juan de Fuca and Puget Sound. The closest identified fault is the Devils Mountain Fault. Readers wishing additional data on fault locations may wish to review the USGS website.[4]

7.2 HAZARD PROFILE

Seismic-related hazards include ground motion from shallow (less than 20 miles deep) or deep faults; liquefaction and differential settling of soil in areas with saturated sand, silt, or gravel; and tsunamis that result from seismic activities. Earthquakes also can cause damage by triggering landslides or bluff failure. The Puget Sound region is entirely within Seismic Risk Zone 3, requiring that buildings be designed to withstand major earthquakes measuring 7.5 in magnitude. It is anticipated, however, that earthquakes caused from subduction plate stress can reach a magnitude greater than 8.0.

High-magnitude earthquakes are possible in planning area when the Juan de Fuca slips beneath the North American plates. Deep zone or Benioff zone quakes have occurred within the Juan de Fuca plate (1949, 1965, and 2001) and can be expected in the future.

7.2.1 Extent and Location

Washington State is one of the most seismically active states in United States. Figure 7-5 depicts the faults known or suspected to be active within the state. Several major faults are located in the vicinity. Small shallow earthquakes (up to Magnitude 4) associated with these faults are likely. Shallow earthquakes of greater magnitude are expected to occur infrequently in this area.

[4] USGS Quaternary Faults accessed 21 July 2020. Available at: https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=5a6038b3a1684561a9b0aadf88412fcf

One of the most notable faults, according to the Washington State Department of Natural Resources Geology Division, is the Devils Mountain Fault lying near Mt. Vernon which is roughly 125 km (78 miles) long, runs generally east to west through Darrington in Snohomish County to Vancouver Island, Canada, and has been determined to be active with at least one earthquake generated about 2,000 years ago (Personius and others, 2014). If a magnitude seven (M7) or greater the event was to occur, it would affect 15 counties, including Skagit County.

Additional information is available from Washington State Department of Natural Resources Scenario catalogue, available at: https://fortress.wa.gov/dnr/seismicscenarios/index.html?config=canyonRiver.xml.

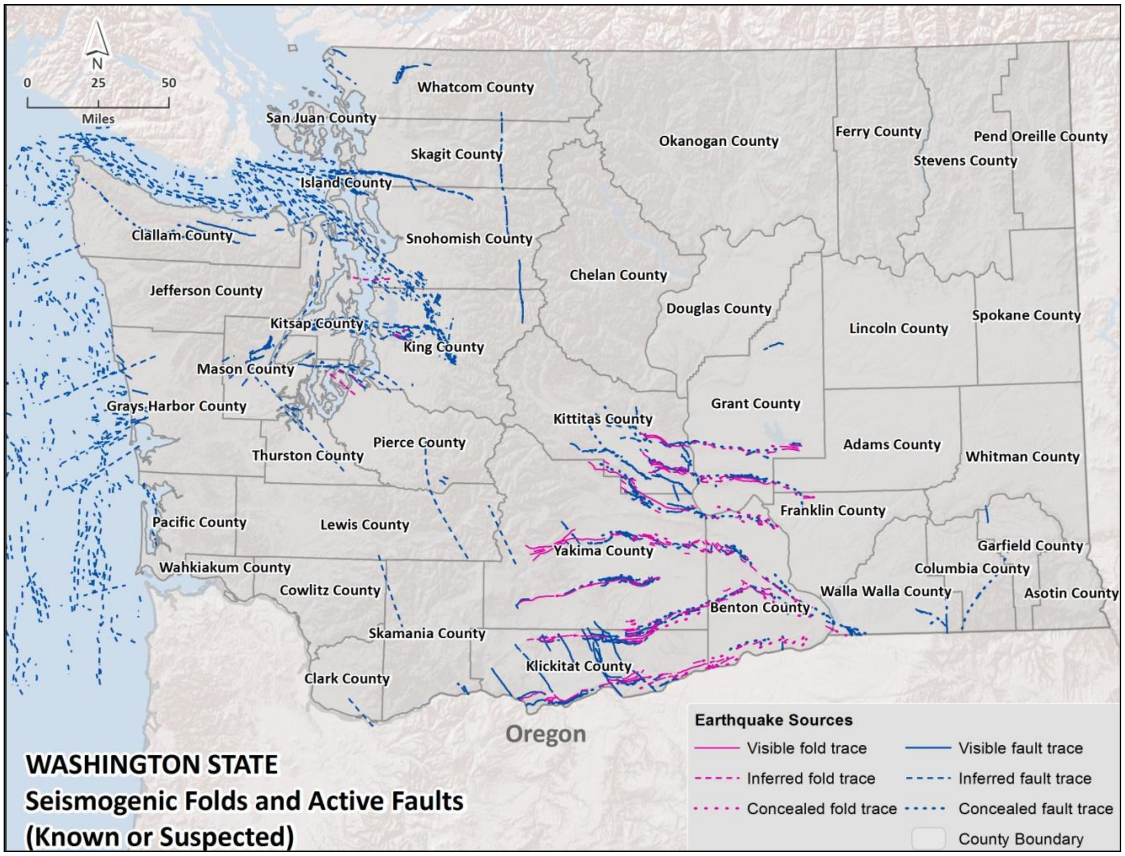


Figure 7-5 Washington State Seismogenic Folds and Active Faults (2013 HMP)

Hazard Mapping

Identifying the extent and location of an earthquake is not as simple as it is for other hazards such as flood, landslide, or wildfire. The impact of an earthquake is largely a function of the following factors:

- Ground shaking (ground motion accelerations)
- Liquefaction (soil instability)
- Distance from the source (both horizontally and vertically).

Mapping that shows the impacts of these components was used to assess the risk of earthquakes within the planning area. While the impacts from each of these components can build upon each other during an earthquake event, the mapping looks at each component individually. The mapping used in this assessment is described below.

ShakeMaps

A shake map is a representation of ground shaking produced by an earthquake (Peak Ground Acceleration). The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because shake maps focus on the ground shaking resulting from the earthquake, rather than the parameters describing the earthquake source. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region, depending on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. A shake map shows the extent and variation of ground shaking in a region immediately following significant earthquakes.

Ground motion and intensity maps are derived from peak ground motion recorded on seismic sensors, with interpolation where data are lacking and site-specific corrections. Color-coded intensity maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity. Two types of shake map are typically generated from the data:

- A probabilistic seismic hazard map shows the hazard from earthquakes that geologists and seismologists agree could occur. The maps are expressed in terms of probability of exceeding a certain ground motion, such as the 10 percent probability of exceedance in 50 years. This level of ground shaking has been used for designing buildings in high seismic areas.

- Earthquake scenario maps describe the expected ground motions and effects of hypothetical large earthquakes for a region. Maps of these scenarios can be used to support all phases of emergency management.

For this plan development, a Devils Mountain M7.5 Earthquake (Figure 7-6) scenario earthquake was chosen.

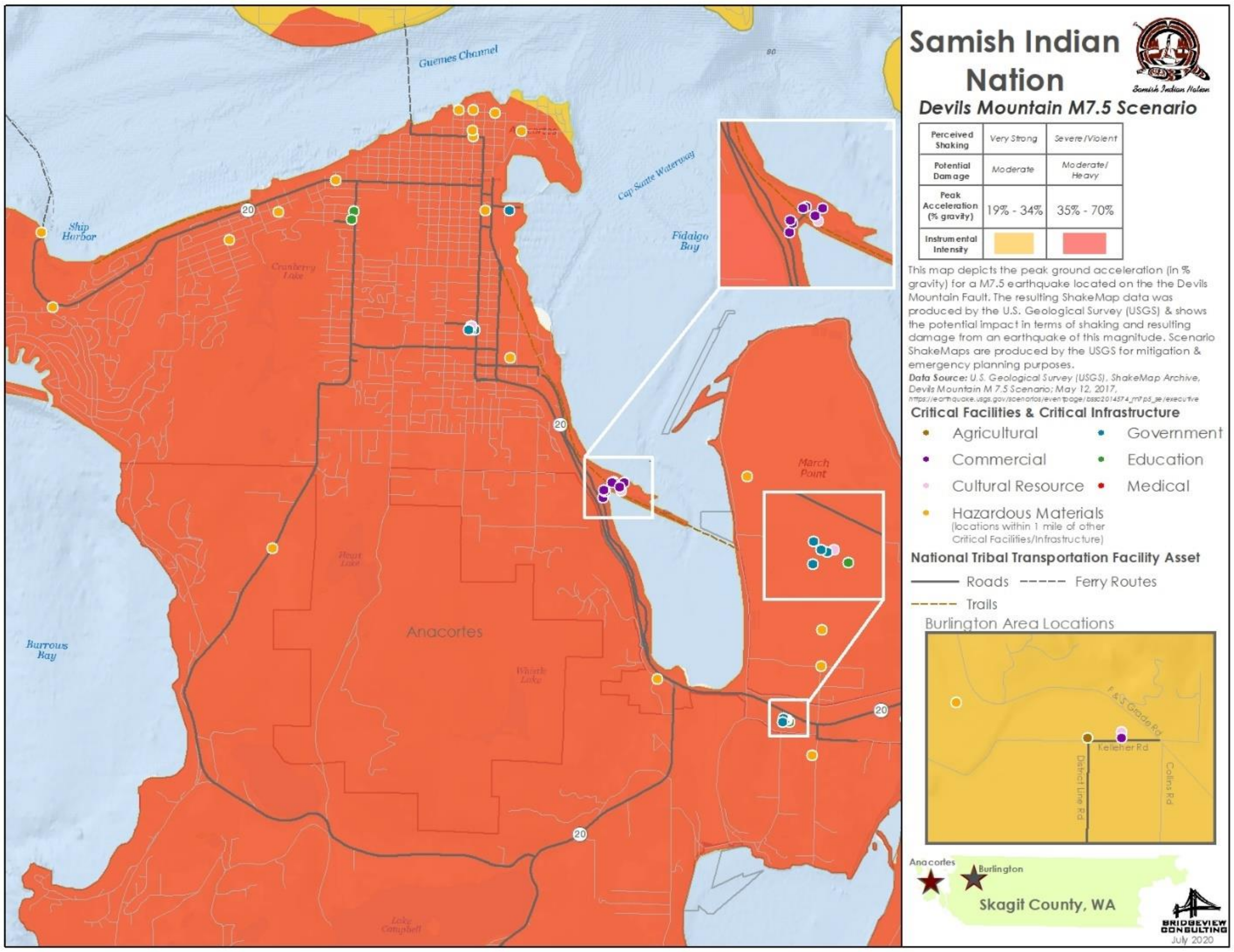


Figure 7-6 Devils Mountain M7.5 Fault Scenario - Modified Mercalli Shaking Intensity

Liquefaction Maps

Soil liquefaction maps are useful tools to assess potential damage from earthquakes. When the ground liquefies, sandy or silty materials saturated with water behave like a liquid, causing pipes to leak, roads and airport runways to buckle, and building foundations to be damaged. In general, areas with NEHRP Soils D, E and F are susceptible to liquefaction. If there is a dry soil crust, excess water will sometimes come to the surface through cracks in the confining layer, bringing liquefied sand with it and creating sand boils. Figure 7-7 shows liquefaction susceptibility in the surrounding area where Tribal structures are located.

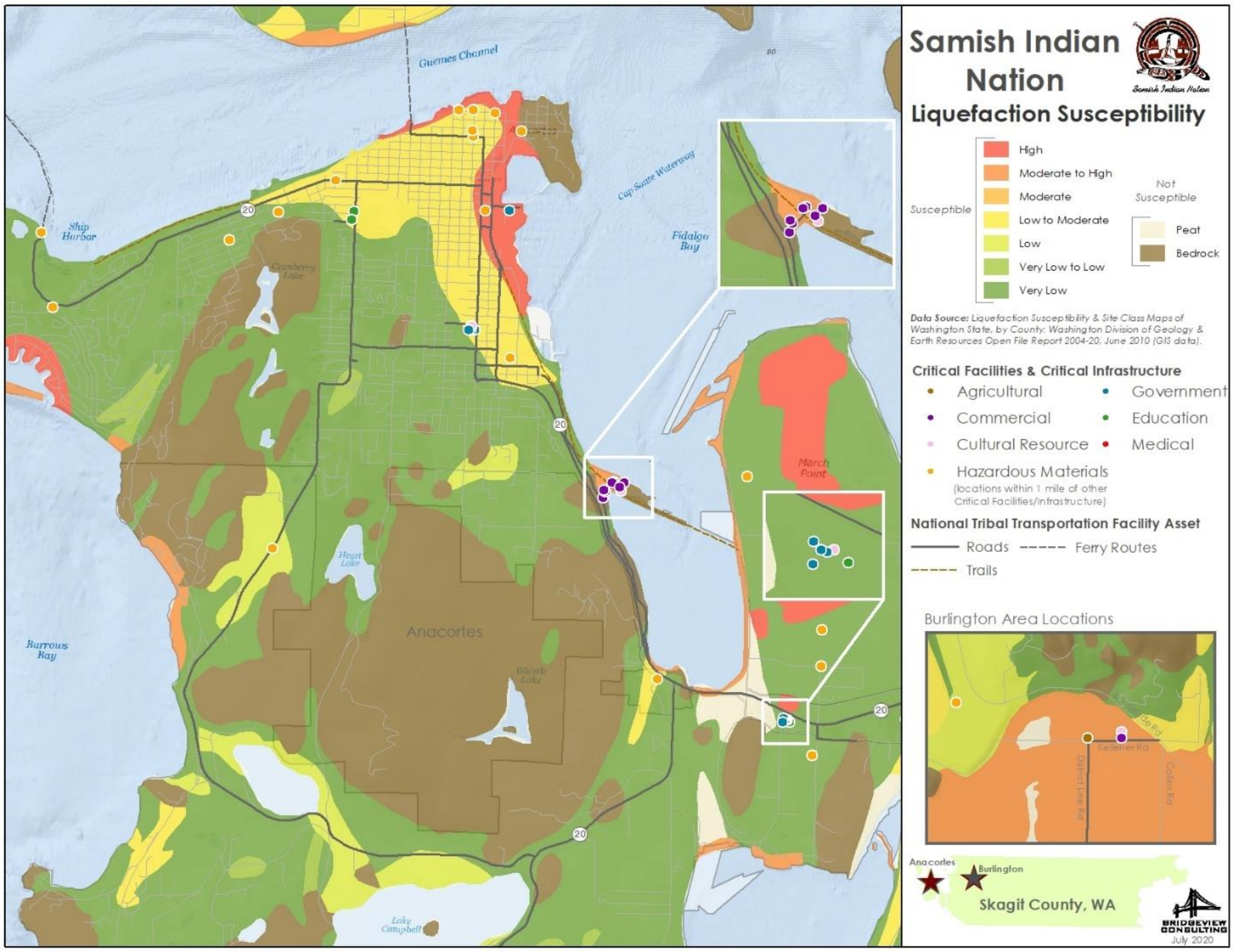


Figure 7-7 Liquefaction Susceptibility Zones

7.2.2 Previous Occurrences

Earthquakes have been reported in the area from as early as the 1872 North Cascades quake. Table 7-5 lists past seismic events that have affected the Puget Sound area.[5] One disaster declaration has occurred in recent past as a result of earthquake damage – the Nisqually Earthquake, which occurred on February 28, 2001 (discussed below). The following facts represent some of the more significant earthquakes occurring in the area:

- **1969, Marblemount -** The largest earthquake recorded in Skagit County by PNSN was a magnitude 4.6 event on November 9, 1969, near Marblemount. It was located at a depth of about 8 miles, which makes it a shallow crustal event, rather than an earthquake that takes place in the subducting crust. This earthquake had M4.3 and M4.0 foreshocks and a rich aftershock sequence, all at depths of less than about 1 mile.
- **1996, Duvall**—This earthquake had a magnitude of 5.6 on the Richter scale. Near the epicenter, merchandise fell off shelves and at least one resident reported a cracked chimney. In Snohomish County, 16,000 residents were reportedly without power for several hours as a result of breakers

[5] PNSN, 2020

tripping in four substations. There was, however, no report of physical damage to electrical power facilities.

- **2001, Nisqually -** The Nisqually earthquake occurred February 2, 2001 with the epicenter about 11 miles northeast of the City of Olympia. It was a deep magnitude 6.8 event and due to extensive damage in several counties, was declared Federal Disaster #1361. One person died of a heart attack; 700 people were injured; damages were greater than $1,000,000,000 as a result of the Nisqually Earthquake.
- **1700 Cascadia Subduction Zone** – Based on geologic evidence along the Washington coast, the Cascadia Subduction Zone has ruptured and created tsunamis at least seven times in the past 3,500 years and has a considerable range in recurrence intervals, from as little as 140 years between events to more than 1,000 years. The last Cascadia Subduction Zone-related earthquake is believed to have occurred on January 26, 1700, and researchers predict a 10 to 14 percent chance that another could occur in the next 50 years.

A Cascadia Subduction Zone earthquake is felt to be the largest earthquake threat to the state as a whole. The fault runs from California to British Columbia. Abundant physical evidence for the 1700 earthquake includes evidence for abrupt tectonic subsidence. This event was probably about M9 and is one of the largest earthquakes in historic or paleoseismic record. The evidence for this earthquake is documented in Atwater and others (2005) and Goldfinger and others (2012). This fault has an average recurrence interval of approximately 500 years for earthquakes of about M9.

TABLE 7-5
HISTORICAL EARTHQUAKES IMPACTING THE PLANNING AREA

Year	Magnitude	Epicenter
1/2009	4.5	Near Kingston
7/2002	3.1	North Bend
5/2002	4.2	Friday Harbor, San Juan Islands
2/28/2001 (DR 1361)	6.8	Olympia (Nisqually)
6/10/2001	5.0	Matlock
7/3/1999	5.8	5 miles north of Satsop
2/1998	2.8	Northeast of Seattle
8/1997	3.4	Unknown*
7/1997	3.1	Duvall
6/23/1997	4.7	Bremerton
7/1996	5.4	5 miles east-northeast of Duvall
5/3/1996	5.5	Duvall
1/29/1995	5.1	Seattle-Tacoma
10/25/1991	3.4	Unknown*
4/14/1990	5.0	Deming Area
2/14/1981	5.5	Mt. St. Helens
9/9/76	4.5	Union
5/11/1965 (DR 196)	6.6	18.3 KM N of Tacoma
4/29/1965	6.5	11 miles North of Tacoma

TABLE 7-5
HISTORICAL EARTHQUAKES IMPACTING THE PLANNING AREA

Year	Magnitude	Epicenter
4/13/1949	7.1	Olympia
1/13/1949	7.0	8 miles east-northeast of Olympia
6/23/1946	7.3	Strait of Georgia
2/14/1946	6.3	Puget Sound
4/29/1945	5.7	North Bend (8 miles south/southeast)
11/13/1939	5.8	Puget Sound – Near Vashon Island
5/15/1936	5.7	Southwest Washington
7/17/1932	5.3	Central Cascades
1/23/1920	5.5	Puget Sound
12/6/1918	7.0	Vancouver Island
8/18/1915	5.6	North Cascades
1/11/1909	6.0	Puget Sound
3/6/1904		Washington coastline and Olympic Mountains
3/27/1884		Hoquiam
4/30/1882	5.8	Olympia area
12/15/1872	6.8	Pacific Coast

Source: Pacific Northwest Seismic Network

7.2.3 Severity

Earthquakes can last from a few seconds to over five minutes; they may also occur as a series of tremors over several days. The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Casualties generally result from falling objects and debris, because the shocks shake, damage or demolish buildings and other structures. Disruption of communications, electrical power supplies and gas, sewer and water lines should be expected. Earthquakes may trigger fires, dam failures, landslides, or releases of hazardous material, compounding their disastrous effects.

Small, local faults produce lower magnitude quakes, but ground shaking can be strong, and damage can be significant in areas close to the fault. In contrast, large regional faults can generate earthquakes of great magnitudes but, because of their distance and depth, they may result in only moderate shaking in an area.

USGS ground motion maps based on current information about fault zones show the PGA that has a certain probability (2 or 10 percent) of being exceeded in a 50-year period. The PGA is measured in %g. Figure 7-8 shows the PGA with a 2 percent exceedance chance in 50 years in Washington.

The Devils Mountain Fault, which is roughly 78 miles long and runs east to west from Snohomish County, through Skagit Counties and continues up to Vancouver Island, Canada, has been determined to be an event of great concern for the planning area. As indicated, if a Magnitude 7.5 event or greater were to occur, it would affect 15 counties within Washington State. Effects of a major earthquake in the Puget Sound basin area could be catastrophic, providing the worst-case disaster short of drought-induced wildfire sweeping through a suburban area. Hundreds of residents could be killed, and a multitude of others left homeless.

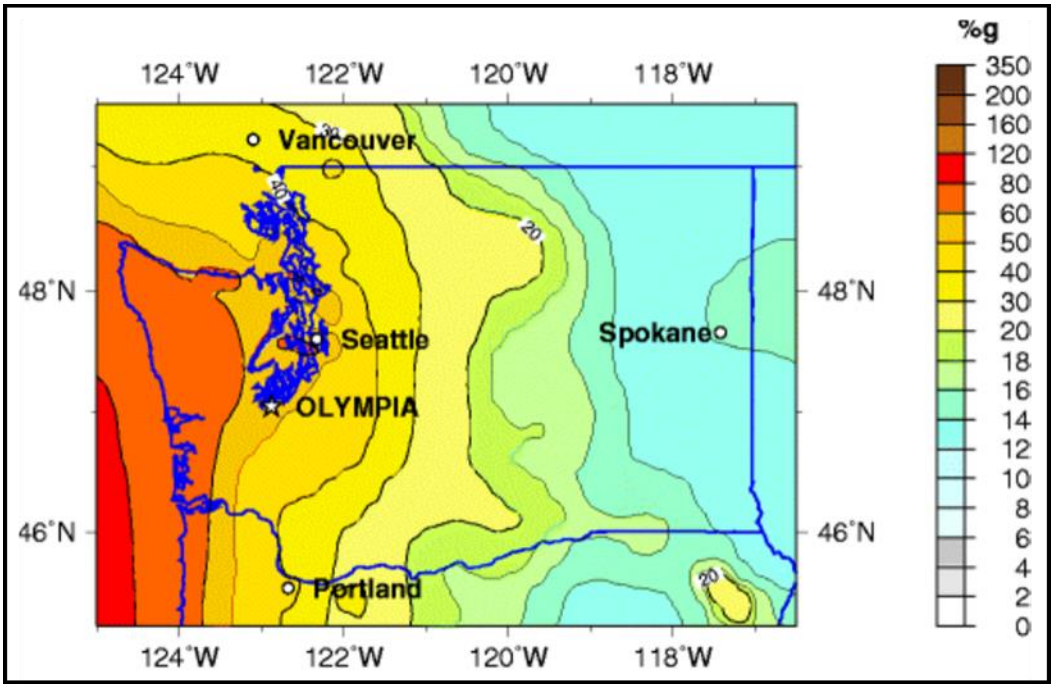


Figure 7-8 PGA with 2-Percent Probability of Exceedance in 50 Years, Northwest Region

7.2.4 Frequency

Scientists are currently developing methods to more accurately determine when an earthquake will occur. Recent advancements in determining the probability of an earthquake in a given period use a log-normal, Brownian Passage Time, or other probability distribution in which the probability of an event depends on the time since the last event. Such time-dependent models produce results broadly consistent with the elastic rebound theory of earthquakes. The USGS and others are beginning to develop such products as new geologic and seismic information regarding the dates of previous events along faults becomes more and more available (USGS, 2015a).

- Current estimates of the likelihood of another potentially damaging intraplate earthquake during a 50-year time window with the Puget Sound region put the probability at 84 percent, with somewhat lower probabilities as one goes southward (Earthquake Hazard Program, 2012).

- Scientists currently estimate that a Magnitude-9 earthquake in the Cascadia Subduction Zone occurs about once every 500 years. The last one was in 1700. Paleoseismic investigations have identified 41 Cascadia Subduction Zone interface earthquakes over the past 10,000 years, which corresponds to one earthquake about every 250 years. About half were M9.0 or greater earthquakes that represented full rupture of the fault zone from Northern California to British Columbia. The other half were M8+ earthquakes that ruptured only the southern portion of the subduction zone.

- The 300+ years since the last major Cascadia Subduction Zone earthquake is longer than the average of about 250 years for M8 or greater and shorter than some of the intervals between M9.0 earthquakes.

- Scientists currently estimate the frequency of deep earthquakes similar to the 1965 Magnitude-6.5 Seattle-Tacoma event and the 2001 Magnitude-6.8 Nisqually event as about once every 35 years.

The USGS estimates an 84-percent chance of a Magnitude-6.5 or greater deep earthquake over the next 50 years.

- Scientists estimate the approximate recurrence rate of a Magnitude-6.5 or greater earthquake anywhere on a shallow fault in the Puget Sound basin to be once in about 350 years. There have been four earthquakes of less than Magnitude 5 in the past 20 years.

- Earthquakes on the Seattle Faults have a 2-percent probability of occurrence in 50 years. A Benioff zone earthquake has an 85 percent probability of occurrence in 50 years, making it the most likely of the three types.

7.3 VULNERABILITY ASSESSMENT

7.3.1 Overview

Several faults within the planning region have the potential to cause direct impact, although there are no faults in the immediate area of Tribal structures (see Skagit County Faults Figure 7-9). The area also is vulnerable to impact from an event outside the area, although the intensity of ground motions diminishes with increasing distance from the epicenter. As a result, the entire population of the planning area is exposed to both direct and indirect impacts from earthquakes. The degree of direct impact (and exposure) is dependent on factors including the soil type on which homes and structures are constructed, the proximity to fault location, the type of materials used to construct residences and facilities, etc. Indirect impacts are associated with elements such as the inability to evacuate the area as a result of earthquakes occurring in other regions of the state as well as impact on commodity flow for goods and services into the area, many of which are serviced only by one roadway in or out. Impact from other parts of the state could require shipment of supplies via a barge due to impact to roadways.

The following are also general areas of vulnerability to be considered:

- Large hazardous materials incidents may occur as the result of damage to local oil refineries, chemical plants, rail lines and major petroleum pipelines. Transportation along the rail lines of chemicals is concerning.
- Levees and salt-water dikes may be damaged.
- Large hydroelectric dams may be damaged or possibly fail.
- Localized seiche action in local waters may result in increased levels of damage along shoreline areas.
- The arrival of outside resources to assist with debris removal, repair of critical facilities, and sheltering of victims may be delayed due to severe damage in adjacent areas with larger populations and needs.
- The overall economy of the area and possibly the region could be affected.
- Large areas lying within the floodplains are susceptible to liquefaction.

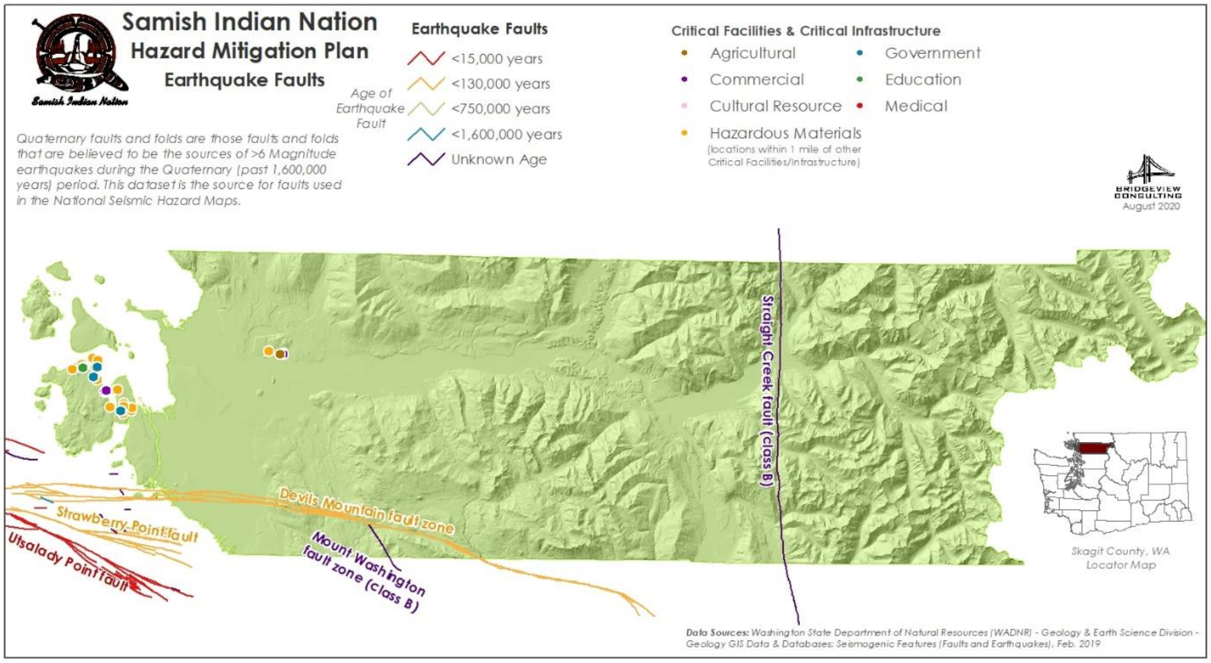


Figure 7-9 Fault Lines Throughout Skagit County

Warning Time

There is currently no reliable way to predict the day or month that an earthquake will occur at any given location. Research is being done with warning systems that use the low energy waves that precede major earthquakes. These potential warning systems give approximately 40 seconds notice that a major earthquake is about to occur. The warning time is very short, but it could allow for someone to get under a desk, step away from a hazardous material they are working with, or shut down a computer system.

7.3.2 Impact on Life, Health, and Safety

The entire population of the planning area is exposed to direct and indirect impacts from earthquakes. This would include residents, visitors, and employees of the Samish Indian Nation. This would also include individuals seeking services or referrals for health, etc., which the Nation provides.

Two of the most vulnerable populations to a disaster incident such as this are the young and the elderly. Linguistically isolated populations and those living below poverty level are also more susceptible. The planning area (when looking at county-based data) has a fairly high population of retirees and individuals with disabilities, both higher than the state averages. The need for increased rescue efforts and/or to aid such a large population base could tax the first-responder resources in the area during an event. Although many injuries may not be life-threatening, people will require medical attention and, in many cases, hospitalization. Potential life-threatening injuries and fatalities are expected; these are likely to be at an increased level if an earthquake happens during the afternoon or early evening when more people are home or traveling home. This would be a significant factor when considering the daily population at the Tribal offices and services provided by the Samish Nation, as well as individuals staying at the Fidalgo Bay Resort, or having an event at the Fidalgo Bay Resort Convention Center.

The degree of exposure is dependent on many factors, including the soil type on which structures are built, quality of construction, their proximity to fault location, etc. Whether impacted directly or indirectly, the entire population will have to deal with the consequences of earthquakes to some degree. Business interruption could keep people from working, road closures could isolate populations, and loss of functions of utilities could impact populations that suffered no direct damage from an event itself.

It should be noted that there are significant variables that exist in the data which is used to populate the inputs necessary to reach conclusions identified within this document, including the type of structure, year built, remodeling, engineered assessments, etc. All these factors play a significant role in determining potential impact, and therefore any outputs from the Hazus model are considered to have a high rate of error unless better, more accurate (engineered) building specific data is utilized. Such efforts far exceed the scope of this project, and as such, outputs gained during this process should be considered for planning purposes only, and in no manner should be considered for life-safety measures.

7.3.3 Impact on Property

All structures owned by the Nation are at risk to impact from earthquake. This current plan development included 32 structures owned and operated by the Samish Indian Nation, with a total structure and content value of $22.8 million dollars. Due to the area of impact and the proximity to the fault or epicenter location, those structures could also be impacted. The majority of structures owned are older in nature, which may increase impact potential. The Nation also has land mass in various areas, which has been restored to its natural environment, with structures removed. Those project areas could be impacted by secondary hazards of landslides or hazardous materials exposure many times associated with earthquakes.

Building Age

Structures that are in compliance with the Uniform Building Code (UBC) of 1970 or later are generally less vulnerable to seismic damage because 1970 was when the UBC started including seismic construction standards based on regional location. This stipulated that all structures be constructed to at least seismic risk Zone 2 standards.

The State of Washington adopted the UBC as its state building code in 1972, so it is assumed that buildings in the planning area built after 1972 were built in conformance with UBC seismic standards and have less vulnerability. Issues such as code enforcement and code compliance could impact this assumption. Construction material is also important when determining the potential risk to a structure. However, for planning purposes, establishing this line of demarcation can be an effective tool for estimating vulnerability. In 1994, seismic risk Zone 3 standards of the UBC went into effect in Washington, requiring all new construction to be capable of withstanding the effects of 0.3 g. More recent housing stock is in compliance with Zone 3 standards. In July 2004, the state again upgraded the building code to follow International Building Code Standards. While the “zones” are still referenced, they are, in large part, no longer used in the capacity they once were as there can be different zones within political subdivisions, making it difficult to apply. For instance, within Washington, there are both Seismic Zones 2B and 3. The Hazus analysis also considers the age in which buildings were built to a specific building code. Hazus identifies key changes in earthquake building codes based on year. Homes built prior to 1941 are considered pre-code; they were constructed before earthquake building codes were put in place. Homes constructed after 1941 are considered moderate code and may include some earthquake building components. Chapter 3, Section **Error! Reference source not found.** identifies the age of structures owned by the Samish Indian Nation.

7.3.4 Impact on Critical Facilities and Infrastructure

Similar to the impact to property, all critical facilities are exposed to the earthquake hazard. The degree of impact from an earthquake is largely determined based on proximity, magnitude, and ground motion causing liquefaction. Based on the distribution of structures owned by the Samish Indian Nation within Skagit County, it can be determined that impact will be similar county-wide.

For purposes of this update, the Planning Team utilized FEMA's Hazus program, identifying a M7.5 Devils Mountain scenario event. A total of seven census tracks in which the Samish Nation owns structures were assessed in this update (see Figure 7-10). Due to the Hazus program, the census tracks also include non-tribal structures (over 10,000), with the primary occupancy type of those structures being single family residences, although the area maintains all occupancy types. It should be noted that Hazus output analysis is supplemented with default data which does not include building-specific information necessary to conduct life-safety determination, as such analysis is well beyond the scope of this project. The results from this analysis provides outputs which at this level of analysis can be used by emergency managers for planning purposes only, but *not* for the purposes of determining life safety measures.

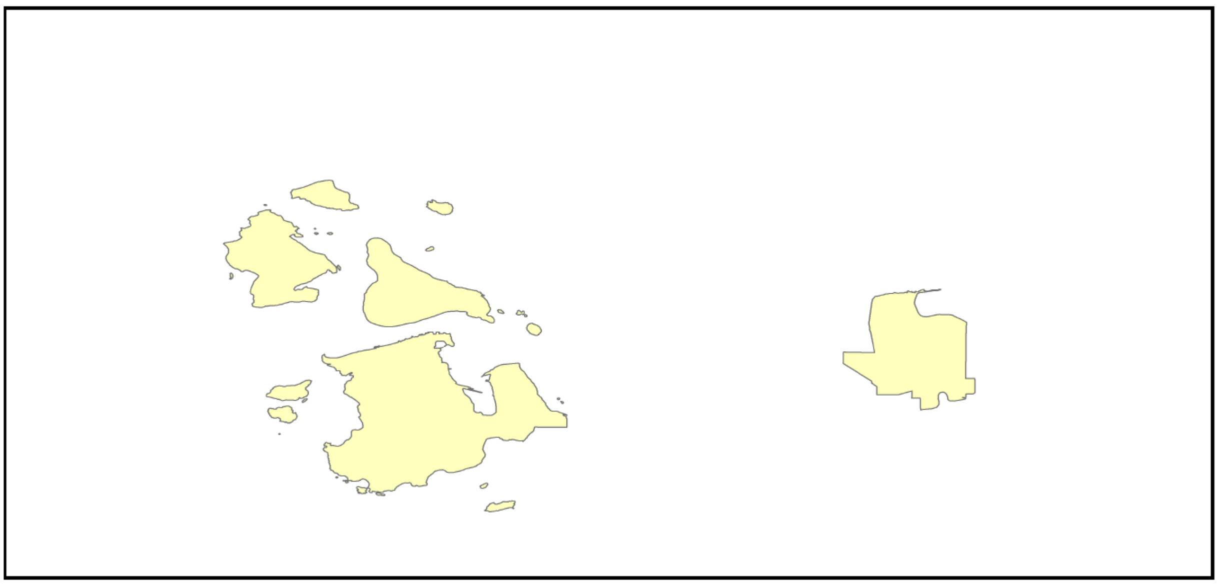


Figure 7-10 Hazus Census Tracks Identified for Study Region

Based on the M7.5 Devils Mountain-type scenario event, review of the identified critical facilities and infrastructure information captured during this process provides the following, which would apply with respect to application of building codes and age of the critical facilities and infrastructure, particularly when considering the ability of structures to withstand ground shaking:

- Several tribal structures are considerably older in nature, some falling on the Historic Preservation List.
- A vintage agricultural barn was built in 1900.
- A newly acquired greenhouse/nursery building was constructed in 1920.
    - The Samish anticipate removal of that structure and replacement with a new Day Care/Early Childhood Development structure over the lifecycle of this plan.
- Two structures were built in 1940

  - One structure is utilized for administration of the medical programs; and
  - One structure is utilized for administrative purposes, maintaining archived records.
- Two office/administrative structures were built in 1948 and 1954.
- A barn currently leased and utilized for farming purposes was constructed in 1961.
  - The area surrounding the 1961 barn is also a conservation area maintained by the Samish.

The remaining structures were built 1977 forward, presumably to higher building code standards. Those structures include:

- 11 manufactured structures placed on permanent foundations, eight of those structures being the cabins (tiny houses) at the Fidalgo Bay RV Resort constructed in 2011 and 2017.
- Two higher-valued structures owned by the Samish (the Cheléngen/Cultural Center and Convention Center) were built in 1994 and 1995, respectively. The Convention Center is an economic hub for the Samish.
- The Summit Park property, which is home to various tribal departments, was constructed in 1996.
- The Cannery Building, which is composed of various commercial condominium units and is the highest-valued structure owned by the Samish, and was built in 2006. Review of data illustrates this structure being the one structure in soils type E – soft clay.

Most of the structures owned by the Samish are constructed of wood, several slab on grade, with a few metal structures included. No structure identified has a basement. This data is also confirmed in the Hazus Global Summary Report for this scenario event, which indicates that wood frame construction makes up 85 percent of the building inventory within the census tracks utilized.

Earthquakes can also cause disruption to communications, electrical power, wastewater and potable water services and supplies. Such disruptions should be expected. Earthquakes may also trigger fires, dam failures, landslides, or releases of hazardous material. Hazardous materials releases can occur during an earthquake from both fixed facilities or transportation-related incidents, leaking into the surrounding area or an adjacent waterway, having a disastrous effect on the environment.

There are several major transmission pipelines carrying oil, gasoline, natural gas, and major water lines. Some of these lines cross major rivers, such as the Skagit River (among others), and include both underground and above-ground lines supported by cable suspension structures. Damage to those pipelines would significantly impact the various waterways of the area, potentially impacting drinking water aquifers. With two major petroleum plants in the immediate area, which also ship oil by rail, such an incident would be of significant concern, both for life safety and potential environmental devastation.

In the event of a major earthquake, areas lying within the floodplain are susceptible to liquefaction. Magnitude 7+ earthquakes can potentially trigger slope failures as well. The potential for landslide-induced roadway closure is of concern, in addition to the steep and/or unstable slopes in various locations susceptible to landslides.

Within the Hazus study region, the lifeline inventory is divided between transportation and utility lifeline systems. The study region identifies seven transportation systems that include highways, railways, light rail, bus, ports, ferry, and airports (no distinction of ownership). There are six utility systems that include potable water, wastewater, natural gas, crude and refined oil, electric power, and communications. The total value of the lifeline inventory is over 2,362.00 (millions of dollars) within the census study region. This inventory includes over 72.08 miles of highways, 21 bridges, 1,276.30 miles of pipes.

The Tribe does own a water system located in one of the barns on Thomas Creek. That water supply is utilized for agricultural needs, including irrigation and livestock. That structure is in a moderate to high liquefaction zone and has a 13 percent level of functionality on day one of the earthquake, which increases to a 99 percent level of functionality on day 90 based on Hazus outputs.

The Samish Indian Nation also own Huckleberry Island, a culturally significant area to the Nation due to its unique wildlife and vegetation on the Island. A crude or refined oil release from the refineries in Anacortes because of an earthquake would be environmentally devastating. Huckleberry Island is near the refinery locations, and with tides carrying any potential oil or other chemical, such would impact the natural habitat on and around the Island.

Bridges are one of the most vulnerable components of highway transportation systems and the loss of bridges will have a direct effect the delivery of emergency services. Very few bridges in the area have been retrofitted to withstand the effects of a major earthquake. In addition, bridge foundations are typically located in soils susceptible to liquefaction thereby allowing bridge piers to move and bridge girders to collapse. In addition, commodities could also be impacted, potentially requiring supplies by air or water.

While new structures and roadways are built to current code standards, they could nonetheless be impacted. Many of the roadways in the area have also been funded through Tribal grant programs, and are part of the National Tribal Transportation Facility Inventory. The Samish Indian Nation works in unison with local authorities to maintain roadways in good repair. An earthquake could cause isolation if the roadways were impacted. Closure of major arterials would also require increased evacuation periods, in some instances by several hours.

The Guemes Island Ferry dock is in proximity to Tribal structures, and is a short distance from the Fidalgo Bay Resort. If impacted, it would isolate populations on Guemes Island. There are no alternative roads or highways that provide access to Guemes Island; as such, the Skagit County ferry system serves as a vital transportation link. Tribal funds have helped enhance the roadways in the area, which could sustain impact from an earthquake. In addition to transporting commuters, the ferry also carries essential services trucks and emergency vehicles and personnel to and from the Island. Beyond the ferry terminal, the I-5 corridor serves as a major transportation corridor from Canada through the State. If impacted, it would significantly hamper response and recovery abilities, as well as evacuation and commodity flow.

7.3.5 Impact on Economy

Economic losses due to earthquake damage include damage to buildings, including the cost of structural and non-structural damage, damage to contents, and loss of inventory, loss of wages and loss of income. Economic impact would also include loss to the various business ventures owned and operated by the Nation. In addition, loss of goods and services may hamper recovery efforts, and even preclude residents from rebuilding within the area, further impacting potential income streams. No specific loss data is available with respect to the Nation’s loss of inventory, wages, or loss of income.

7.3.6 Impact on Environment

Earthquake-induced landslides can significantly impact habitat. It is also possible for streams to be rerouted after an earthquake. This can change water quality, possibly damaging habitat and feeding areas. There is a possibility of streams fed by groundwater drying up because of changes in underlying geology. There also exists the impact from hazardous materials impacting the environment, including the coastlines, estuaries, and watersheds, among others.

7.3.7 Impact from Climate Change

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth's crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity, according to research into prehistoric earthquakes and volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA, 2004).

Secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could experience liquefaction or an increased propensity for slides during seismic activity due to the increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. There are currently no models available to estimate these impacts.

7.4 FUTURE DEVELOPMENT TRENDS

The Samish Nation does utilize the International Building Code as established within the areas of construction. Such requires structures to be built at a level which supports soil types and earthquake hazards (ground shaking). As existing buildings are renovated, provisions are in place which require reconstruction at higher standards.

7.5 ISSUES

While the planning area has a high probability of an earthquake event occurring within its boundaries, an earthquake does not necessarily have to occur in the planning area to have a significant impact as such an event would disrupt transportation to and from the region as a whole, and impact commodity flow. As such, any seismic activity of 6.0 or greater on faults in or near the planning area would have significant impact. Potential warning systems could give approximately 40 seconds notice that a major earthquake is about to occur. This would not provide adequate time for preparation. Earthquakes of this magnitude or higher could lead to massive structural failure of property on NEHRP C, D, E, and F soils. Levees and revetments built on these poor soils would likely fail, representing a loss of critical infrastructure. These events could cause secondary hazards, including landslides and mudslides that would further damage structures. River valley hydraulic-fill sediment areas are also vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction would occur in water-saturated sands, silts, or gravelly soils.

Earthquakes can cause large and sometimes disastrous landslides and mudslides. River valleys are vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction occurs when water-saturated sands, silts or gravelly soils are shaken so violently that the individual grains lose contact with one another and float freely in the water, turning the ground into a pudding-like liquid. Building and road foundations lose load-bearing strength and may sink into what was previously solid ground. Unless properly secured, hazardous materials can be released, causing significant damage to the environment and people. Earthen dams and levees are highly susceptible to seismic events and the impacts of their eventual failures can be considered secondary risks for earthquakes. Earthquakes at sea can generate destructive tsunamis.

7.6 IMPACT AND RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from an Earthquake throughout the area is highly likely. A Devils Mountain-type event, such as that utilized as the scenario modeled for this update, has a high probability of occurring within the region.

A Devils Mountain earthquake could generate a large amount of damage within the general planning area. Also a factor when reviewing Skagit County's 2020 Hazard Mitigation Plan, is the large number of buildings being designated as pre-code buildings which, while not owned by the Nation, in some cases are residences owned by Tribal citizens, or provide services on which the Tribal citizens or Tribal businesses rely (e.g., supply-chain). Due to the age of these buildings and the absence of building codes at time of construction, they may not perform as well during an earthquake compared to structures built after code implementation. That would impact both tribal citizens' safety, as well as the economy of the region.

Based on the potential impact, the Planning Team determined the CPRI score to be 3.65, with overall vulnerability determined to be a high level.

CHAPTER 8.
FLOOD

Floods are one of the most common natural hazards in the U.S. They can develop slowly over a period of days or develop quickly, with disastrous effects that can be local (impacting a neighborhood or community) or regional (affecting entire river basins, coastlines and multiple counties or states) (FEMA, 2010). Most communities in the U.S. have experienced some kind of flooding, after spring rains, heavy thunderstorms, coastal storms, or winter snow thaws. Floods are one of the most frequent and costly natural hazards in terms of human hardship and economic loss, particularly to communities that lie within flood-prone areas or floodplains of a major water source.

DEFINITIONS

Flood—The inundation of normally dry land resulting from the rising and overflowing of a body of water.

Floodplain—The land area along the sides of a river that becomes inundated with water during a flood.

100-Year Floodplain—The area flooded by a flood that has a 1-percent chance of being equaled or exceeded each year. This is a statistical average only; a 100-year flood can occur more than once in a short period of time. The 1-percent annual chance flood is the standard used by most federal and state agencies.

Floodway—The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

8.1 GENERAL BACKGROUND

Flooding is a general and temporary condition of partial or complete inundation on normally dry land from the following:

- Riverine flooding, including overflow from a river channel, flash floods, alluvial fan floods, dam-break floods and ice jam floods;
- Local drainage or high groundwater levels;
- Fluctuating lake levels;
- Coastal flooding;
- Coastal erosion;
- Unusual and rapid accumulation or runoff of surface waters from any source;
- Mudflows (or mudslides);
- Collapse or subsidence of land along the shore of a lake or similar body of water that result in a flood, caused by erosion, waves or currents of water exceeding anticipated levels (Floodsmart.gov, 2012);
- Sea level rise; and
- Climate Change (USEPA, 2012).

8.1.1 Flooding Types

Many floods fall into one of three categories: riverine, coastal, or shallow. Other types of floods include alluvial fan floods, dam failure floods, and floods associated with local drainage or high groundwater. For this hazard mitigation plan, riverine/stormwater flooding are the main flood types of concern for the planning area.

Riverine

Riverine floods are the most common flood type. They occur along a channel and include overbank and flash flooding. Channels are defined ground features that carry water through and out of a watershed. They may be called rivers, creeks, streams, or ditches. When a channel receives too much water, the excess water flows over its banks and inundates low-lying areas.

Flash Floods

A flash flood is a rapid, extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). The time may vary in different areas. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising floodwaters (NWS, 2009).

Coastal Flooding

Coastal flooding is the flooding of normally dry, low-lying coastal land, primarily caused by severe weather events along the coast, estuaries, and adjoining rivers. These flood events are some of the more frequent, costly, and deadly hazards that can impact coastal communities. Factors causing coastal flooding include:

- Storm surges, which are rises in water level above the regular astronomical tide caused by a severe storm's wind, waves, and low atmospheric pressure. Storm surges are extremely dangerous, because they are capable of flooding large coastal areas.

- Large waves, whether driven by local winds or swell from distant storms, raise average coastal water levels and individual waves roll up over land.

- High tide levels are caused by normal variations in the astronomical tide cycle (discussed below).

- Other larger scale regional and ocean scale variations are caused by seasonal heating and cooling and ocean dynamics.

Coastal floods are extremely dangerous, and the combination of tides, storm surge, and waves can cause severe damage. Coastal flooding is different from river flooding, which is generally caused by severe precipitation. Depending on the storm event, in the upper reaches of some tidal rivers, flooding from storm surge may be followed by river flooding from rain in the upland watershed. This increases the flood severity. Within the National Flood Insurance Flood Maps (discussed below), coastal flood zones identify special flood hazard areas (SFHA) which are subject to waves with heights of between 1.5 and 3 feet during a 1-percent annual chance storm (100-year event).

Tidal Flooding

Spring tides, the highest tides during any month, occur with each full and new moon. When these coincide with a northerly wind piling water, tidal flooding can occur. The tides can also enhance flooding in delta areas when rivers or creeks are at or near flood stage. Such flooding is also a threat to low-lying farmlands in the area. Tidal impact is of most concern in delta areas when rivers are at flood stage and high tide exacerbates the situation. Concerns about tidal flooding are anticipated to increase due to the impacts of global climate change and sea level rise.

8.1.2 Dam Failure

Dam failures in the United States typically occur in one of four ways (Association of State Dam Safety Officials, 2012):

- Overtopping of the primary dam structure, which accounts for 34 percent of all dam failures, can occur due to inadequate spillway design, settlement of the dam crest, blockage of spillways, and other factors.

- Foundation defects due to differential settlement, slides, slope instability, uplift pressures, and foundation seepage can also cause dam failure. These account for 30 percent of all dam failures.

- Failure due to piping and seepage accounts for 20 percent of all failures. These are caused by internal erosion due to piping and seepage, erosion along hydraulic structures such as spillways, erosion due to animal burrows, and cracks in the dam structure.

- Failure due to problems with conduits and valves, typically caused by the piping of embankment material into conduits through joints or cracks, constitutes 10 percent of all failures.

The remaining 6 percent of U.S. dam failures are due to miscellaneous causes. Many dam failures in the United States have been secondary results of other disasters. The prominent causes are earthquakes, landslides, extreme storms, massive snowmelt, equipment malfunction, structural damage, foundation failures, and sabotage. The most likely disaster-related cause of dam failure in the planning area is related to earthquakes. Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies.

The potential for catastrophic flooding due to dam failures led to passage of the National Dam Safety Act (Public Law 92-367). The National Dam Safety Program requires a periodic engineering analysis of every major dam in the country. The goal of this FEMA-monitored effort is to identify and mitigate the risk of dam failure so as to protect the lives and property of the public.

There have been no reported incidents of dam failure impacting the Samish Indian Nation.

Washington Department of Ecology Dam Safety Program

The Dam Safety Office (DSO) of the Washington Department of Ecology regulates over 1,000 dams in the state that impound at least 10 acre-feet of water. The DSO has developed dam safety guidelines to provide dam owners, operators, and design engineers with information on activities, procedures, and requirements involved in the planning, design, construction, operation, and maintenance of dams in Washington. The authority to regulate dams in Washington and to provide for public safety is contained in the following laws:

- State Water Code (1917)—RCW 90.03

- Flood Control Act (1935)—RCW 86.16

- Department of Ecology (1970)—RCW 43.21A .

Where water projects involve dams and reservoirs with a storage volume of 10 acre-feet or more, the laws provide for the Department of Ecology to conduct engineering review of the construction plans and specifications, to inspect the dams, and to require remedial action, as necessary, to ensure proper operation, maintenance, and safe performance. The DSO was established within Ecology's Water Resources Program to carry out these responsibilities.

The DSO provides reasonable assurance that impoundment facilities will not pose a threat to lives and property, but dam owners bear primary responsibility for the safety of their structures, through proper design, construction, operation, and maintenance. The DSO regulates dams with the sole purpose of reasonably securing public safety; environmental and natural resource issues are addressed by other state agencies. The DSO neither advocates nor opposes the construction and operation of dams.

U.S. Army Corps of Engineers Dam Safety Program

The U.S. Army Corps of Engineers is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. The Corps has inventoried dams; surveyed each state and federal agency's capabilities, practices and regulations regarding design, construction, operation, and maintenance of the dams; and developed guidelines for inspection and evaluation of dam safety (U.S. Army Corps of Engineers, 1997).

Federal Energy Regulatory Commission Dam Safety Program

The Federal Energy Regulatory Commission (FERC) cooperates with a large number of federal and state agencies to ensure and promote dam safety. There are 3,036 dams that are part of regulated hydroelectric projects in the FERC program. Two-thirds of these are more than 50 years old. As dams age, concern about their safety and integrity grows, so oversight and regular inspection are important. FERC staff inspects hydroelectric projects on an unscheduled basis to investigate the following:

- Potential dam safety problems;
- Complaints about constructing and operating a project;
- Safety concerns related to natural disasters;
- Issues concerning compliance with the terms and conditions of a license.

Every five years, an independent engineer approved by the FERC must inspect and evaluate projects with dams higher than 32.8 feet (10 meters), or with a total storage capacity of more than 2,000 acre-feet.

FERC staff monitors and evaluates seismic research and applies it in investigating and performing structural analyses of hydroelectric projects. FERC staff also evaluates the effects of potential and actual large floods on the safety of dams. During and following floods, FERC staff visits dams and licensed projects, determines the extent of damage, if any, and directs any necessary studies or remedial measures the licensee must undertake. The FERC publication *Engineering Guidelines for the Evaluation of Hydropower Projects* guides the FERC engineering staff and licensees in evaluating dam safety. The publication is frequently revised to reflect current information and methodologies.

The FERC requires licensees to prepare emergency action plans and conducts training sessions on how to develop and test these plans. The plans outline an early warning system if there is an actual or potential sudden release of water from a dam due to failure. The plans include operational procedures that may be used, such as reducing reservoir levels and reducing downstream flows, as well as procedures for notifying affected residents and agencies responsible for emergency management. These plans are frequently updated and tested to ensure that everyone knows what to do in emergency situations.

Hazard Ratings

The DSO classifies dams and reservoirs in a hazard rating system based solely on the potential consequences to downstream life and property that would result from a failure of the dam and sudden release of water. The following codes are used as an index of the potential consequences in the downstream valley if the dam were to fail and release the reservoir water:

- 1A = Greater than 300 lives at risk (High hazard);

- 1B = From 31 to 300 lives at risk (High hazard);
- 1C = From 7 to 30 lives at risk (High hazard);
- 2 = From 1 to 6 lives at risk (Significant hazard);
- 3 = No lives at risk (Low hazard).

The Corps of Engineers developed the hazard classification system for dam failures shown in Table 8-1. The Washington and Corps of Engineers hazard rating systems are both based only on the potential consequences of a dam failure; neither system takes into account the probability of such failures.

TABLE 8-1
CORPS OF ENGINEERS HAZARD POTENTIAL CLASSIFICATION

Hazard Category[a]	Direct Loss of Life[b]	Lifeline Losses[c]	Property Losses[d]	Environmental Losses[e]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

a. Categories are assigned to overall projects, not individual structures at a project.
b. Loss of life potential based on inundation mapping of area downstream of the project. Analyses of loss of life potential should take into account the population at risk, time of flood wave travel, and warning time.
c. Indirect threats to life caused by the interruption of lifeline services due to project failure or operational disruption; for example, loss of critical medical facilities or access to them.
d. Damage to project facilities and downstream property and indirect impact due to loss of project services, such as impact due to loss of a dam and navigation pool, or impact due to loss of water or power supply.
e. Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

Source: U.S. Army Corps of Engineers, 1995

The owner of a dam is responsible for developing an inundation map, which is used in determining exposure to a potential dam failure or breech during development of dam response plans. Presently, no such maps are available for public release for any of the dams as inundation maps are considered privileged information. Therefore, it is difficult to estimate the population living within the inundation zone beyond the information designated in the dam classification analysis. Without the ability to perform an inundation study, it is also not possible to estimate property losses from a dam failure which could ultimately affect the planning area.

While no additional dam failure inundation studies are available, in some instances those inundation areas coincide with flood hazard areas. Review of the flood profile may provide a general concept of structures at risk, although, based on the size of the dams, damage would vary. As development occurs downstream of dams, it is necessary to review the dams' emergency action plans and inundation maps to determine whether the dams require reclassification based on the established standards.

There are no dams in the area which would impact Samish properties.

8.1.3 Measuring Floods and Floodplains

A floodplain is the area adjacent to a river, creek or lake that becomes inundated during a flood. Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon. Connections between a river and its floodplain are most apparent during and after major flood events. These areas form a complex physical and biological system that not only supports a variety of natural resources, but also provides natural flood and erosion control. When a river is separated from its floodplain with levees and other flood control facilities, natural, built-in benefits can be lost, altered, or significantly reduced.

In the case of riverine or flash flooding, once a river reaches flood stage, the flood extent or severity categories used by the NWS include minor flooding, moderate flooding, and major flooding. Each category has a definition based on property damage and public threat (NWS, 2011):

- Minor Flooding—Minimal or no property damage, but possibly some public threat or inconvenience.
- Moderate Flooding—Some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- Major Flooding—Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.

8.1.4 Flood Insurance Rate Maps

According to FEMA, flood hazard areas are defined as areas that are shown to be inundated by a flood of a given magnitude on a map (see Figure 8-1). These areas are determined using statistical analyses of records of river flow, storm tides, and rainfall; information obtained through consultation with the community; floodplain topographic surveys; and hydrologic and hydraulic analyses. Three primary areas make up the flood hazard area: the floodplains, floodways, and floodway fringes. Figure 8-2 depicts the relationship among the various designations, collectively referred to as the special flood hazard area.

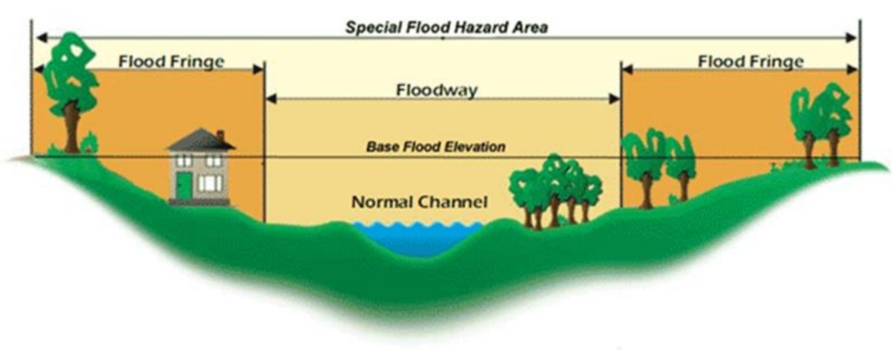


Figure 8-1 Flood Hazard Area Referred to as a Floodplain

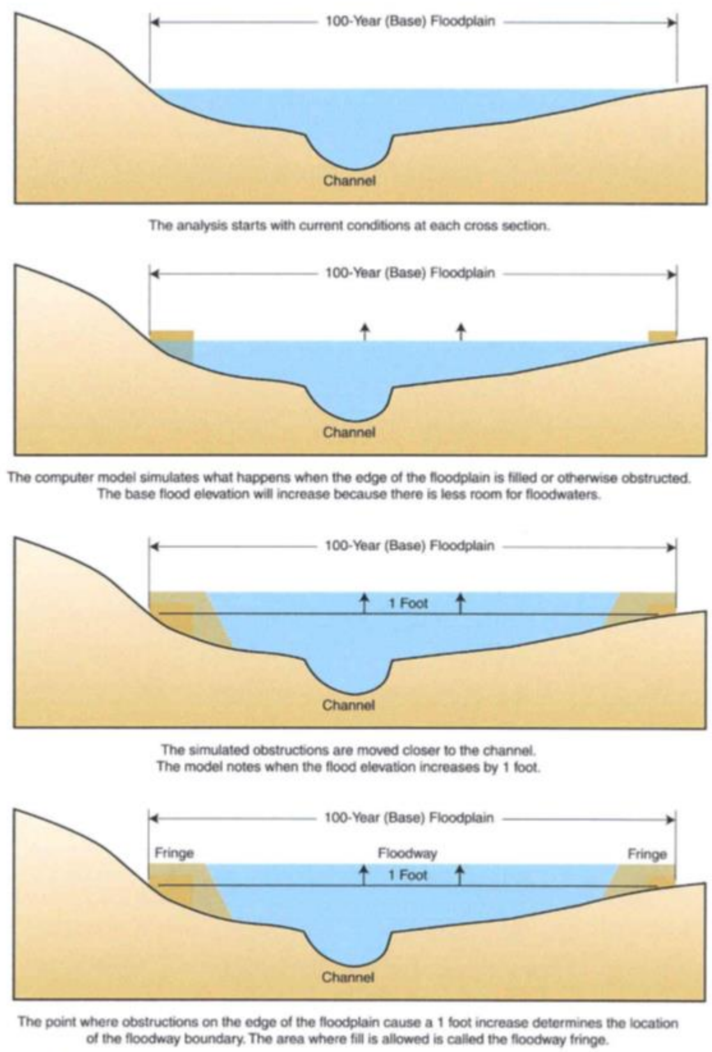


Figure 8-2 Special Flood Hazard Area

Flood hazard areas are delineated on FEMA's Flood Insurance Rate Maps (FIRM), which are official maps of a community on which the Federal Insurance and Mitigation Administration has indicated both the special flood hazard areas (SFHA) and the risk premium zones applicable to the community. These maps identify the geographic areas or zones that FEMA has defined according to varying levels of flood risk, and include: special flood hazard areas; the location of a specific property in relation to the special flood hazard area; the base (100-year) flood elevation at a specific site; the magnitude of a flood hazard in a specific area; and undeveloped coastal barriers where flood insurance is not available. The maps also locate regulatory floodways and floodplain boundaries—the 100-year and 500-year floodplain boundaries (FEMA, 2003; FEMA, 2005; FEMA, 2008). Table 8-2 identifies the various rate map zones.[6]

[6]http://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations

TABLE 8-2 FLOOD INSURANCE RATE MAP ZONES	
Moderate to Low Risk Areas: Areas of moderate or minimal hazard are studied based upon the principal source of flood in the area. However, buildings in these zones could be flooded by severe, concentrated rainfall coupled with inadequate local drainage systems. Local stormwater drainage systems are not normally considered in a community's flood insurance study. The failure of a local drainage system can create areas of high flood risk within these zones. Flood insurance is available in participating communities but is not required by regulation in these zones. Nearly 25-percent of all flood claims filed are for structures located within these zones.	
Zone	**Description**
B and X (shaded)	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floodplain area with a 0.2% (or 1 in 500 chance) annual chance of flooding. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than one (1) square mile.
C and X (unshaded)	Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year flood level. Zone C may have ponding and local drainage problems that do not warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.
High Risk Areas: Special Flood Hazard Areas represent the area subject to inundation by 1-percent-annual chance flood. Structures located within the SFHA have a 26-percent chance of flooding during the life of a standard 30-year mortgage. Federal floodplain management regulations and mandatory flood insurance purchase requirements apply to participating communities in these zones.	
Zone	**Description**
A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones.
AE	The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.
A1-30 (old map format)	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format). Older maps still utilize this numbered system, but newer FEMA products no longer use the "numbered" A Zones. (Zone AE is used on new and revised maps in place of Zones A1–A30.)
AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.
A99	Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.
High Risk - Coastal High Hazard Areas (CHHA): These represent the area subject to inundation by 1-percent-annual chance flood, extending from offshore to the inland limit of a primary front al dune along an open	

TABLE 8-2 FLOOD INSURANCE RATE MAP ZONES	
coast and any other area subject to high velocity wave action from storms or seismic sources. Structures located within the CHHA have a 26-percent chance of flooding during the life of a standard 30-year mortgage. Federal floodplain management regulations and mandatory purchase requirements apply in the following zones.	
Zone	**Description**
V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
VE, V1-30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
Undetermined Risk Areas	
Zone	**Description**
D	Areas with possible but undetermined flood hazard. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

The frequency and severity of flooding are measured using a discharge probability, which is a statistical tool used to define the probability that a certain river discharge (flow) level will be equaled or exceeded within a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels.

The extent of flooding associated with a 1-percent annual probability of occurrence (the base flood or 100-year flood) is used as the regulatory boundary by many agencies. Also referred to as the special flood hazard area, this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the elevation of water that will result from a given discharge level, which is one of the most important factors used in estimating flood damage.

A structure located within a 1 percent (100-year) floodplain has a 26 percent chance of suffering flood damage during the term of a 30-year mortgage. The 100-year flood is a regulatory standard used by federal agencies and most states to administer floodplain management programs. The 1 percent (100-year) annual chance flood is used by the NFIP as the basis for insurance requirements nationwide. FIRMs also depict 500-year flood designations, which is a boundary of the flood that has a 0.2-percent chance of being equaled or exceeded in any given year (FEMA, 2003; FEMA, 2005). It is important to recognize, however, that flood events and flood risk are not limited to the NFIP delineated flood hazard areas. The table below illustrates the estimated probability of flood events as utilized by the NFIP.

TABLE 8-3 ESTIMATED PROBABILITY OF FLOOD EVENT	
EVENT	**ANNUAL CHANCE OF OCCURRENCE**
10-year flood	10%
25-year flood	4%
50-year flood	2%
100-year flood	1%
500-year flood	0.2%

8.1.5 National Flood Insurance Program (NFIP)

The NFIP is a federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damage. The U.S. Congress established the NFIP with the passage of the National Flood Insurance Act of 1968 (FEMA's 2002 *National Flood Insurance Program (NFIP): Program Description*). There are three components to the NFIP: flood insurance, floodplain management, and flood hazard mapping. Nearly 20,000 communities across the U.S. and its territories participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in these communities. Community participation in the NFIP is voluntary.

For most participating communities, FEMA has prepared a detailed Flood Insurance Study. The study presents water surface elevations for floods of various magnitudes, including the 1-percent annual chance flood and the 0.2-percent annual chance flood (the 500-year flood). Base flood elevations and the boundaries of the 100- and 500-year floodplains are shown on Flood Insurance Rate Maps (FIRMs), which are the principle tool for identifying the extent and location of the flood hazard. FIRMs are the most detailed and consistent data source available, and for many communities they represent the minimum area of oversight under their floodplain management program.

NFIP participants must regulate development in floodplain areas in accordance with NFIP criteria. Before issuing a permit to build in a floodplain, participating jurisdictions must ensure that three criteria are met:

- New buildings and those undergoing substantial improvements must, at a minimum, be elevated to protect against damage by the 100-year flood.
- New floodplain development must not aggravate existing flood problems or increase damage to other properties.
- New floodplain development must exercise a reasonable and prudent effort to reduce its adverse impacts on threatened salmonid species.

NFIP Status and Severe Loss/Repetitive Loss Properties

The Samish Indian Nation currently is not a member of the NFIP, but will continue to evaluate this opportunity as it feels appropriate. The Nation has identified this as a potential mitigation strategy.

The Tribe has previously been impacted by a King tide/high wind/storm surge. In November 2012, because of the King tide event, the Fidalgo Bay Resort Convention Center was flooded and damaged. The cost of damage and labor to repair the damage was approximately $120,000. (See Figure 8-7 below – a photograph of some of the sustained damages from the event.)

Repetitive Flood Claims

Residential or non-residential (commercial) properties that have received one or more NFIP insurance payments are identified as repetitive flood properties under the NFIP. Such properties are eligible for funding to help mitigate the impacts of flooding through various FEMA programs, subject to meeting certain criteria and maintaining a Repetitive Loss Strategy. Repetitive flood claims provide funding to reduce or eliminate the long-term risk of flood damage to structures insured under the NFIP that have had one or more claim payments for flood damages.

A Repetitive Loss Strategy must identify the specific actions taken to reduce the number of repetitive loss properties, which must include severe repetitive loss properties, and specify how the Tribe intends to reduce the number of such repetitive loss properties. In addition, the hazard mitigation plan must describe the strategy it will take to reduce the number of these properties, including the development of Tribal hazard mitigation plan.

In preparation of this plan, the Planning Team did review Washington State's 2018 Hazard Mitigation Plan, which does contain a Repetitive Loss Strategy. While a sovereign nation and not required to adhere to state policies and procedures, the Nation, as appropriate, will continue to work with the state in its endeavor to reduce impact from flooding within the tribal planning area. At the Samish Indian Nation's election, this may include seeking opportunities for mitigation funds under the various Stafford Act Grant Programs.

Tribal Repetitive Loss Strategy:

The Samish will continue to address repetitive loss properties by ensuring that new construction is built to the highest building code standards required, and also continue to view the mitigation plan for identified areas of risk. As was previously done, the Tribe will continue to mitigate structures within the floodplain, including, if feasible, to move structures out of the floodplain or to take other such corrective actions as appropriate.

The Samish currently do not have extensive land use regulations in place. However, the Planning Team will use the five-year updates of this Hazard Mitigation Plan as an opportunity to evaluate hazard management laws, regulations, and policies, and work with the Nation's legal department to create the most effective and efficient regulatory authority when necessary to do so in an effort to continue to mitigate flood issues on the properties owned by the Samish Indian Nation.

Severe Repetitive Loss Program

The severe repetitive loss program is authorized by Section 1361A of the National Flood Insurance Act (42 U.S.C. 4102a), with the goal of reducing flood damages to residential properties that have experienced *severe* repetitive losses under flood insurance coverage and that will result in the greatest savings to the NFIP in the shortest period of time. A severe repetitive loss property is a residential property that is covered under an NFIP flood insurance policy and:

- a) That has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or

- b) For which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.

For both (a) and (b) above, at least two of the referenced claims must have occurred within any 10-year period, and must be greater than 10 days apart.

- The Samish Indian Nation has no severe repetitive loss properties.

The Community Rating System

The Community Rating System (CRS) is a voluntary program within the NFIP that encourages floodplain management activities that exceed the minimum NFIP requirements. Flood insurance premiums are discounted to reflect the reduced flood risk resulting from community actions.

- The Samish Indian Nation is not a CRS Community.

8.2 HAZARD PROFILE

8.2.1 Extent and Location

Flooding is the most common hazard occurring in the tribal planning area. The severity of flood damage is also dependent upon ground elevation, the surrounding topography, peak flow volumes, surface flow velocities, tides, driving winds, and storm surge.

The most common form of flooding to occur in the area is because of storm surge, which occurs to some extent annually. Tidal flooding, particularly associated with King Tides, has the potential to impact the Samish Indian Nation, particularly around Fidalgo Bay Resort (see Figure 8-3 below)[7].

[7] NOAA Office for Coastal Management. Accessed 15 July 2020. Available online at: https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=dddff4fa30bb4a91bfd1d9e758a56929

Figure 8-3 Fidalgo Bay Resort High Tide Flooding

In addition, the impact from sea level rise on the area would also be significant (see Figure 8-4). The Samish have done a significant amount of analysis with respect to impact from Sea Level Rise, and have published a separate document containing the results of that study, which is available at: https://www.samishtribe.nsn.us/departments/environment/climate-change/climate-change-resources

While flooding events can cause death and injury, Samish Indian Nation has not suffered such a loss to date. This is due, in part, to the ability of weather forecasters to provide early warning to citizens when significant weather-related events are to occur. In most cases, flooding events are more of a nuisance-type, causing disturbance to daily life in the area. Roadways can be blocked both by floodwaters and the roadways themselves being undercut, causing people to be unable to engage in normal activities of traversing roadways.

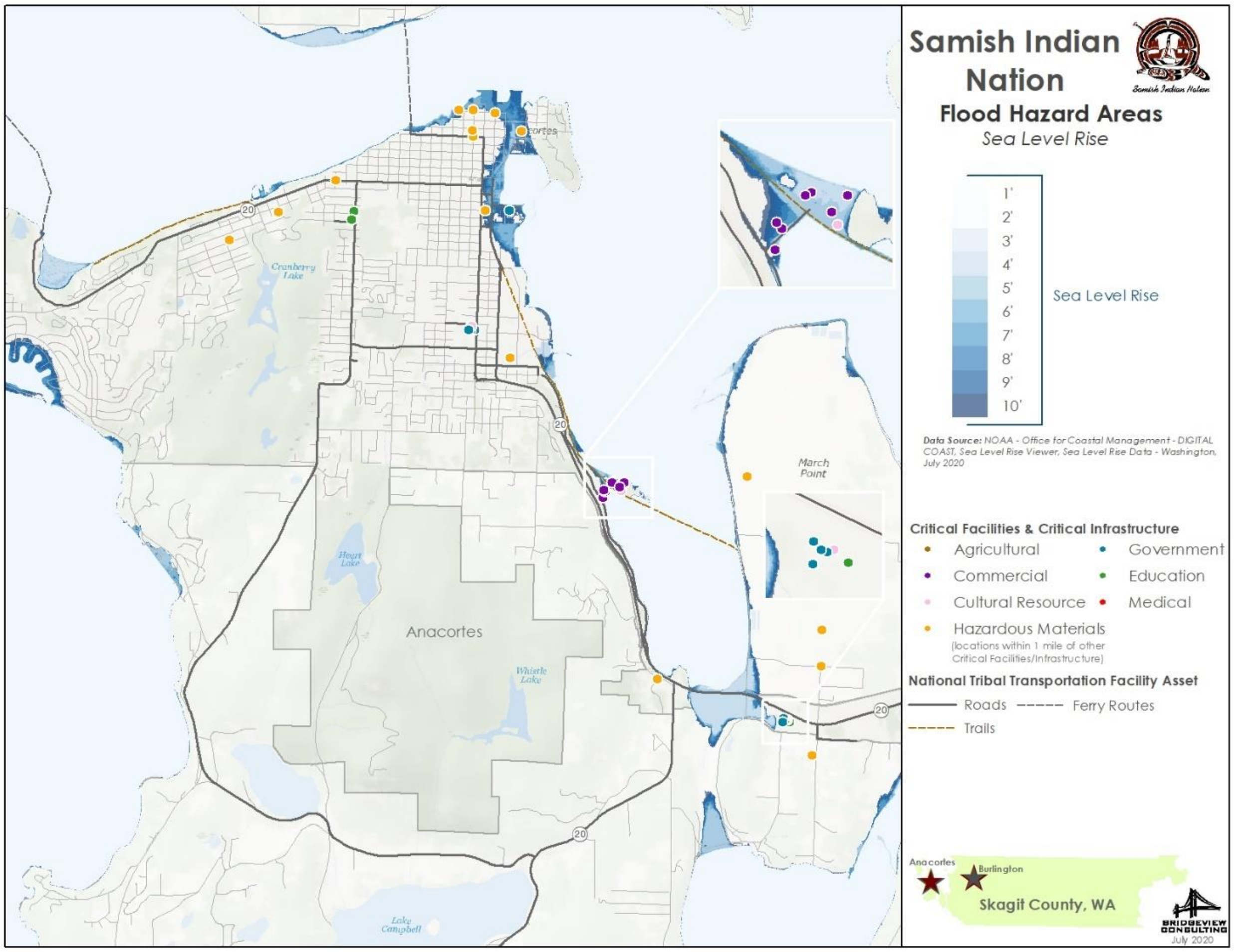


Figure 8-4 Potential Sea Level Risk Impact in Planning Area

FEMA Flood Maps

While FEMA performed a Flood Insurance Study (FIS) for Skagit County in 2017, those maps have not been adopted due to potential errors or discrepancies in the data. Therefore, the most recent adopted study for Skagit County are the 1989 maps, which remain the official record encompassing the Samish properties. As that information constitutes best available data, the 1989 maps were used in this analysis. Figure 8-5 illustrates the 100-year flood hazard area on which tribal properties are located. There are no tribal structures located within the 500-year floodplain.

Figure 8-6 illustrates shallow coastal flooding impact in the area. Shallow coastal flooding areas are those flood-prone coastal areas impacted by predicted water levels exceeding specific tidal heights as issued by the local National Weather Service offices.

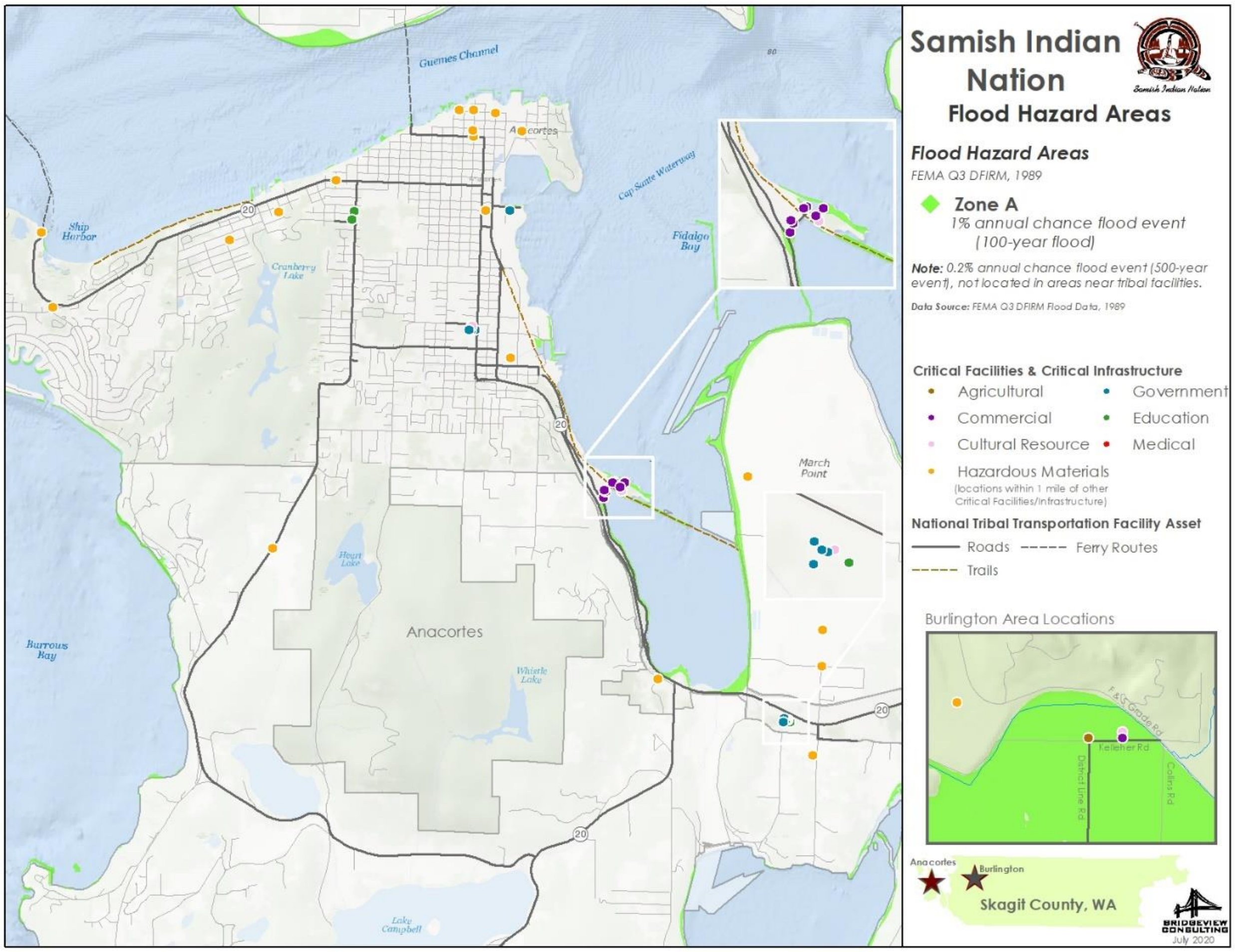


Figure 8-5 Skagit County 100-year Flood Hazard Area

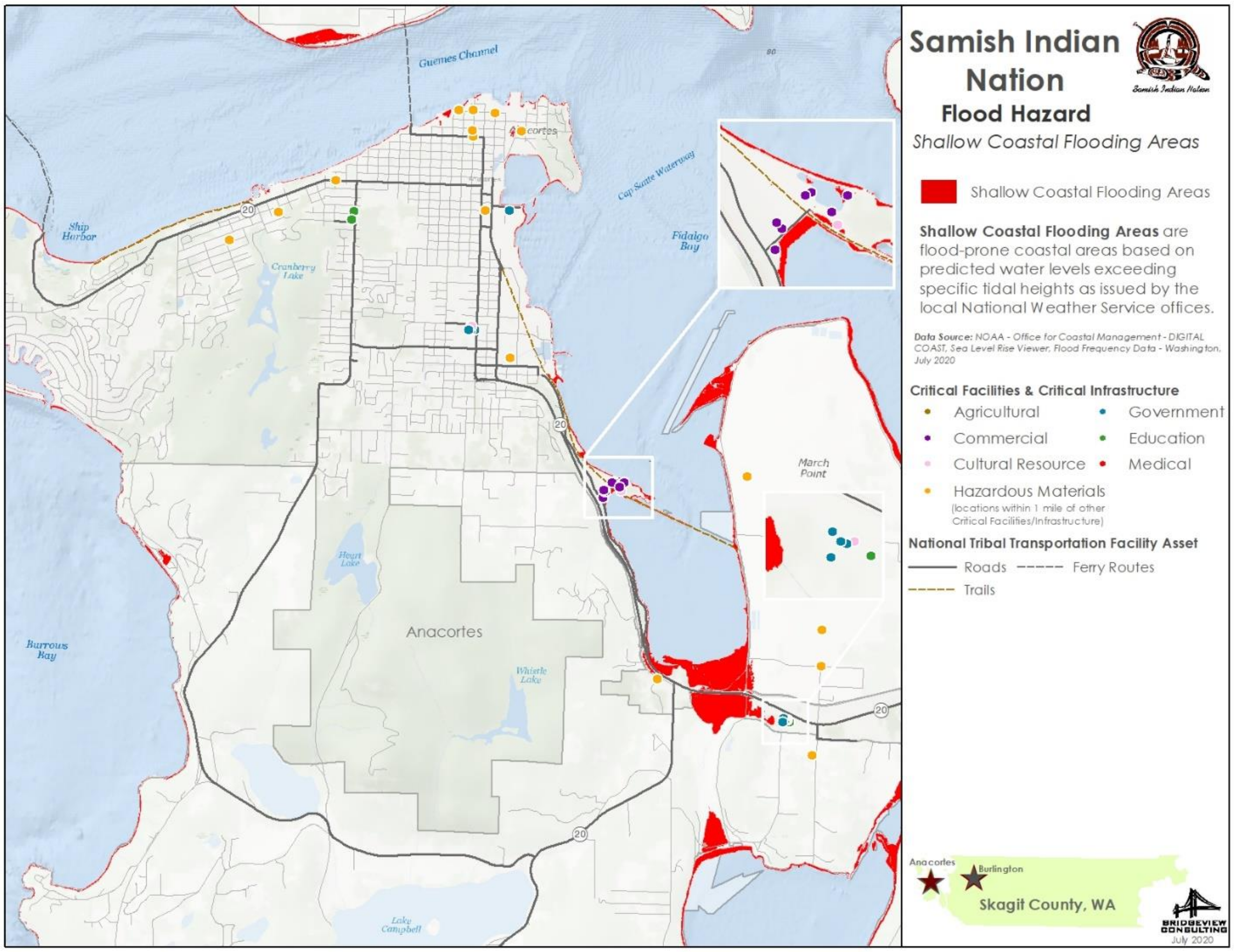


Figure 8-6 Shallow Coastal Flooding

8.2.2 Previous Occurrences

Major floods in the planning area have resulted from intense rainstorms customarily between October and February. The highest months for declared flood or flood-included events occur in December.

As identified in Chapter 3, Section 3.4 – Major Past Hazard Events Table, the planning area has been impacted by seven disaster declarations typed by FEMA as flood events. There are also seven events typed by FEMA as severe storm, which include flooding, for a total of 14 flood-related events occurring during the period 1971- (January) 2020. The Samish have no additional dollar figures which indicate loss impact from any of the events listed, but have identified the capturing of such data as a mitigation strategy for use in future updates.

Beyond the declared events, the Samish Nation was impacted by a 2012 King Tide event, which included a storm surge and wind (see Figure 8-7). That event caused approximately $120,000 of damage to the Fidalgo Bay Resort Convention Center, and introduced salt water into the City of Anacortes' water treatment system. While the incident was not a declared event, it was very significant for the Samish Nation. In addition to structure damages, roadways may also become impassable due to flood-induced landslide events. In many instances, the landslides can undercut the roadway. To date, no landslides have occurred, but this is of concern of the Samish Nation, particularly along the Fidalgo Bay Resort, which would restrict access to the resort for its occupants, or first responders, if needed.

Figure 8-7 Impact to Fidalgo Bay Resort from 2012 Storm event

8.2.3 Severity

The severity of a flood depends not only on the amount of water that accumulates in a period of time, but also on the land's ability to manage this water. One element is the size of rivers and streams that have the potential to impact an area; but an equally important factor is the land's absorbency. When it rains, soil acts as a sponge. When the land is saturated or frozen, infiltration into the ground slows and any more water that accumulates must flow as runoff (Harris, 2001).

The principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high velocity flows and transporting debris and sediment. Flood severity is often evaluated by examining peak discharges. The USGS maintains current stream gage data, and is available real-time for viewing. Figure 8-8 illustrates the type of data available from the USGS. Readers may elect to obtain data on stream gages directly from the USGS at: https://waterdata.usgs.gov/wa/nwis/rt.

Early flood management were local efforts such as the construction of dike and levee systems. As problems increased, the United State Army Corps of Engineers (USACE) began to play an important role in supporting flood management activities.

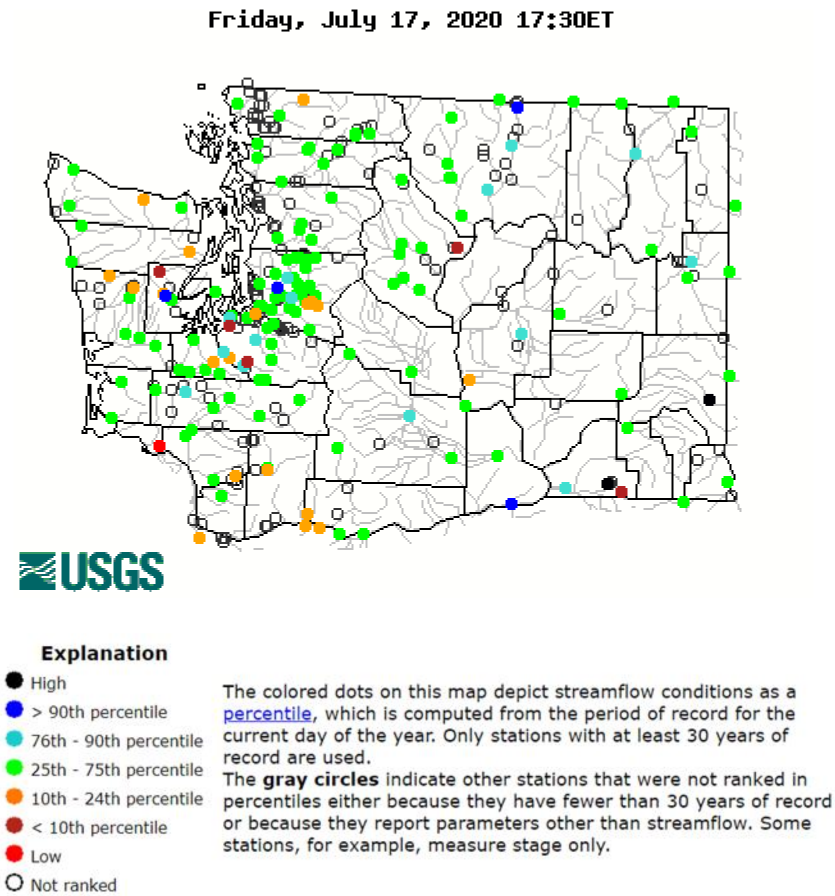


Figure 8-8 USGS Stream Flow Data for July 17, 2020

8.2.4 Frequency

The area historically experiences some level of flooding annually, although in some instances, the event exists more as a nuisance flooding related to drainage issues versus floods causing significant damage.

Floods are commonly described as having a 10-, 50-, 100-, and 500-year recurrence interval, meaning that floods of these magnitudes have (respectively) a 10-, 2-, 1-, or 0.2-percent chance of occurring in any given year. These measurements reflect statistical averages only; it is possible for two or more rare floods (with a 100-year or higher recurrence interval) to occur within a short time period. Assigning recurrence intervals to historical floods on different rivers can help indicate the intensity of a storm over a large area.

Flooding has continued to increase over the decades, with all of the declared incidents impacting the Reservation being flood-related, although not typed by FEMA as a flood. According to records, 14 major flood events from 1971 to present in Skagit County were included in Federal Disaster Declarations (some of these events were typed as severe storm rather than just flood). There are also incidents involving flooding issues which did not rise to the level of a disaster declaration. As damages have grown in frequency and in size, flood management efforts have accelerated throughout Skagit County as a CRS community to help reduce the impact of flooding.

8.3 VULNERABILITY ASSESSMENT

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For this planning purpose, the flood hazard areas identified include the 1-percent (100-year) and 0.2 % (500-year) floodplains. These events are generally those considered by planners and evaluated under federal programs such as the NFIP. The following text evaluates and estimates the potential impact of flooding throughout Skagit County as a whole, and specifically to the Samish Indian Nation.

8.3.1 Overview

All types of flooding can cause widespread damage throughout rural and urban areas, including but not limited to: water-related damage to the interior and exterior of buildings; destruction of electrical and other expensive and difficult-to-replace equipment; injury and loss of life; proliferation of disease vectors; disruption of utilities, including water, sewer, electricity, communications networks and facilities; loss of agricultural crops and livestock; placement of stress on emergency response and healthcare facilities and personnel; loss of productivity; and displacement of persons from homes and places of employment.

Warning Time

Due to the sequential pattern of meteorological conditions needed to cause serious flooding, it is unusual for a flood to occur without some warning. Warning times for floods can be between 24 and 48 hours. Flash flooding can be less predictable, but potential hazard areas can be warned in advanced of potential flash flooding danger. Dam inundation due to dam failure can occur within mere minutes of a dam breach or failure.

The potential warning time a community has to respond to a flooding threat is a function of the time between the first measurable rainfall and the first occurrence of flooding. The time it takes to recognize a flooding threat reduces the potential warning time to the time that a community has to take actions to protect lives and property. Another element that characterizes a community's flood threat is the length of time floodwaters remain above flood stage. Flood threat systems in the planning area consist of a network of precipitation gauges throughout the watersheds and stream gauges at strategic locations that constantly monitor and report stream levels. This information is fed into a U.S. Geological Survey forecasting program, which assesses the flood threat based on the amount of flow in the stream (measured in cubic feet per second). In addition to this program, data and flood warning information is provided by the National Weather Service (NWS). All of this information is analyzed to evaluate the flood threat and possible evacuation needs.

The NWS issues watches and warnings when forecasts indicate rivers may approach bank-full levels. When a watch is issued, the public should prepare for the possibility of a flood. When a warning is issued, the public is advised to stay tuned to a local radio station for further information and be prepared to take quick action if needed. A warning means a flood is imminent, generally within 12 hours, or is occurring. Local media broadcast NWS warnings.

8.3.2 Impact on Life, Health, and Safety

The impact of flooding on life, health, and safety is dependent upon several factors, including the severity of the event and whether adequate warning time is provided to residents. Exposure represents the population living in or near floodplain areas that could be impacted should a flood event occur. Additionally, exposure should not be limited to only those who reside in a defined hazard zone, but everyone who may be affected by the effects of a hazard event (e.g., people are at risk while traveling in flooded areas, or their access to emergency services is compromised during an event). The degree of that impact will vary and is not measurable. However, of significant concern within the planning area is the number of tourists who can be impacted during periods of flooding. Tourism is a very large economic base for the Samish Indian Nation and the area as a whole, with many tourists traveling through the area at all times of the year. The Fidalgo Bay Resort is open year-round for rentals of the cabins, the RV Park, and the Convention Center.

The Samish Indian Nation does not currently own residential structures; however, there are several thousands of visitors to the area annually, as well as individuals traveling to the various services provided by the Nation, such as health referral services, among others. In addition, there are also tribal employees, both full and part time (approximately 80-85), working for tribal government which would factor in for consideration.

Of the population exposed, the most vulnerable include the economically disadvantaged and the population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact on their family. The population over the age of 65 is also more vulnerable because they are more likely to seek or need medical attention which may not be available due to isolation during a flood event and they may have more difficulty evacuating.

The number of injuries and casualties resulting from flooding is generally limited based on advance weather forecasting, blockades, and warnings. Therefore, injuries and deaths generally are not anticipated if proper warning and precautions are in place. Ongoing mitigation efforts should help to avoid the most likely cause of injury, which results from persons trying to cross flooded roadways or channels during a flood.

8.3.3 Impact on Property

Review of the flood hazard areas indicates that six structures are within the 100-floodplain; no additional structures are within the 500-year floodplain. The majority of all structures owned by the Nation (with the exception of a few structures) were identified and assessed as critical facilities due to the limited number of structures owned, and the services provided.

8.3.4 Impact on Critical Facilities and Infrastructure

As indicated, six structures identified as critical facilities are exposed in the FEMA 100-year flood hazard areas. Identified are three commercial facilities at the Fidalgo Bay Resort in Anacortes, with a building and content value at risk of $991,346 combined. There are also three structures located in the Burlington area, one cultural resource, one commercial, and one agricultural structure, with a building and content value at risk of $498,544.00. Total potential flood loss is approximately $1.49 million. Of those structures, three were constructed in 1995, one in 2000, and the culturally significant structure built in 1961. The agricultural facility is considered a historic structure, built in 1900.

In addition, portions of Interstate 5, as well as other federal and state highways, county roadways, and roadways for which Tribal funds have been utilized to construct or maintain could be inundated and impassable as a result of a flood event. While many roadways in the area have been built above flood level or serve the function as a levee to prevent flooding, in certain instances, they may be impacted. Some of these roadways have been constructed with Tribal Transportation Program (TTP) funding (Bureau of Indian Affairs), in conjunction with state and local funds.

In cases where short-term functionality of a structure is impacted by a hazard, other facilities of neighboring municipalities may need to increase support response functions during a disaster event. Mitigation planning should consider means to reduce impact on critical facilities and ensure sufficient emergency services remain when a significant event occurs.

The area does have coastal landforms and feeder bluffs, which are also subject to landslides because of floods. As such, readers should also review the Landslide profile for additional details with respect to potential impact.

8.3.5 Impact on Economy

Impact on the economy related to a flood event would include loss of property, inventory, equipment, and loss of business revenue. Flooding has the potential to impact all industrial sectors. Depending on the duration between the onset of the event and recovery, businesses within the area may not be able to sustain the economic loss of their business being disrupted for an extended period of time. The Samish Indian Nation does have several business ventures in place, which could be significantly impacted. The existing loss data includes commercial structures at the Fidalgo Bay Resort.

In addition to the Samish Nation's economic loss, Tribal citizens who work for either the Nation or non-native surrounding businesses would be impacted due to loss of income. There is also a high volume of agricultural lands in the county which may be subject to flooding, with inundation affecting croplands. Forestland is also vulnerable to floods due to erosion, as are the bluff areas of the County. As such, all of those industrial sectors could also be negatively impacted.

8.3.6 Impact on Environment

Flooding is a natural event, and floodplains provide many natural and beneficial functions. Nonetheless, with human development factored in, flooding can impact the environment in negative ways. Because they border water bodies, floodplains have historically been popular sites to establish settlements. Human activities tend to concentrate in floodplains for a number of reasons: water is readily available; land is fertile and suitable for farming; transportation by water is easily accessible; and land is flatter and easier to develop. But human activity in floodplains frequently interferes with the natural function of floodplains. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development can create local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream's capacity to contain flows, and it increases flow rates or velocities downstream during all stages of a flood event. Pollution from roads, such as oil, and hazardous materials can wash into rivers and streams. During floods, these can settle onto normally dry soils, polluting them for agricultural uses. Human development such as bridge abutments and levees, and logjams from timber harvesting can increase stream bank erosion, causing rivers and streams to migrate into non-natural courses. Flooding has significant impact on migrating fish, which can be washed onto roadways or over leaves, with no possibility of escape, or the chemicals or pollutants can wash into rivers and streams, killing the fish and their food supplies. With the refineries directly across from the Fidalgo Bay Resort, impact from such an event would be extremely devastating.

Floodplains can support ecosystems that are rich in quantity and diversity of plant and animal species. A floodplain can contain 100 or even 1000 times as many species as a river. Wetting of the floodplain soil releases an immediate surge of nutrients: those left over from the last flood, and those that result from the rapid decomposition of organic matter that has accumulated since then. Microscopic organisms thrive and larger species enter a rapid breeding cycle. Opportunistic feeders (particularly birds) move in to take advantage. The production of nutrients peaks and falls away quickly; however, the surge of new growth endures for some time. This makes floodplains particularly valuable for agriculture. Species growing in floodplains are markedly different from those that grow outside floodplains. For instance, riparian trees

(trees that grow in floodplains) tend to be very tolerant of root disturbance and very quick growing compared to non-riparian trees.

8.3.7 Impact from Climate Change

According to University of Washington scientists, global climate changes resulting in warmer, wetter winters are projected to increase flooding frequency in most Western Washington river basins. Future floods are expected to exceed the capacity and protective abilities of existing flood protection facilities, threatening lives, property, major transportation corridors, communities, and regional economic centers.

Changes in Hydrology

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models and to forecast snowmelt runoff for water supply. This method of forecasting assumes that the climate of the future will be similar to that of the period of historical record. However, the hydrologic record cannot be used to predict changes in frequency and severity of extreme climate events such as floods. Going forward, model calibration or statistical relation development must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted. Climate change is already impacting water resources, and resource managers have observed the following:

- Historical hydrologic patterns can no longer be solely relied upon to forecast the water future.
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management and ecosystem functions.
- Extreme climatic events will become more frequent, necessitating improvement in flood protection, drought preparedness and emergency response.

The amount of snow is critical for water supply and environmental needs, but so is the timing of snowmelt runoff into rivers and streams. Rising snowlines caused by climate change will allow more mountain area to contribute to peak storm runoff. High frequency flood events (e.g. 10-year floods) in particular will likely increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As stream flows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality. With potential increases in the frequency and intensity of wildfires due to climate change, there is potential for more floods following fire, which increase sediment loads and water quality impacts.

As hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, bypass channels and levees, as well as the design of local sewers and storm drains.

Sea Level Rise

Sea level and temperature are interrelated (U.S. EPA, 2016). Warmer temperatures result in the melting of glaciers and ice sheets. This melting means that less water is stored on land and, thus, there is a greater volume of water in the oceans. Water also expands as it warms, and the heat content of the world’s oceans has been increasing over the last several decades. According to the EPA, there is likely to be 13 inches of sea level rise in the Puget Sound basin by 2100. According to the Washington State Department of Ecology the impacts of sea level rise could include the following: increased coastal community flooding, coastal erosion and landslides, seawater well intrusion, acidification of waters, and lost wetlands and estuaries.

8.4 FUTURE DEVELOPMENT TRENDS

Development has affected the natural features of the land over time as the area has been developed from a wilderness to the present day. Along with development came land alternations that have been a factor in increasing the magnitude and frequency of floods in the area. Encroachment on floodplains by structures and fill material reduces carrying capacity and increases flood heights and velocities.

The local municipalities in the area are subject to the provisions of the Washington State Growth Management Act (GMA) which regulate identified critical areas, but until those lands directly impacted can be returned to their normal condition, flooding will continue. Samish currently have limited land use regulations in place. However, the Nation is prepared to address flooding issues through various mitigation activities, including its restoration projects, and building outside of the floodplain when new construction occurs. In some cases, when development may occur in the floodplain, it will be regulated such that the degree of risk will be reduced through building standards and performance measures as the Nation deems appropriate.

8.5 ISSUES

Some portions of the Tribal lands have the potential to be impacted from a flood event, generally in response to a succession of winter rainstorms, or tidal surge. Storm patterns of warm, moist air are normal events, usually occurring between October and April. Such events can cause some level of flooding in the Samish Traditional Territory, although flooding can occur at any time.

A worst-case scenario for a flood event would be a series of storms that result in high accumulations of runoff surface water within a relatively short time period, especially when occurring simultaneous with a high-tide event. These types of events have occurred in the planning area. High in-channel flows would cause watercourses to scour, possibly washing out roads or impacting bridges, causing levee structures to be impacted, and potentially creating more isolation problems, and further exacerbating erosion along the coast- and shorelines. In the case of multi-basin flooding, repairs could not be made quickly enough to restore critical facilities and infrastructure. While human activities influence the impact of flooding events, human activities can also interface effectively with a floodplain as long as steps are taken to mitigate the activities' adverse impacts on floodplain functions.

8.6 IMPACT AND RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from Flood throughout the area is likely. The area experiences some level of flood annually, albeit not to the level of a disaster declaration.

While structural damage may vary due to flood depths and existing floodplain management regulations, the Samish have been fortunate in that limited structures have been impacted historically by floods. In addition to structure damage, though, there have been restoration projects that have been impacted. Based on the potential impact, the Planning Team determined the CPRI score to be 2.65 with overall vulnerability determined to be a medium level.

CHAPTER 9.
LANDSLIDE

9.1 GENERAL BACKGROUND

DEFINITIONS

Landslide—The sliding movement of masses of loosened rock and soil down a hillside or slope. Such failures occur when the strength of the soils forming the slope is exceeded by the pressure, such as weight or saturation, acting upon them.

Mass Movement—A collective term for landslides, debris flows, falls and sinkholes.

Mudslide (or Mudflow or Debris Flow)—A river of rock, earth, organic matter and other materials saturated with water.

A landslide is defined as the sliding movement of masses of loosened rock and soil down a hillside or slope. Such failures occur when the strength of the soils forming the slope is exceeded by the pressure acting upon them, such as weight or saturation. Earthquakes provide many times more energy than needed to initiate soil liquefaction, enhancing not only the probability of a landslide, but also its magnitude. Washington State climate, topography, and geology create a perfect setting for landslides, which occur in the state every year. They can be initiated by storms, earthquakes, fires, volcanic eruptions, or human modification of the land.

In Western Washington, most landslides are triggered during fall and winter after storms dump large amounts of rain or snow (Washington Department of Natural Resources, 2015). Landslides can be shallow or deep. Shallow landslides typically occur in winter in Western Washington and summer in Eastern Washington, but are possible at any time. They often form as slumps along roadways or fast-moving debris flows down valleys or concave topography. They are commonly called “mudslides” by the news media. Deep-seated landslides are often slow moving, but can cover large areas and devastate infrastructure and housing developments.

Mudslides (or mudflows or debris flows) are rivers of rock, earth, organic matter, and other soil materials saturated with water. They develop in the soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt. Water pressure in the pore spaces of the material increases to the point that the internal strength of the soil is drastically weakened. The soil’s reduced resistance can then easily be overcome by gravity, changing the earth into a flowing river of mud or “slurry.” A mudslide or debris flow is a fast-moving fluid mass of rock fragments, soil, water, and organic material with more than half of the particles being larger than sand size. Generally, these types of movement occur on steep slopes or in gullies and can travel long distances. A debris flow or mudflow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars, and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water, due to the mass of material included in them. Locally, they can be some of the most destructive events in nature.

A rock fall is the fall of newly detached segments of bedrock of any size from a cliff or steep slope. The rock descends by free fall, bouncing, or rolling. Movements are very rapid to extremely rapid, and may not be preceded by minor movements.

All mass movements are caused by a combination of geological and climate conditions, as well as the encroaching influence of urbanization. Vulnerable natural conditions are affected by human residential, agricultural, commercial, and industrial development and the infrastructure that supports it.

The occurrence of a landslide is dependent on a combination of site-specific conditions and influencing factors. Most commonly, the factors that contribute to landslides fall into four broad categories:

- Climatic or hydrologic (rainfall or precipitation);
- Geomorphic (slope form and conditions, e.g., slope, shape, height, steepness, vegetation and underlying geology);
- Geologic/geotechnical/hydrogeological (groundwater);
- Human activity.

Change in slope of the terrain, increased load on the land, shocks, and vibrations, change in water content, groundwater movement, frost action, weathering of rocks, and removing or changing the type of vegetation covering slopes are all contributing factors. In general, landslide hazard areas are where the land has characteristics that contribute to the risk of the downhill movement of material, such as the following:

- Areas identified as having slopes greater than 40 percent;
- A history of landslide activity or movement during the last 10,000 years;
- Stream or wave activity, which has caused erosion, undercut a bank or cut into a bank to cause the surrounding land to be unstable;
- The presence of an alluvial fan, indicating vulnerability to the flow of debris or sediments;
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils such as sand and gravel.

Flows and slides are commonly categorized by the form of initial ground failure. Common types of slides are shown on Figure 9-1 through Figure 9-4 (Washington State Department of Ecology, 2014). The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms, where antecedent conditions are prevalent (Baum, et. al, 2000). The largest and most destructive are deep-seated slides, although they are less common.

Deep-seated landslides are much larger than shallow landslides and can occur at any time of the year. Soil degradation can happen over years, decades, and centuries with little to no warning to people above ground. The most notable and deadliest deep-seated landslide event in the United States was SR 530 (also known as the Oso Landslide) that took the lives of 43 people in Oso, Washington, in 2014.

Slides and earth flows can pose serious hazard to property in hillside terrain. They tend to move slowly and thus rarely threaten life directly. When they move—in response to such changes as increased water content, earthquake shaking, addition of load, or removal of downslope support—they deform and tilt the ground surface. The result can be destruction of foundations, offset of roads, breaking of underground pipes, or overriding of downslope property and structures.

The primary types of landslides that occur in the planning area are debris flows and earth flows. While small slides and debris flows occur on a somewhat regular basis, there have been slides and/or debris flows that have resulted in loss of life and/or property damage.

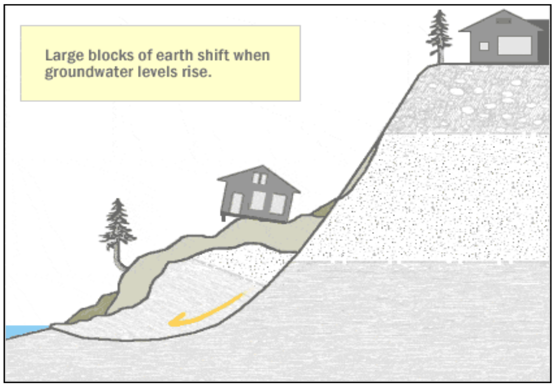


Figure 9-1 Deep Seated Slide

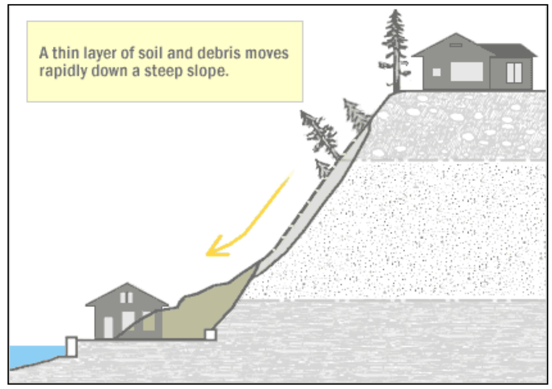


Figure 9-2 Shallow Colluvial Slide

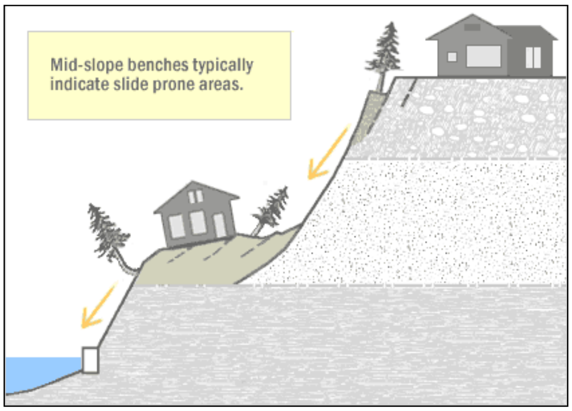


Figure 9-3 Bench Slide

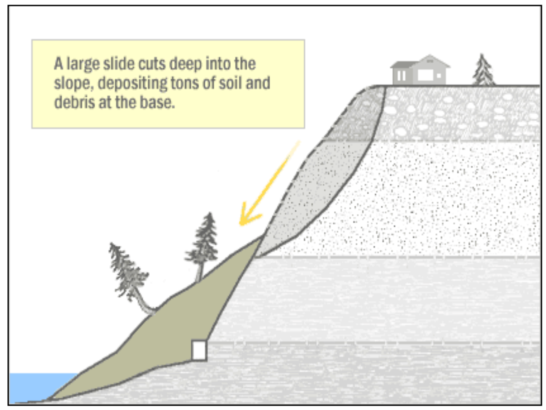


Figure 9-4 Large Slide

Coastal Erosion

Coastal erosion is a natural process that is common along the shoreline interface of a water body and the land. Along sedimentary coasts, a beach is commonly found at this interface, with sediments moving and changing the shape of the beach in response to hydrodynamic forcing. As such, the beach typically serves as a buffer zone between the water's edge and the more stable back beach dune or upland margin. While a net loss of sediment from a beach may be noticeable and affect human uses and the environment, often much greater concern and impact occurs when there is dune or upland erosion, particularly where this land has been considered to be stable and suitable for development.

Coastal erosion is defined as the wearing of coastal land by natural forces, such as by water waves, wind, and tidal currents. Beach sediments are routinely mobilized by these forces, which can change the shape and size of a beach over a range of time scales from hours to years. These changes are often only recognized as erosion when there is a significant net loss of material that causes an impact or instability to the adjacent upland. Coastal erosion can occur during an episodic event, such as a large storm, or as a chronic condition with the gradual loss of the beach or coastal land.

Washington's coastlines are subject to high energy waves that can cause rapid coastal erosion during typical winter storms that coincide with high tides and elevated water levels.

Localized coastal erosion such as adjacent to shoreline armoring or along a river mouth can result from the interactions of forces that locally change the transport and distribution of sediments. Large-scale coastal erosion can occur during the infrequent, yet periodic, Cascadia subduction zone earthquakes, associated with coastal subsidence and large tsunamis.

Much of shorelines in the area are composed of fine sand derived from the various rivers that are readily mobilized by wind and wave action. Seasonal fluctuations in waves and water levels typically cause beach erosion in the winter and beach accretion (or build up) in the summer. Where the beaches are backed by bluffs composed of older sedimentary deposits, bluff erosion constitutes a permanent loss of the upland.

In addition to rock composition, the geology may control the elevation and slope of the nearshore area, which in turn can determine how wave energy is dissipated before reaching the shoreline. A shallow and mild-sloped shoreface will cause waves to break offshore and greatly reduce their ability to erode coastal uplands. In contrast, a deep and steep shoreface will enable high waves to break directly onto the beach and dissipate as run-up onto the upper beach or bluff. In general, a deep and steep shoreface will manifest as a steep and rocky beach composed of larger particles, such as cobbles or boulders, because smaller particles, such as sand and gravel, are readily transported away and deposited in areas having a lower energy regime.

On a seasonal scale, coastal erosion typically occurs during the winter, when distant and local storms produce large waves, high winds, and elevated water levels. Winter storms typically approach the shoreline from the southwest, resulting in northerly and offshore sediment transport that erodes beaches, whereas as fair-weather summer conditions generally produce smaller waves approaching from the northwest that result in southerly and onshore sediment transport that builds up the beaches. During strong El Niño events, sustained elevated water levels can accentuate seasonal coastal erosion.

Coastal erosion is dependent on a combination of site-specific conditions and influencing factors. Most commonly, the factors that contribute to erosion fall into three broad categories:

- Hydraulic energy regime (waves, water levels, currents, winds, storm climatology).
- Geomorphic setting (sediment supply and grain size, geologically inherited substrate, landform and composition, e.g., coastal barrier, bluff, geology, vegetation, streams, rivers).
- Human activity (e.g. dams, jetties, coastal structures that affect sediment transport and sediment budget).

While a certain amount of erosion is natural and healthy for an ecosystem—such as gravel continuously moving downstream in watercourses—excessive erosion causes serious problems, such as receiving water sedimentation, ecosystem damage and loss of soil and slop stability. Erosion can cause a loss of forests and trees, which causes serious damage to aquatic life, irrigation, and power development by heavy silting of streams, reservoirs, and rivers. Concentrated surface water runoff in drainages and swales can lead to channel-confined slope failures, involving the rapid transport of fluidized debris, known as debris flows.

Skagit County GIS has identified soils which have a higher likelihood of being susceptible to erosion. [8] This type of information is helpful to identify appropriate building codes and development practices and to ensure proper performance based on the lands' use. Great differences in the soil properties can occur within relatively short distances.

[8] Data derived from Skagit County GIS, available at: https://www.skagitcounty.net/GIS/Documents/GeoHazard/cw103-53.pdf

The original soils study was conducted by the US Department of Agriculture in 1960, and identified areas throughout the County with a low, moderate, or severe potential for erosion based on soil classifications. Figure 9-5 identifies those areas of higher risk to erosion in proximity to Tribal-owned structures.[9]

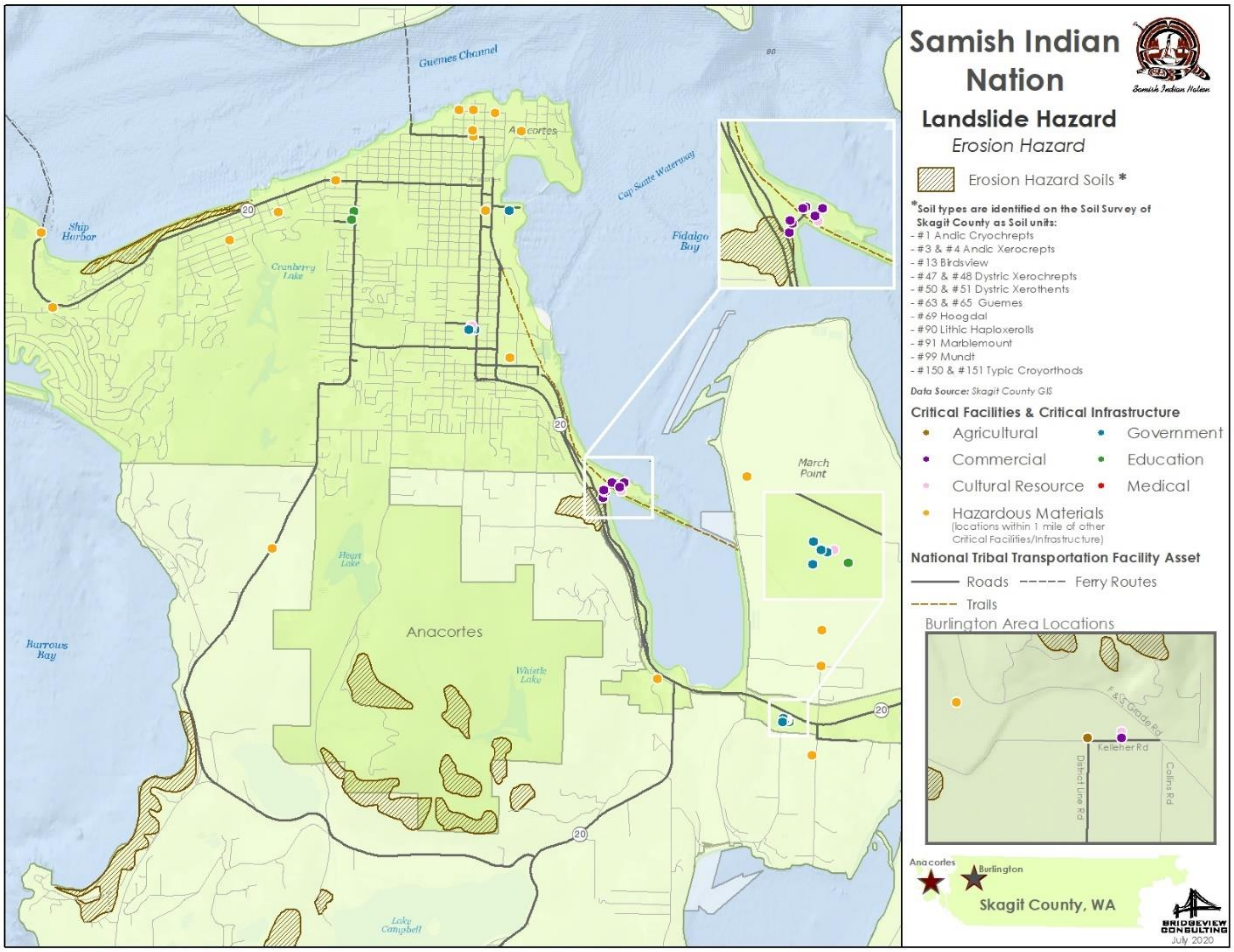


Figure 9-5 Potential Erosion Hazard in Proximity to Samish Structures

Feeder Bluff

Puget Sound has more than 1,400 miles of beaches, most built from sand and gravel eroded from nearby bluffs. Puget Sound's glacial history and unique geology make these feeder bluffs an important source of beach sediment.

A feeder bluff is a term used to describe coastal cliff or headland which, through erosion and weathering, provides sediment to down-current beaches. A bluff is more susceptible to erosion if the sediment is unconsolidated, and more resistant in crystalline rocks, like granite. Rocks that are heavily fractured are also likely to suffer from erosion because the water can flow between the cracks, causing the erosion to occur more quickly. A bluff will retreat towards land as the erosion processes continue. Knowing where feeder bluffs are located helps us protect them and the beaches they help build.

[9] USDA (1989) Soils Survey. Accessed on line 23 July 2020. Available at: https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/washington/WA657/0/wa657_text.pdf

Washington State Department of Ecology began mapping feeder bluffs in Puget Sound in 2013 to describe actively eroding bluffs that provide sediment to nearby beaches. Knowing where feeder bluffs are situated allows for the prioritization and restoration of bluffs being impacted as they many times influence the formation of spawning and other coastal habitats. Figure 9-6 illustrates the feeder bluffs within the planning area. Additional information is available at the Department of Ecology's website.[10]

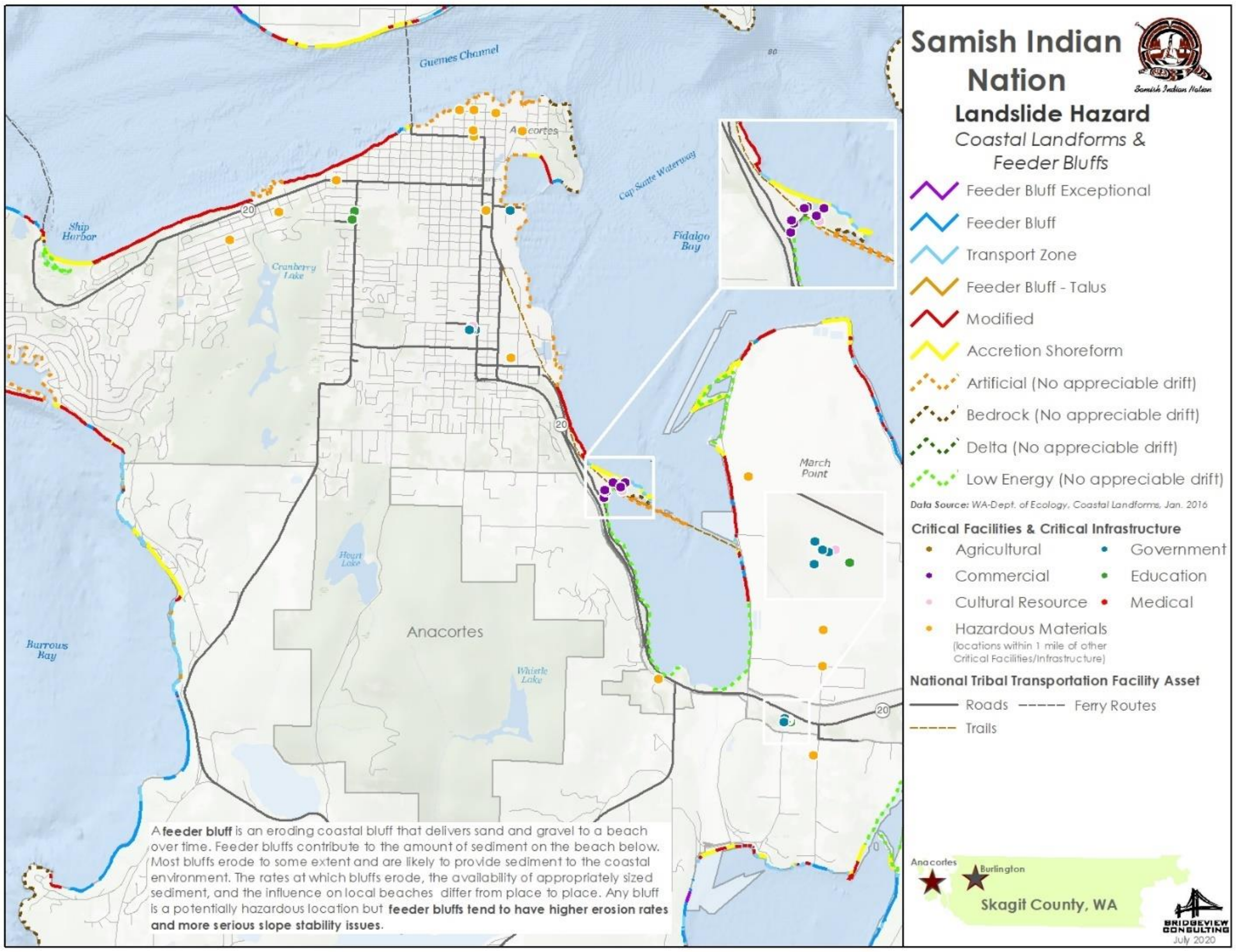


Figure 9-6 Coastal Landforms and Feeder Bluffs

9.2 HAZARD PROFILE

9.2.1 Extent and Location

The best predictor of where slides and earth flows might occur is the location of past movements. Past landslides can be recognized by their distinctive topographic shapes, which can remain in place for thousands of years. Most landslides recognizable in this fashion range from a few acres to several square miles. Most show no evidence of recent movement and are not currently active. A small portion of them

[10] Washington State Department of Ecology Feeder Bluff. Accessed 22 July 2020. Available online at: https://ecology.wa.gov/Research-Data/Monitoring-assessment/Coastal-monitoring-assessment/Projects/Puget-Sound-feeder-bluff

may become active in any given year. The recognition of ancient dormant mass movement sites is important in the identification of areas susceptible to flows and slides because they can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding. A 2007 USGS Landslide Hazard area which occurred for the Seattle, Washington area further confirms that "when slopes are dry, steepness and strength control potential instability. However, where ground water perches on lower permeability clay layers, extended wet winter conditions can increase the water table near the bluff face. Elevated ground-water pressures can lower slope stability" (USGS, 2007).

As indicated, the primary types of landslides that occur in the area are debris flows and earth flows. Debris flows are also called mudslides, mudflows, or debris avalanches. They are rivers of a combination of loose soil, rock, organic matter, water, and air that flow downhill. As they continue downhill, they tend to grow in volume with the addition of water, soil, boulders, and other materials. When the flow reaches flatter ground, it can spread over a large area. Earth flows usually occur in fine-grained materials or clay bearing rocks on moderate slopes. The slope's material liquefies and forms a bowl shape depression at the source area.

Figure 9-7 illustrates the locations of where previous landslides have occurred in proximity to the Samish Indian Nation's owned structures based on data available by WA DNR (2020).

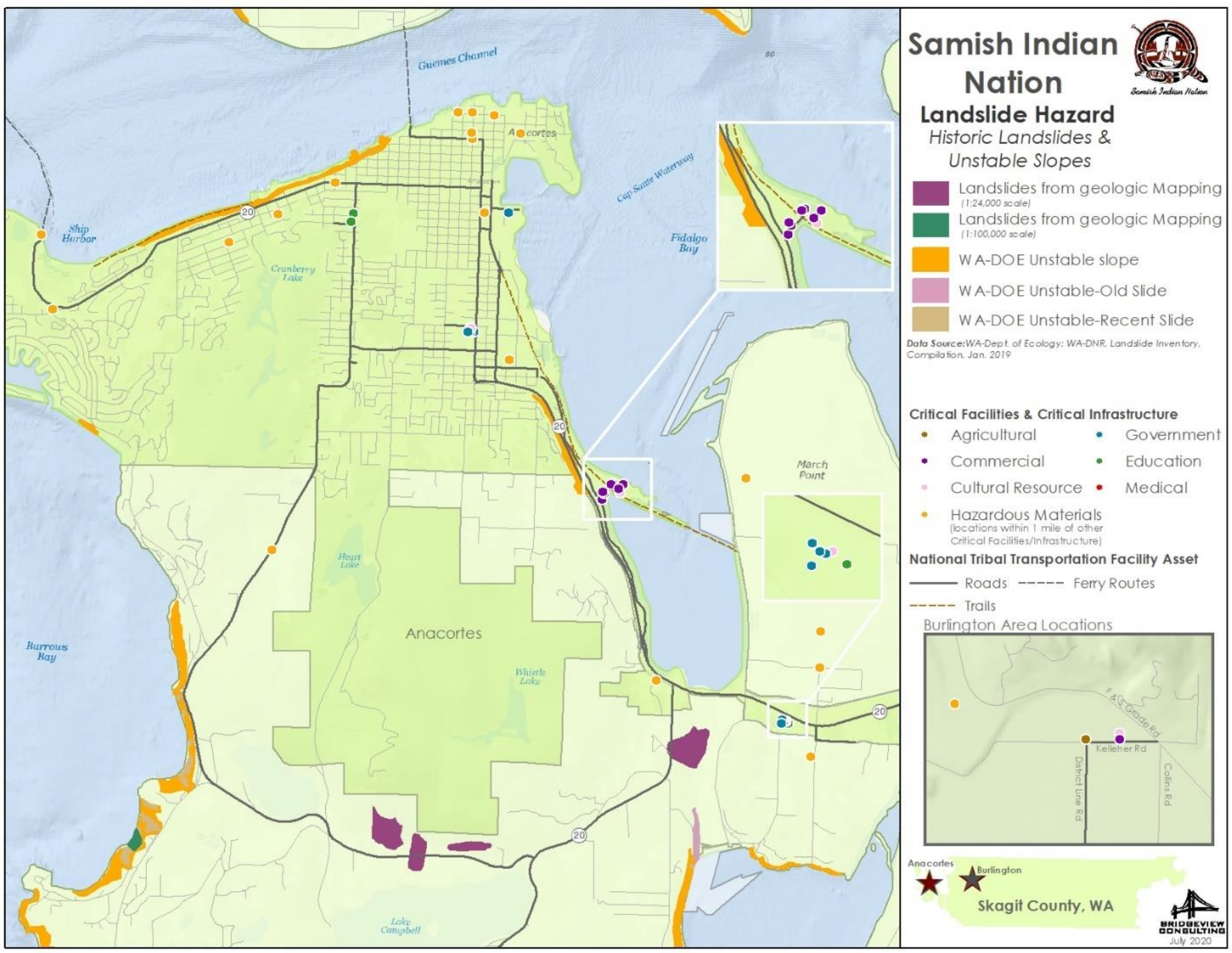


Figure 9-7 Historic Landslide and Unstable Slop Areas

9.2.2 Previous Occurrences

Landslides of some degree are common within the State of Washington as a whole, and are one of the most frequently occurring natural hazards, but they are also difficult to quantify, both in terms of frequency, and in cost.[11]

Since 1963, a total of eight weather events have included impact from landslides or mudslides. However, the County has never received a disaster declaration specifically typed *Landslide* by FEMA. As such, reviewers should also examine the Disaster Event tables in Section 3, as well as both the Severe Weather and Flood Chapters to identify disaster-related landslide occurrences included with other hazards of concern.

Two of the state's largest and most tragic landslides include the SR-530 slide in Snohomish County, which occurred in March 2014, causing 43 fatalities. The SR-530 slide is frequently referred to as the Oso Landslide, and it is one of the deadliest and most significant landslides to have occurred in U.S. history. The cost of damage and repair for the Oso Landslide is estimated to be in excess of $30 million.

A second significant landslide in Washington is the Aldercrest-Banyon landslide, which occurred in Kelso, Washington. Beginning in 1998 as a slow-moving slide, it ended in 1999 with the destruction of or damage to138 homes, accounting for $30-$40 million in losses (2006 figures).

In addition to these two major slides, there have been additional deaths in Washington which have occurred as a result of slides, slope collapses, and sinkholes, including within Skagit County. A list of the more notable slides to occur in the county are as follows:

- A debris flow occurring in the area of Marblemount on November 2, 1985 caused four deaths. That landslide swept into a mobile home park.

- In January 2009, a typical atmospheric river (Pineapple Express) storm rolled through the state, bringing warm rains that rapidly melted lowland snow. The Washington Geological Survey reported that the storm caused more than 1,500 landslides greater than 5,000 ft. in size. Approximately 300 to 500 landslides occurred in Skagit and Whatcom Counties.

- In October 2003, heavy rainfall caused severe flooding and landslides in 15 Washington counties. Landslides or ground failure caused temporary closures on nine state highways. Landslides closed SR 20 between Skagit and Okanogan Counties.

- In the late 1960's, a large landslide occurred east of Marblemount on the south side of the Cascade River in the isolated recreational community of Cascade River Park. While limited data is available on the slide and total impact, this slide did destroy several recreational cabins and covered a large number of vacant lots with debris; the County has been unable to determine if persons were injured or killed as a result of this slide. The slide was serious enough that a large portion of the development was permanently abandoned.

Landslides of some type do occur within the area in general regularly, although to date, none have impacted Tribal Structures. Those slides also have the potential to impact ingress and egress to the area. While not immediately impacting or damaging those segments of Tribal NTTFI roadways for which BIA funds were

[11] Washington Department of Natural Resources Publications. (2016-2017). Accessed 21 July 2020. Available at: https://file.dnr.wa.gov/publications/ger_geologic_risk.pdf

utilized to build or reconstruct, other segments of the roadways have been impacted and damaged, which has restricted access to some degree.

9.2.1 Severity

Landslides destroy property and infrastructure, and can have a long-lasting effect on the environment and can take the lives of people. Nationally, landslides account for between $2 and $4 billion in losses annually and result in an estimated 25 to 50 deaths a year (American Geosciences Institute, 2020; Spiker and Gori, 2003; Schuster and Highland, 2001; Schuster, 1996; USGS).

Washington is one of seven states listed by the Federal Emergency Management Agency as being especially vulnerable to severe land stability problems. Topographic and geologic factors cause certain areas to be highly susceptible to landslides. Ground saturation and variability in rainfall patterns are also important factors affecting slope stability in area susceptible to landslides. Strong earthquake shaking can cause landslides on slopes that are otherwise stable.

Figure 9-8 illustrates the Samish structures in proximity to steep slopes as identified by WA DNR which meet the thresholds of 40 percent or greater slopes. 40 percent or great slops are what WA DNR defines as those areas being more susceptible to landslide events. As no such other data currently exists, this is considered the best available data as of this update; however, WA DNR is currently in the process of updating landslide data in various parts of Washington. Such data may change the existing areas of concern, particularly as the Samish Indian Nation continues to acquire land mass, including those within frequently flooded areas.

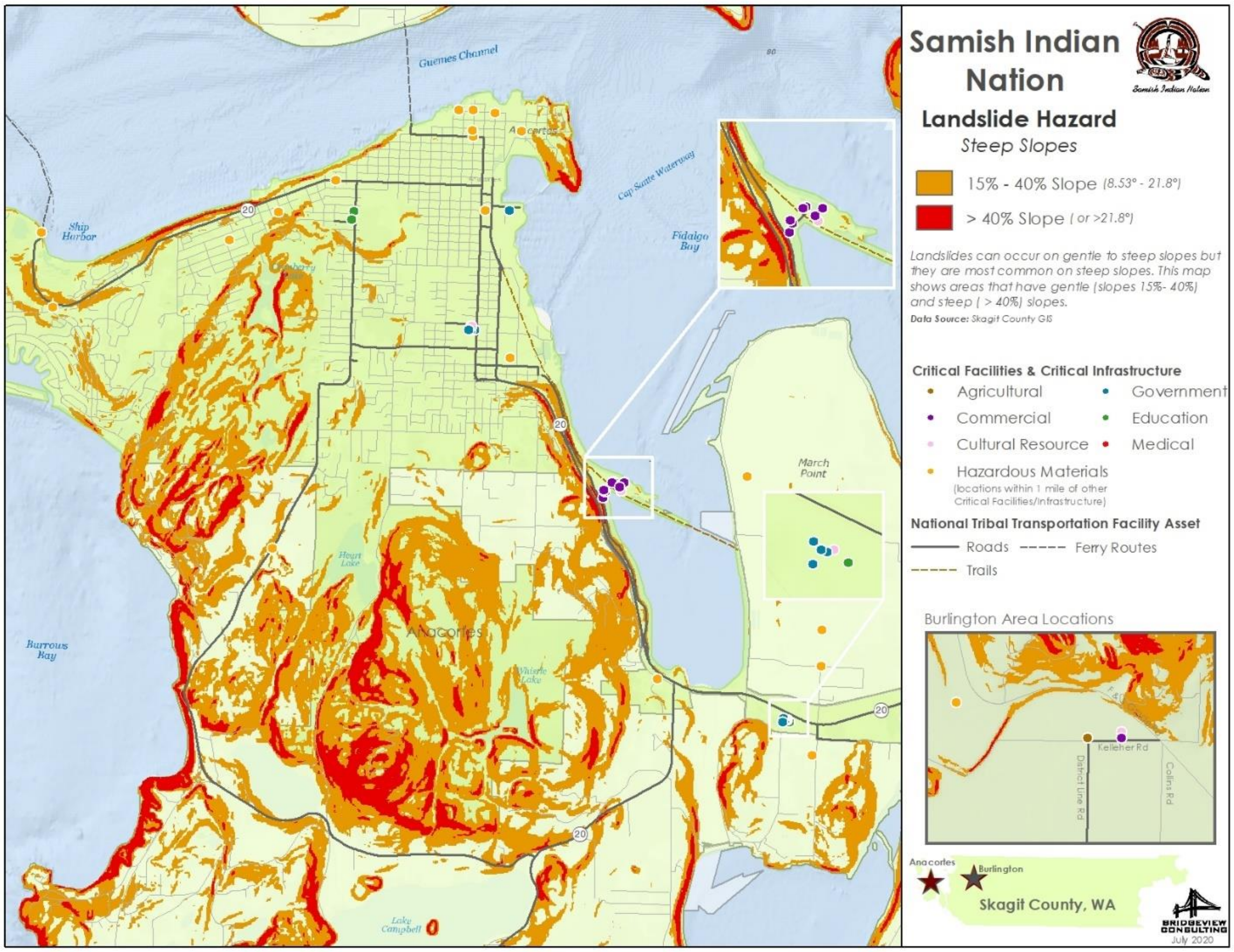


Figure 9-8 Landslide Hazard Areas

9.2.2 Frequency

A specific recurrence interval has not been established by geologists, but historical data indicates several successive years of slide activities may be followed by dormant periods, such as was the case with the Marblemount landslides which occurred in the same area of Skagit County in 1960, and again in 1985. Landslides are also often triggered by other natural hazards such as earthquakes, heavy rain, floods, or wildfires, so landslide frequency is often related to the frequency of these other hazards.

Precipitation influences the timing of landslides on three scales: total annual rainfall, monthly rainfall, and single precipitation events. In general, landslides likely occur during periods of higher than average rainfall, so the potential for landslides largely coincides with the potential for sequential severe storms and flood events that saturate steep, vulnerable soils.

Studies conducted by the USGS have identified two precipitation thresholds to help identify when landslides are likely (USGS, 2007)[12]:

- Cumulative Precipitation Threshold (Figure 9-9)—A measure of precipitation over the last 18 days, indicating when the ground is wet enough to be susceptible to landslides. Rainfall of 3.5

[12] USGS Landslide Hazards in the Seattle, Washington, Area. Accessed 20 June 2019. Available at: https://pubs.usgs.gov/fs/2007/3005/pdf/FS07-3005_508.pdf

to 5.3 inches is required to exceed this threshold, depending on how much rain falls in the last 3 days.

- Intensity Duration Threshold (Figure 9-10)—A measure of rainfall during a storm, indicating when it is raining hard enough to cause multiple landslides if the ground is already wet.

These thresholds are most likely to be crossed during the rainy season. The 2007 USGS study indicates that by comparing recent and forecast rainfall amounts to the thresholds, meteorologists, geologists and city officials can help people know when to be prepared for landslides. The thresholds as developed and tested are accurate, but imperfect indicators of when landslides may occur. During the study, statistical analysis of landslides that occurred between 1978 and 2003 showed that 85% occurred when the Cumulative Precipitation Threshold was exceeded (USGS, 2007).

Review of existing disaster-related data illustrates that slide events in the planning area most commonly occur from November through January, after water tables have risen. Review of historic disasters illustrates that the month of December experienced the greatest number of slides, followed by January and November.

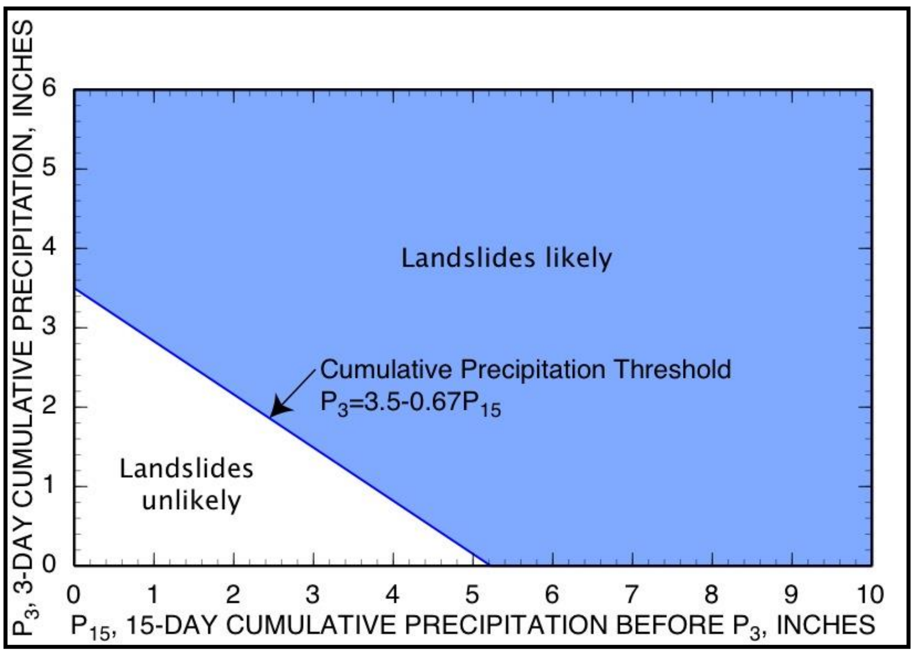


Figure 9-9 Cumulative Precipitation Threshold

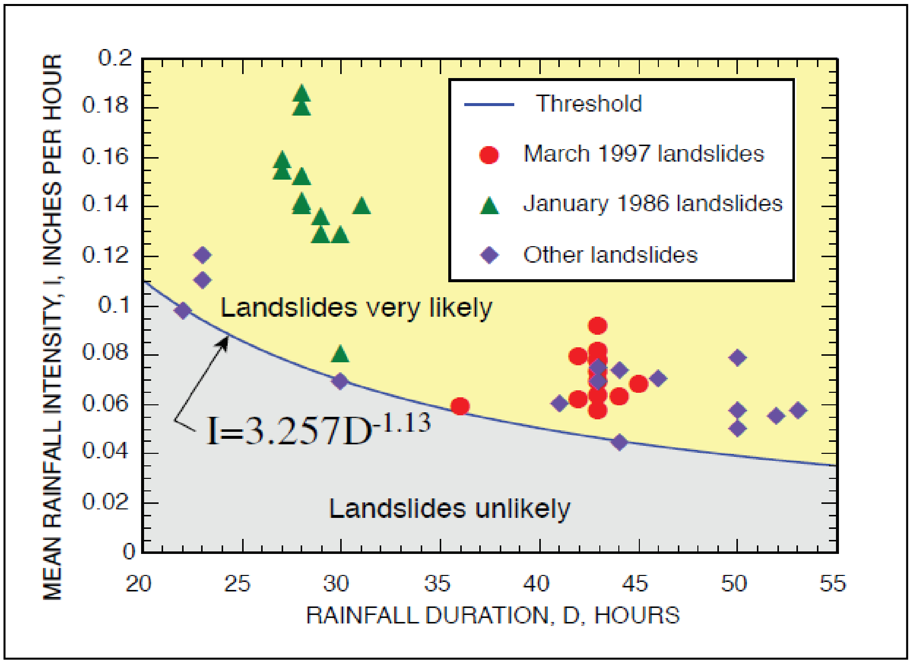


Figure 9-10 Landslide Intensity Duration Threshold

9.3 VULNERABILITY ASSESSMENT

9.3.1 Overview

Landslides have the potential to cause widespread damage throughout both rural and urban areas. While some landslides are more of a nuisance-type event, even the smallest of slides has the potential to injure or kill individuals and damage infrastructure. Studies have also indicated that of the slides recorded, the majority had some element of human-related causes which exacerbated the slide, such as development in hazard prone areas (City of Seattle 2015 Hazard Mitigation Plan).

Warning Time

Unlike flood hazards which often are predictable, mass movements or landslides are generally unpredictable, with little or no advanced warning. The speed of onset and velocity associated with a slide event can have devastating impacts. While some methods used to monitor mass movements can provide an idea of the type of movement and provide some indicators (potentially) with respect to the amount of time prior to failure, exact science is not available.

Mass movements can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material, and water content. Generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before;
- New cracks or unusual bulges in the ground, street pavements or sidewalks;
- Soil moving away from foundations;
- Ancillary structures such as decks and patios tilting and/or moving relative to the main house;
- Tilting or cracking of concrete floors and foundations;

- Broken water lines and other underground utilities;
- Leaning telephone poles, trees, retaining walls or fences (or offset fence lines);
- Sunken or down-dropped road beds;
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content);
- Sudden decrease in creek water levels though rain is still falling or just recently stopped;
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb;
- A faint rumbling sound that increases in volume as the landslide nears;
- Unusual sounds, such as trees cracking or boulders knocking together.

It is possible, based on historical occurrences, to determine what areas are at a higher risk. Assessing the geology, vegetation, and amount of predicted precipitation for an area can help in these predictions; such an analysis is beyond the scope of this planning effort. However, there is no practical warning system for individual landslides. Historical events remain the best indicators of potential landslide activity, but it is generally impossible to determine with precision the size of a slide event or when an event will occur. Increased precipitation in the form of snow or rain increases the potential for landslide activity. Steep slopes also increase the potential for slides, especially when combined with specific types of soil.

Within Washington State, in a partnership with the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service, Washington State Department of Natural Resources monitors conditions that could produce shallow landslides. Landslide warning information can be viewed at: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/landslides#landslide-warning-signs-and-triggers.1.

9.3.2 Impact on Life, Health, and Safety

There are currently no residential structures owned by the Samish which are utilized as residences. There are, however, approximately 80-85 employees working for the Tribe (Government/Enterprise, Tribal Member Services, etc.) who could be negatively impacted by a landslide event. In addition, potential population impact also includes visitors to the various business enterprises owned by the Tribe, and the various medical services available to all tribal citizens, regardless of tribal affiliation.

While landslide hazard areas are identified in the various maps contained in this hazard profile, it should be noted that areas identified within this document were based on existing data; no geotechnical or scientific analyses were conducted for development of this hazard mitigation plan as such analyses far exceed the intent of this document; therefore, no data should not be relied upon for life safety measures, or anything other than informing emergency managers of potential risk for planning purposes.

Also to be taken into account when determining affected population are the area-wide impacts on transportation systems and the isolation of residents who may not be directly impacted, but whose ability to ingress and egress is restricted, such as areas along major highways, which have a high transient population of tourists, especially during summertime months.

Landslides can be fast moving, or slow creeping, with the fast moving obviously increasing the potential for injury or death from such an event. Landslides can also damage water treatment facilities, distribution lines, and wells, potentially harming water quality. Hazardous materials may also be released during landslide events in areas not in the immediate vicinity, which would still have impact.

9.3.3 Impact on Property

Landslides and erosion affect both private property and public infrastructure and facilities. The predominant land use by the Samish Indian Nation is for commercial/business and governmental operations, including health services administration. The Nation does anticipate development of residential structures during the life cycle of this plan. In addition, there are several restoration and preservation projects underway. Development in landslide hazard area is guided by building code and the critical area ordinance, which help to prevent the acceleration of manmade and natural geological hazards, and to neutralize or reduce the risk to the property owner or adjacent properties from development activities.

The Washington State Department of Natural Resources Landslide Dataset was utilized to identify areas of historic landslide events. Increased hazard begins to occur on slopes 15-40 percent slope. In addition, slopes identified as being forty (40) percent or steeper were included in this analysis as those being of higher risk to landslides based on WA DNR analysis and identification. For these planning purposes, risk area is defined as slopes 40% and above, and areas identified within WA DNR mapped historic landslides. Data presented are not a substitute for site-specific investigations by qualified practitioners, such as geologists or engineers.

The number of structures and area exposed to the landslide hazard are summarized as follows, and are identified in Figures 9-5 through 9-8 (above):

- Two structures at the Fidalgo Bay Resort are in the landslide/erosion area, with a total building and content value of ~$770,000;
- Eight rental cabins at the Fidalgo Bay Resort are within 500 feet of landslide/erosion areas, with a building and content value of ~$638,000; and
- 14 structures are within 500 feet of the Feeder Bluff areas, with a building and content value of ~$4.7 million.

9.3.4 Impact on Critical Facilities and Infrastructure

All structures and properties analyzed for this effort are identified Critical Facilities and Infrastructure due to the limited number of structures owned by the Samish Indian Nation. As such, the same properties identified in Section 9.3.3 are considered critical facilities. In addition to those structures identified above, roadways constructed by the Samish Indian Nation would be considered critical in nature, including the Fidalgo Bay Roadway.

The Samish Indian Nation will continue to rely on the County's plan for identification of non-tribal owned critical infrastructure and facilities in the planning area at risk. Review of the County's plan identifies that several types of infrastructure are exposed to mass movements, including transportation facilities, airports, bridges, and water, sewer, and power infrastructure. The Tribe relies primarily on water supplied by the City of Anacortes (e.g., wells, pump houses, storage tanks and filtration/purifications systems). While not (wholly) owned by Samish, highly susceptible areas include mountain and coastal roads and transportation infrastructure, impact to which is of concern to the Tribal Planning Area as they serve as primary resources to the Tribe. All infrastructure and transportation corridors exposed to the landslide hazard are considered vulnerable. Significant infrastructure in the planning region exposed to mass movement include the following:

- **Roads**—Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Landslides can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems and delays for public and private transportation. This can result in economic losses for businesses.

- **Bridges, Marinas, and Boat/Ferry Docks**—Landslides can significantly impact road bridges, marinas, and boat/ ferry docks. Mass movements can knock out bridge and dock abutments, causing significant misalignment and restricting access and usages, as well as significantly weaken the soil supporting the structures, making them hazardous for use.

- **Power Lines**—Power lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil beneath a tower, causing it to collapse and ripping down the lines. Power and communication failures due to landslides can create problems for vulnerable populations and businesses.

Based on review of Skagit County's Hazard Mitigation Plans, there are a significant number of bridges, marinas, and boat/ferry docks that would be at risk from the landslide and erosion hazards; however, the Tribe does not own any such structures. Throughout the planning area, and in particular the areas where Samish owns structures, there are also more above-ground power lines than below ground, increasing the risk of power outages due to landslides. However, Planning Team members do not recall many instances during which power outages have lasted for extended periods of time, the majority lasting less than one day.

9.3.5 Impact on Economy

A landslide or erosion event could have catastrophic impact on both the private sector and governmental agencies. Economic losses include damage costs as well as lost revenue, lost inventory, and lost wages. Damaged bridges, roadways, marinas, boat docks, municipal airports all can have a significant impact on the economy, including statewide depending on the impacted roadways and the ability to re-route traffic.

The impact on commodity flow from a significant landslide shutting down major access routes would not only limit available resources, but also would cause economic impact on businesses in the area. Debris accumulations from clearing sites could also impact cargo staging areas and lands needed for business operations. With primary transportation routes in the hazard areas impacted, the use of primary roadways increases travel time, and in some cases, restricts ingress and egress. Due to the limited roadways leading to the structures owned by the Samish, such as the Fidalgo Bay Resort or within the Lake Campbell area, in some cases, travel time increases could significantly reduce the tourism/entertainment industry for the Tribe.

9.3.6 Impact on Environment

Environmental problems as a result of mass movements can be numerous. Landslides or erosion that fall into water bodies, wetlands or streams may significantly impact fish, salmon, and wildlife habitat, as well as affecting water quality. Hillsides that provide wildlife habitat can be lost for prolonged periods of time due to landslides or an erosion event. Impact to salmon spawning grounds have a long-term impact, and is not something which can be remedied once impact occurs. With impact already occurring due to increased sediment loads in the floodplain, landslides could cause additional impact within the area watersheds.

9.3.7 Impact from Climate Change

Climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Increase in global temperature could affect the snowpack and its ability to hold and store water. Warming temperatures also could increase the occurrence and duration of droughts, which would increase the probability of wildfire, reducing the vegetation that helps to support steep slopes. As the planning area maintains fairly dense forested areas, such incidents would be significant All of these factors would increase the probability for landslide occurrences.

9.4 FUTURE DEVELOPMENT TRENDS

Continued application of land use regulations, as well as implementation of the International Building Codes, will assist in reducing the risk of impact from landslide hazards. The Tribal Planning Area has experienced continued growth over the past 10 years, and anticipates such growth to continue. The Tribe continues to attempt to expand its business base, which will increase economic vitality by providing businesses that stimulate retail sales and services and increased tourism. The Tribe is also hopeful that with the construction of new residential structures, more Tribal Citizens will return to the area. The Tribe is committed to assessing the landslide risk and developing mitigation efforts to reduce impact or enhance resiliency. There are four basic strategies to mitigate landslide risk:

- Stabilization
- Protection
- Avoidance
- Maintenance and monitoring.

Stabilization seeks to counter one or more key failure mechanisms necessary to prevent slope failure or erosion. The other three strategies seek to avoid, protect against or limit associated impacts. Development of this mitigation plan creates an opportunity to enhance and develop wise land use decision-making policies. It allows for the Nation’s continued expansion of capital improvement plans to sustain future growth through the use of these four basic strategies.

9.5 ISSUES

Landslides and erosion occur as a result of soil conditions that have been affected by severe storms, groundwater, wave action, or human development. The worst-case scenario for landslide hazards in the planning area would generally correspond to a severe storm with a strong storm surge that had heavy rain and caused flooding and erosion. Landslides are most likely during late fall or early spring —months when the water tables are high. After heavy rains during October to April, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. A short intense storm could cause saturated soil to move, resulting in landslides. As rains continue, the groundwater table rises, adding to the weakening of the slope. Gravity, a small tremor or earthquake, poor drainage, steep bank cutting, a rising groundwater table, and poor soil exacerbate hazardous conditions.

Mass movements are becoming more of a concern as development moves outside of urban centers and into areas less developed in terms of infrastructure. While most mass movements would be isolated events affecting specific areas, the areas impacted can be very large. It is probable that private and public property, including infrastructure, will be affected. Mass movements could affect bridges that pass over landslide prone ravines. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas, and impact commodity flows. Property/structures exposed to steep slopes or the undercutting of bluffs may suffer damage. Landslides carrying vegetation such as shrubs and trees may cause a break in utility lines, cutting off power and communication access to residents; landslides and erosion may block ingress and egress to areas of the reservation, especially for areas with limited roadways.

Coastal erosion is both a chronic and episodic problem that affects coastal communities. The severity of coastal erosion changes seasonally, interannually, and over decadal time scales in response to climate variability, sediment budgets, and human activities such as dredged material management and erosion mitigation methods that can either compound or reduce the impact. Previous studies and ongoing coastal change monitoring provide a solid scientific baseline for anticipating future erosion hazards, particularly as climate change will increase sea level risk, and the severity of storm events. However, coastal conditions are changing over time, sea level and wave heights are increasing, strong El Niño events are predicted to increase, and the probability of a Cascadia subduction zone earthquake and tsunami increase with time since the previous event.

9.6 IMPACT AND RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from a landslide throughout the general area is possible, particularly when considering the potential to impact roadways, including those funded by Tribal funds and grants. The surrounding area experiences some level of landslides almost annually when viewed with severe storm events, although no declared event has occurred based on the landslide typing. The City of Anacortes has also identified the landslide hazard as one of their top-three hazards of concern.

While the Samish Indian Nation has not experienced a loss due to landslide, review of WADNR landslide data as well as the erosion data indicate a level of susceptible to the landslide hazard. Landslides can also occur on fairly low slopes, and areas with no slopes can be impacted by slides at a distance.

Based on the potential impact, the Planning Team determined the CPRI score to be 2.35, with overall vulnerability determined to be a medium level due to the likelihood of potential impacts.

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CHAPTER 10. SEVERE WEATHER

Severe weather refers to any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life. It includes thunderstorms, downbursts, wind, tornadoes, waterspouts, and snowstorms. Severe weather differs from extreme weather, which refers to unusual weather events at the extremes of the historical distribution.

General severe weather covers wide geographic areas; localized severe weather affects more limited geographic areas. The severe weather event that most typically impacts the planning area is a damaging windstorm, which causes storm surges exacerbating coastal erosion. Flooding and erosion associated with severe weather are discussed in their respective hazard chapters. Snow historically does not accumulate in great amounts in the area, although even small amounts can impact the area through traffic-related issues and safety for citizens walking in areas of snow accumulation or ice. Excessive heat and cold events, while they have occurred, are rare and Skagit County has never received a disaster declaration for either type of event.

DEFINITIONS

Freezing Rain—The result of rain occurring when the temperature is below the freezing point. The rain freezes on impact, resulting in a layer of glaze ice up to an inch thick. In a severe ice storm, an evergreen tree 60 feet high and 30 feet wide can be burdened with up to six tons of ice, creating a threat to power and telephone lines and transportation routes.

Hail Storm—Any thunderstorm which produces hail that reaches the ground is known as a hailstorm. Hail has a diameter of 0.20 inches or more. Hail is composed of transparent ice or alternating layers of transparent and translucent ice at least 0.04 inches thick. Although the diameter of hail is varied, in the United States, the average observation of damaging hail is between 1 inch and golf ball-sized 1.75 inches. Stones larger than 0.75 inches are usually large enough to cause damage.

Severe Local Storm—"Microscale" atmospheric systems, including tornadoes, thunderstorms, windstorms, ice storms and snowstorms. These storms may cause a great deal of destruction and even death, but their impact is generally confined to a small area. Typical impacts are on transportation infrastructure and utilities.

Thunderstorm—A storm featuring heavy rains, strong winds, thunder and lightning, typically about 15 miles in diameter and lasting about 30 minutes. Hail and tornadoes are also dangers associated with thunderstorms. Lightning is a serious threat to human life. Heavy rains over a small area in a short time can lead to flash flooding.

Tornado— Most tornadoes have wind speeds less than 110 miles per hour are about 250 feet across, and travel a few miles before dissipating. The most extreme tornadoes can attain wind speeds of more than 300 miles per hour, stretch more than two miles across, and stay on the ground for dozens of miles They are measured using the Enhanced Fujita Scale, ranging from EF0 to EF5.

Windstorm—A storm featuring violent winds. Southwesterly winds are associated with strong storms moving onto the coast from the Pacific Ocean. Southern winds parallel to the coastal mountains are the strongest and most destructive winds. Windstorms tend to damage ridgelines that face into the winds.

Winter Storm—A storm having significant snowfall, ice, and/or freezing rain; the quantity of precipitation varies by elevation.

10.1 GENERAL BACKGROUND

The planning area has a predominantly maritime climate, influenced by the Pacific Ocean and the Olympic Mountain Range. The County can experience all types of severe weather (except hurricanes).

10.1.1 Semi-Permanent High- and Low-Pressure Areas Over the North Pacific Ocean

During summer and fall, the circulation of air around a high-pressure area over the north Pacific brings a prevailing westerly and northwesterly flow of comparatively dry, cool, and stable air into the Pacific Northwest. As the air moves inland, it becomes warmer and drier, resulting in a dry season. In the winter and spring, the high pressure is further south and low pressure prevails in the northeast Pacific. Circulation of air around both pressure centers brings a prevailing southwesterly and westerly flow of mild, moist air into the Pacific Northwest. Condensation occurs as the air moves inland over the cooler land and rises along the windward slopes of the mountains. This results in a wet season beginning in October or November, reaching a peak in winter, and gradually decreasing by late spring.

West of the Cascade Mountains, summers are cool and relatively dry while winters are mild, wet, and generally cloudy. Measurable rainfall occurs on 150 days each year in interior valleys and on 190 days in the mountains and along the coast.

Thunderstorms occur up to 10 days each year over the lower elevations and up to 15 days over the mountains. Damaging hailstorms are rare in western Washington. During July and August, the driest months, two to four weeks can pass with only a few showers; however, in December and January, the wettest months, precipitation is frequently recorded on 25 days or more each month. Snowfall is light in the lower elevations and heavier in the mountains. During the wet season, rainfall is usually of light to moderate intensity and continuous over a long period rather than occurring in heavy downpours for brief periods; heavier intensities occur along the windward slopes of the mountains.

Severe storms hit the coastlines during the winter, bringing heavy rains, winds, and high waves. Windstorms with sustained winds of 50 miles per hour or greater occur with some regularity within the planning area and are powerful enough to cause significant damage. On occasion, winter storms have exceeded hurricane force winds. Most of these storms cause transportation-related problems and damage to utilities. On occasion, homes and other structures are damaged either by high winds or falling trees. With its geographic position between the waters of Puget Sound and the Cascade Range, the local hills and valleys can generate variable wind patterns which are locally accelerated. Likewise, portions of the planning area can also experience locally accelerated winds due to the narrowing of the river valley and the close proximity to mountain passes. The Cascade Range located to the east, forms a natural barrier to moisture-laden marine air masses resulting in regular rainfall events as these air masses rise in elevation and pass over the mountains.

10.1.2 Thunderstorms

A thunderstorm is a rain event that includes thunder and lightning. A thunderstorm is classified as “severe” when it contains one or more of the following: hail with a diameter of three-quarter inch or greater, winds gusting in excess of 50 knots (57.5 mph), or tornado. Thunderstorms have three stages (see Figure 10-1):

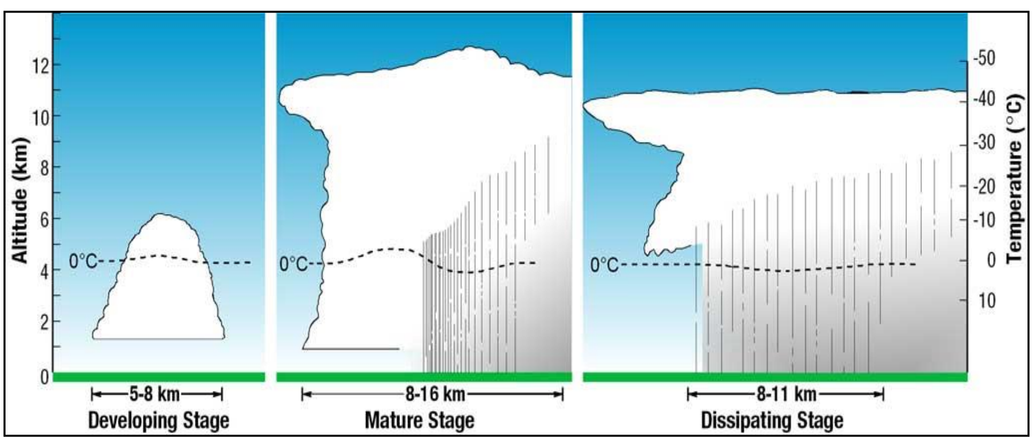


Figure 10-1 The Thunderstorm Life Cycle

Three factors cause thunderstorms: moisture, rising unstable air (air that keeps rising once disturbed), and a lifting mechanism to provide the disturbance. The sun heats the surface of the earth, which warms the air above it. If this warm surface air is forced to rise (hills or mountains can cause rising motion, as can the interaction of warm air and cold air or wet air and dry air) it will continue to rise as long as it weighs less and stays warmer than the air around it. As the air rises, it transfers heat from the earth surface to the upper atmosphere (the process of convection). The water vapor it contains begins to cool and it condenses into a cloud. The cloud eventually grows upward into areas where the temperature is below freezing. Some of the water vapor turns to ice and some of it turns into water droplets. Both have electrical charges. Ice particles usually have positive charges, and rain droplets usually have negative charges. When the charges build up enough, they are discharged in a bolt of lightning, which causes the sound heard as thunder. There are four types of thunderstorms:

- **Single-Cell Thunderstorms—**Single-cell thunderstorms usually last 20 to 30 minutes. A true single-cell storm is rare, because the gust front of one cell often triggers the growth of another. Most single-cell storms are not usually severe, but a single-cell storm can produce a brief severe weather event. When this happens, it is called a pulse severe storm.

- **Multi-Cell Cluster Storm—**A multi-cell cluster is the most common type of thunderstorm. The multi-cell cluster consists of a group of cells, moving as one unit, with each cell in a different phase of the thunderstorm life cycle. Mature cells are usually found at the center of the cluster and dissipating cells at the downwind edge. Multi-cell cluster storms can produce moderate-size hail, flash floods and weak tornadoes. Each cell in a multi-cell cluster lasts only about 20 minutes; the multi-cell cluster itself may persist for several hours. This type of storm is usually more intense than a single cell storm.

- **Multi-Cell Squall Line—**A multi-cell line storm, or squall line, is a long line of storms with a continuous well-developed gust front at the leading edge. The storms can be solid, or have gaps and breaks in the line. Squall lines can produce hail up to golf-ball size, heavy rainfall, and weak tornadoes, but they are best known as the producers of strong downdrafts. Occasionally, a strong downburst will accelerate a portion of the squall line ahead of the rest of the line. This produces what is called a bow echo. Bow echoes can develop with isolated cells as well as squall lines. Bow echoes are easily detected on radar but are difficult to observe visually.

- **Super-Cell Storm—**A super-cell is a highly organized thunderstorm that poses a high threat to life and property. It is similar to a single-cell storm in that it has one main updraft, but the updraft is extremely strong, reaching speeds of 150 to 175 miles per hour. Super-cells are rare. The main characteristic that sets them apart from other thunderstorms is the presence of rotation. The rotating updraft of a super-cell (called a mesocyclone when visible on radar) helps the super-cell to produce extreme weather events, such as giant hail (more than 2 inches in diameter), strong downbursts of 80 miles an hour or more, and strong to violent tornadoes.

As of 2019 (most recent full-year analysis available) Washington ranks 50th nationwide in deaths associated with lightning strikes, having five deaths during the time period 1959-2019.[13],[14] Annually, 30 percent of all power outages nationwide are lightning related, with total costs approaching $1 billion dollars (CoreLogic, 2015). Lightning starts approximately 4,400 house fires each year, with estimated losses exceeding $280 million.

Based on an analysis updated in 2020 by John Jensenius, Jr., of the National Lightning Safety Council victims of lightning fatalities are most often engaged in leisure activities; of those, 80 percent of victims involved were male (see Figure 10-2).

[13] Accessed 24 July 2020. Available at: https://www.weather.gov/media/safety/lightning/15-19lightning_density_state.pdf

[14] NOAA Lightning Safety. Accessed 24 July 2020. https://www.weather.gov/media/safety/Analysis06-19.pdf

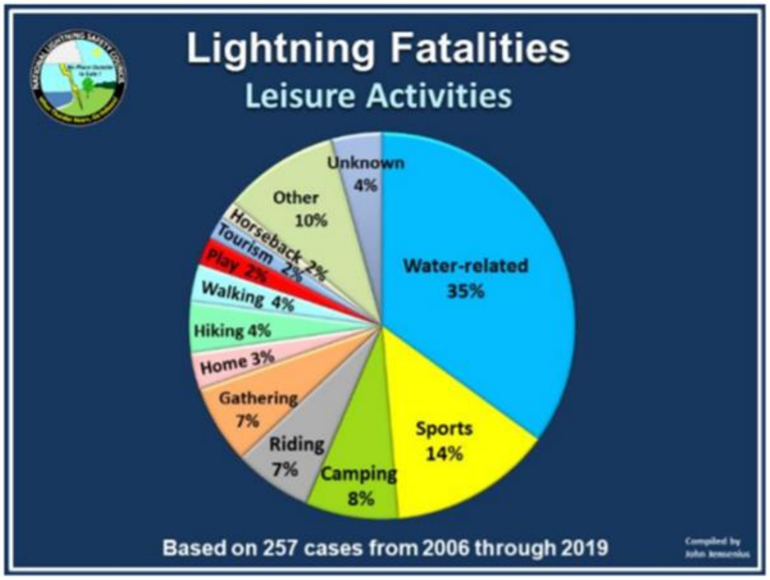


Figure 10-2 Lightning Fatalities by Leisure Activities

10.1.3 Damaging Winds

Damaging winds are classified as those exceeding 60 mph. Damage from such winds accounts for half of all severe weather reports in the lower 48 states and is more common than damage from tornadoes. Wind speeds can reach up to 100 mph and can produce a damage path extending for hundreds of miles. There are seven types of damaging winds:

- **Straight-line winds** —Any thunderstorm wind that is not associated with rotation; this term is used mainly to differentiate from tornado winds. Most thunderstorms produce some straight-line winds as a result of outflow generated by the thunderstorm downdraft.
- **Downdrafts** —A small-scale column of air that rapidly sinks toward the ground.
- **Downbursts**—A strong downdraft with horizontal dimensions larger than 2.5 miles resulting in an outward burst or damaging winds on or near the ground. Downburst winds may begin as a microburst and spread out over a wider area, sometimes producing damage similar to a strong tornado. Although usually associated with thunderstorms, downbursts can occur with showers too weak to produce thunder.
- **Microbursts**—A small concentrated downburst that produces an outward burst of damaging winds at the surface. Microbursts are generally less than 2.5 miles across and short-lived, lasting only 5 to 10 minutes, with maximum wind speeds up to 168 mph. There are two kinds of microbursts: wet and dry. A wet microburst is accompanied by heavy precipitation at the surface. Dry microbursts, common in places like the high plains and the intermountain west, occur with little or no precipitation reaching the ground.
- **Gust front**—A gust front is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow. Gust fronts are characterized by a wind shift, temperature drop, and gusty

winds out ahead of a thunderstorm. Sometimes the winds push up air above them, forming a shelf cloud or detached roll cloud.

- **Derecho—**A derecho is a widespread thunderstorm wind caused when new thunderstorms form along the leading edge of an outflow boundary (the boundary formed by horizontal spreading of thunderstorm-cooled air). The word "derecho" is of Spanish origin and means "straight ahead." Thunderstorms feed on the boundary and continue to reproduce. Derechos typically occur in summer when complexes of thunderstorms form over plains, producing heavy rain and severe wind. The damaging winds can last a long time and cover a large area.

- **Bow Echo—**A bow echo is a linear wind front bent outward in a bow shape. Damaging straight-line winds often occur near the center of a bow echo. Bow echoes can be 200 miles long, last for several hours, and produce extensive wind damage at the ground.

There are four main types of windstorm tracks that impact the Pacific Northwest as identified in Figure 10-3. These four tracks are distinguished by two basic windstorm patterns that have emerged in the Puget Sound Region: the South Wind Event and the East Wind Event. South wind events are generally large-scale events that affect large portions of Western Washington and possibly Western Oregon.

In contrast, easterly wind events are more limited. High pressure on the east side of the Cascade Mountain Range creates airflow over the peaks and passes, and through the funneling effect of the valleys, the wind increases dramatically in speed. As it descends into these valleys and then exits into the lowlands, the wind can pick up enough speed to damage buildings, rip down power lines, and destroy fences. Once it leaves the proximity of the Cascade foothills, the wind tends to die down rapidly.

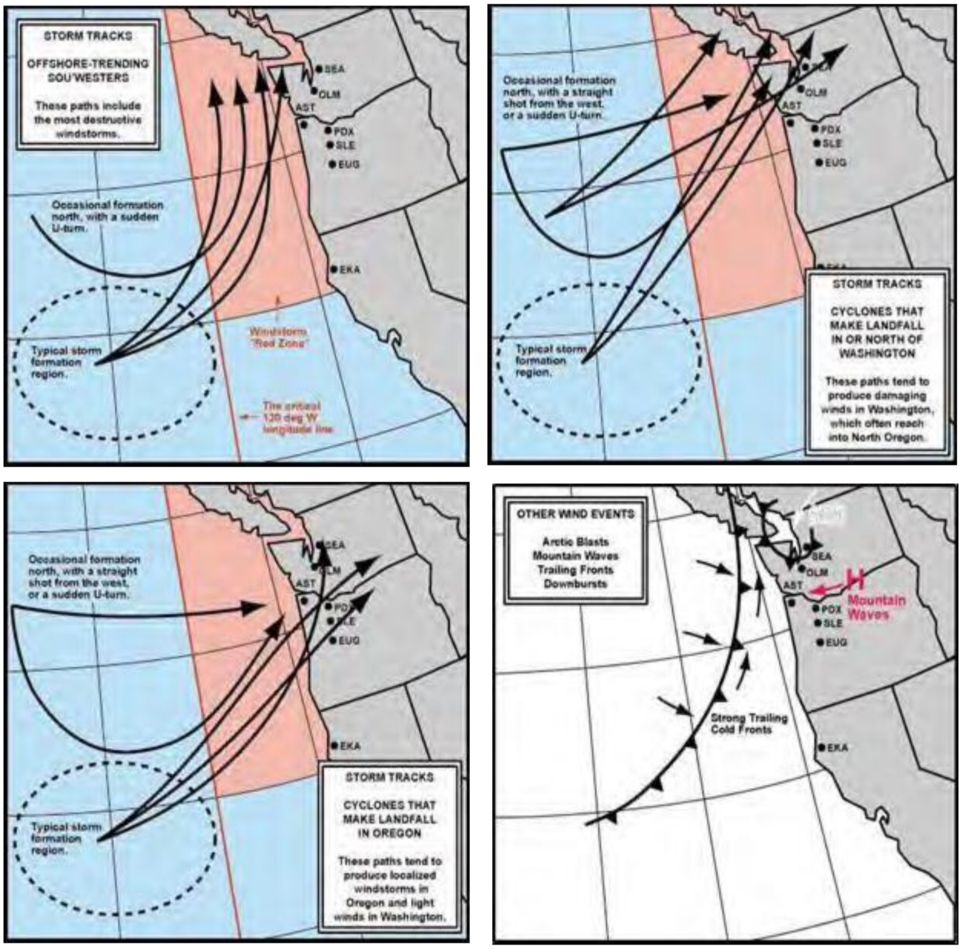
National Wind Zones are featured in Figure 10-4. These zones were utilized to guide structure development beginning with the 2006 International Building Code. These exposure zones further identify areas that are at higher risk from impacts of high winds. The closer development is to open waters and on top of steep cliffs, the higher the design criteria that is required through building code.

For each wind direction considered, an exposure category that adequately reflects the characteristics of ground surface irregularities are determined for the site at which the building or structure is to be constructed. Account shall be taken of variations in ground surface roughness that arise from natural topography and vegetation as well as from constructed features. Based on the International Building Code, the zones are further broken down into surface roughness categories and are defined as follows:

- Surface Roughness B. Urban and suburban areas, wooded areas or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

- Surface Roughness C. Open terrain with scattered obstructions having heights generally less than 30 feet (9144 mm). This category includes flat open country, grasslands, and all water surfaces in hurricane-prone regions.

- Surface Roughness D. Flat, unobstructed areas, and water surfaces outside hurricane-prone regions. This category includes smooth mud flats, salt flats and unbroken ice.



Source: Oregon Climate Service, 2015

Figure 10-3 Windstorm Tracks Impacting the Pacific Northwest

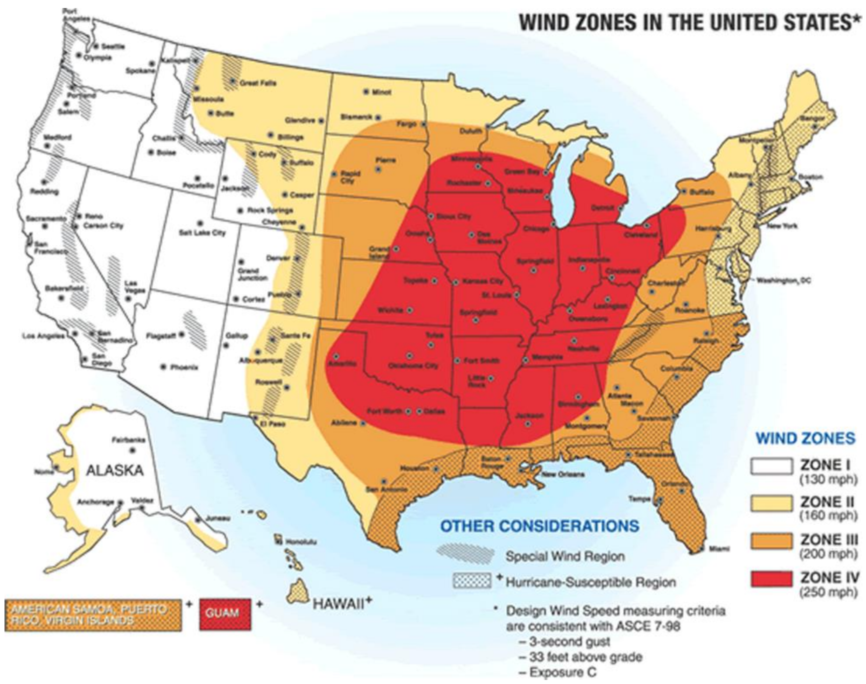


Figure 10-4 United States Wind Zones

The strongest winds are generally from the south or southwest and occur during fall and winter. In interior valleys, wind velocities reach 40 to 50 mph each winter, and 75 to 90 mph a few times every 50 years. The highest summer and lowest winter temperatures generally occur during periods of easterly winds.

10.1.4 Hail Storms

Hail occurs when updrafts in thunderstorms carry raindrops upward into extremely cold areas of the atmosphere where they freeze into ice. Recent studies suggest that super-cooled water may accumulate on frozen particles near the back side of a storm as they are pushed forward across and above the updraft by the prevailing winds near the top of the storm. Eventually, the hailstones encounter downdraft air and fall to the ground.

Hailstones grow two ways: by wet growth or dry growth. In wet growth, a tiny piece of ice is in an area where the air temperature is below freezing, but not super cold. When the tiny piece of ice collides with a super-cooled drop, the water does not freeze on the ice immediately. Instead, liquid water spreads across tumbling hailstones and slowly freezes. Since the process is slow, air bubbles can escape, resulting in a layer of clear ice. Dry growth hailstones grow when the air temperature is well below freezing and the water droplet freezes immediately as it collides with the ice particle. The air bubbles are “frozen” in place, leaving cloudy ice.

10.1.5 Ice and Snow Storms

The National Weather Service defines an ice storm as a storm that results in the accumulation of at least 0.25 inches of ice on exposed surfaces. Ice storms occur when rain falls from a warm, moist, layer of atmosphere into a below freezing, drier layer near the ground. The rain freezes on contact with the cold ground and exposed surfaces, causing damage to trees, utility wires, and structures (see Figure 10-5).

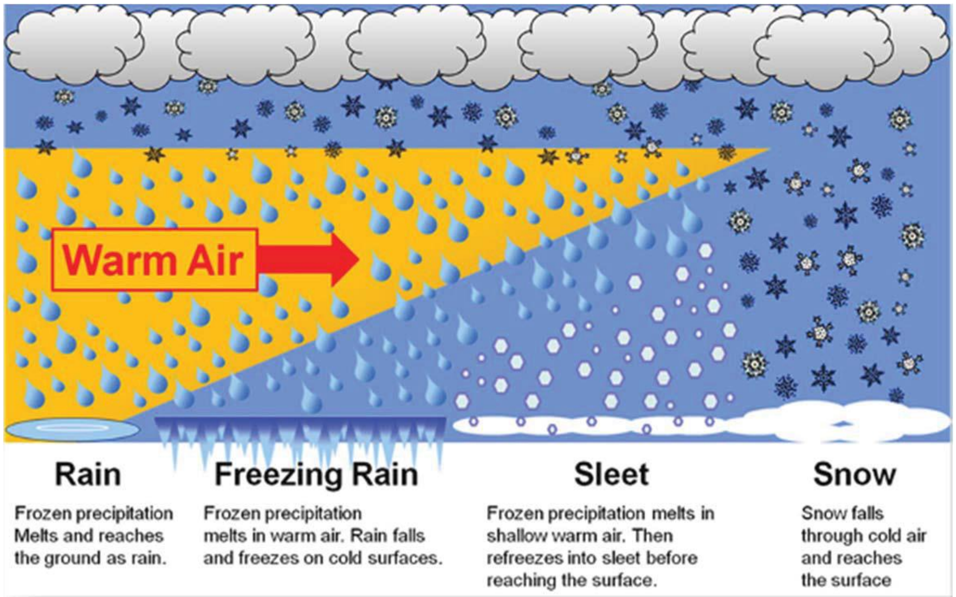


Figure 10-5 Types of Precipitation

Precipitation falls as snow when air temperature remains below freezing throughout the atmosphere. In many climates, precipitation that forms in wintertime clouds starts out as snow because the top layer of the storm is usually cold enough to create snowflakes. Snowflakes are just collections of ice crystals that cling to each other as they fall toward the ground. Precipitation continues to fall as snow when the temperature remains at or below 0 degrees Celsius from the cloud base to the ground. The following are used to define snow events:

- Snow Flurries. Light snow falling for short durations. No accumulation or light dusting is all that is expected.
- Snow Showers. Snow falling at varying intensities for brief periods of time. Some accumulation is possible.
- Snow Squalls. Brief, intense snow showers accompanied by strong, gusty winds. Accumulation may be significant. Snow squalls are best known in the Great Lakes Region.
- Blowing Snow. Wind-driven snow that reduces visibility and causes significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.
- Blizzards. Winds over 35mph with snow and blowing snow, reducing visibility to 1/4 mile or less for at least 3 hours.

Portions of the planning area do experience a significant amount of snow on a regular basis, particularly in those areas abutting the mountainous regions.

10.1.6 Extreme Temperatures

Extreme temperature includes both heat and cold events, which can have a significant impact on human health, commercial/agricultural businesses, and primary and secondary effects on infrastructure (e.g., burst pipes and power failure). What constitutes “extreme cold” or “extreme heat” can vary across different areas of the country, based on what the population is accustomed to within the region (CDC, 2014).

Extreme Cold

Extreme cold events are when temperatures drop well below normal in an area. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered “extreme cold.” Extreme cold can often accompany severe winter storms, with winds exacerbating the effects of cold temperatures by carrying away body heat more quickly, making it feel colder than is indicated by the actual temperature (known as wind chill). Figure 10-6 demonstrates the value of wind chill based on the ambient temperature and wind speed.

Exposure to cold temperatures, whether indoors or outside, can lead to serious or life-threatening health problems such as hypothermia, cold stress, frostbite or freezing of the exposed extremities such as fingers, toes, nose, and ear lobes. Hypothermia occurs when the core body temperature is <95ºF. If persons exposed to excessive cold are unable to generate enough heat (e.g., through shivering) to maintain a normal core body temperature of 98.6ºF, their organs (e.g., brain, heart, or kidneys) can malfunction. Extreme cold also can cause emergencies in susceptible populations, such as those without shelter, those who are stranded, or those who live in a home that is poorly insulated or without heat. Infants and the elderly are particularly at risk, but anyone can be affected.

Extremely cold temperatures often accompany a winter storm, so individuals may have to cope with power failures and icy roads. Although staying indoors as much as possible can help reduce the risk of car crashes and falls on the ice, individuals may also face indoor hazards. Many homes will be too cold—either due to a power failure or because the heating system is not adequate for the weather. The use of space heaters and fireplaces to keep warm increases the risk of household fires and carbon monoxide poisoning.

	Temperature (ºF)																	
Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (ºF)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (ºF) V= Wind Speed (mph)

Effective 11/01/01

Figure 10-6 NWS Wind Chill Index

During cold months, carbon monoxide may be high in some areas because the colder weather makes it difficult for car emission control systems to operate effectively. Carbon monoxide levels are typically higher during cold weather because the cold temperatures make combustion less complete and cause inversions that trap pollutants close to the ground (USEPA, 2009).

Extreme Heat[15]

Temperatures that hover 10 degrees or more above the average high temperature for the region and last for several days or weeks are defined as extreme heat (FEMA, 2006; CDC, 2006). An extended period of extreme heat of three or more consecutive days is typically called a heat wave and is often accompanied by high humidity (Ready America, Date Unknown; NWS, 2005). There is no universal definition of a heat wave because the term is relative to the usual weather in a particular area. The term heat wave is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century (Meehl and Tebaldi, 2004). A basic definition of a heat wave implies that it is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population (Robinson, 2000). Figure 10-7 identifies some of those consequences and associated temperatures. [16]

Certain populations are considered vulnerable or at greater risk during extreme heat events. These populations include the elderly age 65 and older, infants and young children under five years of age (see Figure 10-8), pregnant woman, the homeless or poor, the overweight, and people with mental illnesses, disabilities and chronic diseases (NYS HMP, 2008).

[15] Photo of Order of St. Benedict Nuns Accessed 30 Nov 2017. Available at: http://www.historylink.org/File/5630
[16] NCDC, 2000

Relative Humidity (%)	Temperature (°F) 80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke / Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Figure 10-7 Heat Stress Index

Wind-Chill Factor Chart (in Fahrenheit)

Air Temperature	Wind Speed in mph: Calm	5	10	15	20	25	30	35	40
40	40	36	34	32	30	29	28	28	27
30	30	25	21	19	17	16	15	14	13
20	20	13	9	6	4	3	1	0	-1
10	10	1	-4	-7	-9	-11	-12	-14	-15
0	0	-11	-16	-19	-22	-24	-26	-27	-29
-10	-10	-22	-28	-32	-35	-37	-39	-41	-43

Comfortable for out door play — Caution — Danger

Heat Index Chart (in Fahrenheit %)

Air Temperature (F)	Relative Humidity (Percent): 40	45	50	55	60	65	70	75	80	85	90	95	100
80	80	80	81	81	82	82	83	84	84	85	86	86	87
84	83	84	85	86	88	89	90	92	94	96	98	100	103
90	91	93	95	97	100	103	105	109	113	117	122	127	132
94	97	100	103	106	110	114	119	124	129	135			
100	109	114	118	124	129	130							
104	119	124	131	137									

Figure 10-8 Heat and Wind Chill Index for Children

10.1.7 Tornado

A tornado is a violently rotating column of air extending between, and in contact with, a cloud and the surface of the earth. Tornadoes are often (but not always) visible as a funnel cloud. Tornadoes are rated by their intensity and damage to vegetation and property. There are two common rating scales, the Fujita scale (F-Scale) and the Enhanced Fujita Scale (EF-Scale). The Fujita scale is a tornado scale introduced in 1971 by Tetsuya Fujita and the scale evaluates total damage. In the United States the Fujita scale was replaced with the Enhanced Fujita scale, which is now the primary scale used the United Sites and Canada. The Enhanced Fujita scale not only considers damage, but also considers wind speed. Figure 10-9 illustrates the two tornado rating scales.

On a local-scale, tornadoes are the most intense of all atmospheric circulations and wind can reach destructive speeds of more than 300 mph. A tornado's vortex is typically a few hundred meters in diameter, and damage paths can be up to 1 mile wide and 50 miles long. Figure 10-10, adapted from FEMA, illustrates the potential impacts and damage from tornadoes of different magnitudes. Tornadoes can occur throughout the year at any time of day but are most frequent in the spring during the late afternoon. As shown in Figure 10-11, Washington has a low risk compared to states in the Midwestern and Southern U.S.; however, the area does have recorded Tornadoes.

Enhanced Fujita Scale	
EF-0	65 - 85 mph winds
EF-1	86 - 110 mph
EF-2	111 - 135 mph
EF-3	136 - 165 mph
EF-4	166 - 200 mph
EF-3	>200 mph

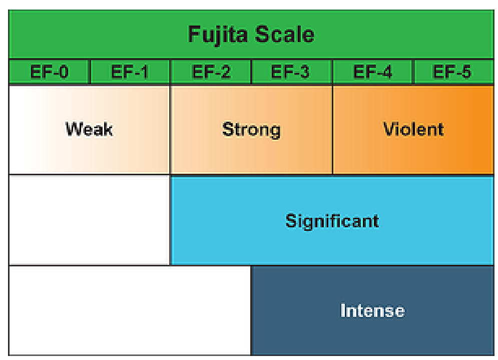


Figure 10-9 Tornado Ratings

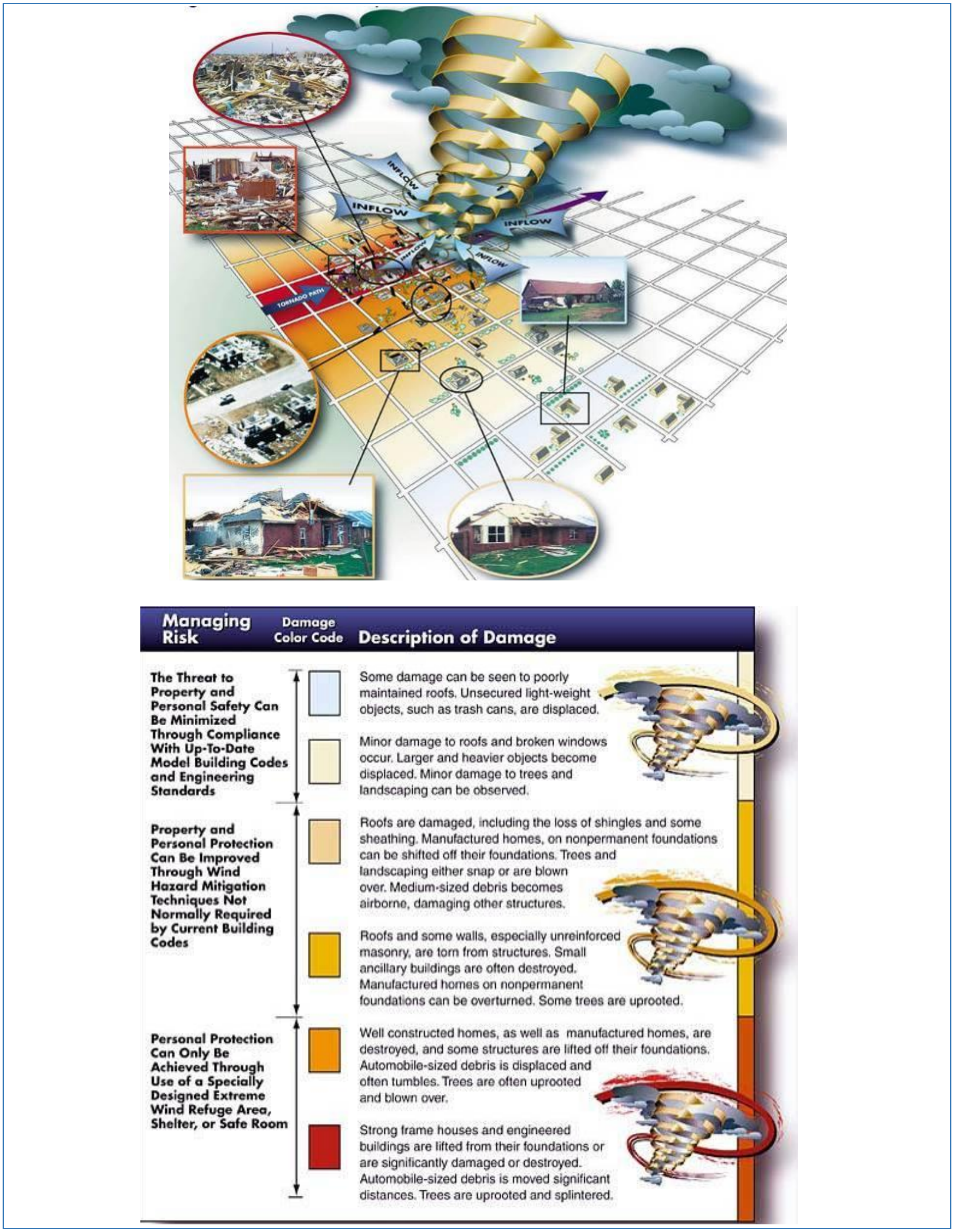


Figure 10-10 Potential Impact and Damage from a Tornado

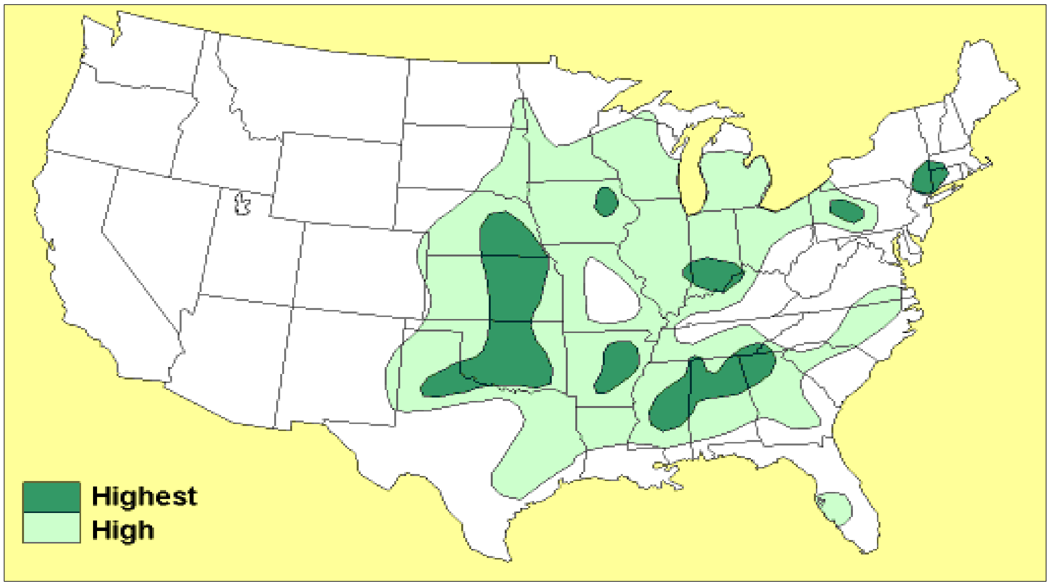


Figure 10-11 Tornado Risk Areas in the United States

Figure 10-12 identifies the number of weather fatalities based on 10-year and 30-year averages.[17] Extreme heat is the number one weather-related cause of death in the U.S. over the 30-year average, followed by flood. On average, more than 1,500 people die each year from excessive heat.

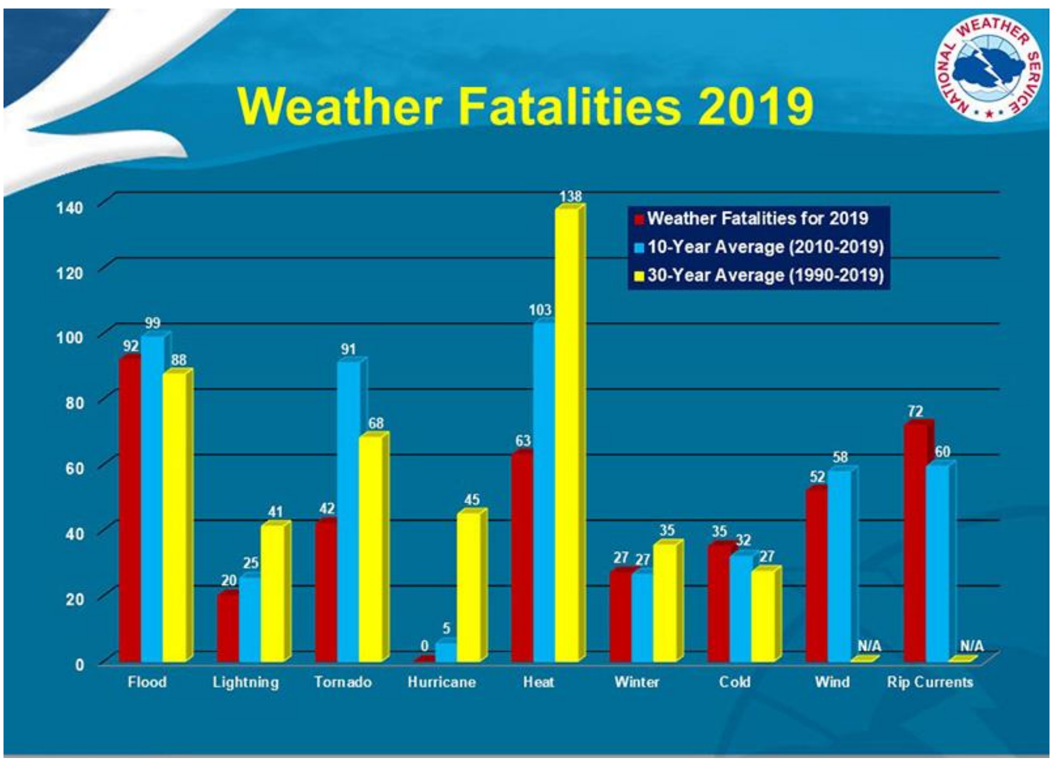


Figure 10-12 Average Number of Weather Related Fatalities in the U.S.

[17] NOAA, 2020. Accessed 24 July 2020. Available online at https://www.weather.gov/hazstat/

Depending on severity, duration, and location, extreme heat events can create or provoke secondary hazards, which include dust storms, droughts, wildfires, water shortages and power outages (FEMA, 2006; CDC, 2006). This could result in a broad and far-reaching set of impacts throughout a local area or entire region. Impacts could include significant loss of life and illness; economic costs in transportation; agriculture; production; energy and infrastructure; and losses of ecosystems, wildlife habitats, and water resources (Adams, Date Unknown; Meehl and Tebaldi, 2004; CDC, 2006; NYSDPC, 2008).

10.2 HAZARD PROFILE

10.2.1 Extent and Location

The entire planning area is susceptible to the impacts of severe weather. Severe weather events customarily occur during the months of October to March, although they have occurred year-round. When reviewing NOAA and FEMA data, the months of December, January, and November have the highest severe weather occurrences, with six, four and three events occurring, respectively, in each of those months.

The area has been impacted by strong winds, rain, snow, or other precipitation, and have experienced thunder or lightning storms, although rare. Considerable snowfall does not customarily occur throughout the entire region, but does occur more regularly and significantly in the foothills of the mountains, with higher accumulations occurring.

Communities in low-lying areas next to coastlines, rivers, streams, or lakes are more susceptible to flooding as a result of storm surge, which the Samish have experienced in March 1991 and again in November 2012. Wind events are damaging to the planning area. Winds coming off of the Pacific Ocean can have a significant impact on the planning region as a result of both the wind and associated storm surge and increased precipitation. For the planning region as a whole, wind events are one of the most common weather-related incidents to occur, often times leaving the area without power, although customarily not for long extended periods. Due to the geologic makeup of the area, winds can be accelerated in small areas.

Severe storms and weather also affect transportation. Access is sometimes unpredictable as roads are vulnerable to damage from severe storms, storm surges, flooding, and landslide/erosion. Severe storms and storm surges also cause flooding and channel migration, and can travel inland for many miles along waterways.

Average snowfall in the area is 12 inches per year, higher than the state-wide average, with precipitation falling approximately 168 days per year. Annual average temperature is 51 degrees, with the average daily high in July is ~74 degrees, with the January lows at approximately 25 degrees. On average, the area experiences only one or two days when the temperature is over 90 degrees, which is cooler than many places in Washington. Annually, the area experiences slightly over 40 days per year when nighttime low temperatures fall below freezing. Seldom does the area experience zero or negative temperatures.

November is the wettest month, and the driest month is July with 1.3 inches. The wettest season is Spring with 34 percent of yearly precipitation (~43 inches) and 11percent occurs in Autumn, which is the driest season. The annual rainfall of ~49 inches means that it is wetter than most places in Washington, which average ~39 inches. Windspeeds vary by month, with January and October/November customarily gaining highest speeds, and August lowest speeds.

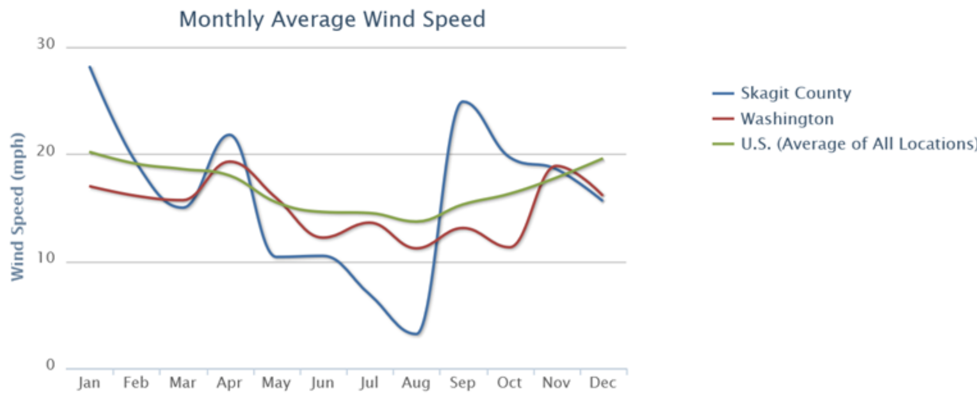


Figure 10-13 Monthly Wind Speed in Skagit County

A tornado is the smallest and potentially most dangerous of local storms. A tornado is formed by the turbulent mixing of layers of air with contrasting temperature, moisture, density, and wind flow. This mixing accounts for most of the tornadoes occurring in April, May, and June, when cold, dry air moving into the Puget Sound region from the north or northwest meets warm, moister air moving up from the south. If a major tornado struck a populated area, damage could be widespread. Businesses could be forced to close for an extended period or permanently, fatalities could be high, many people could be homeless for an extended period, and routine services such as telephone or power could be disrupted. In the case of extremely high winds, some buildings may be damaged or destroyed. Due to the (often) short warning period, livestock are commonly the victims of a tornado or windstorm.

10.2.2 Previous Occurrences

Since 1971, 15 severe weather events have been declared in Skagit County; two of those events specifically typed high winds (November and January), while two include high tides (both December). Snowstorms in the planning area have also occurred, including declared snowstorms in 1971 and 2008.

In addition to the federally declared events identified in Table 10-1, the area also sustains impact from severe wind events which do not rise to the level of a declaration, but have significant impact on the area. Wind and associated storm effects impact a much greater area than incidents associated only with floods in most instances, and also occur more regularly. The Samish Nation sustained $120,000 in damages in November 2012 as a result of a wind event causing a storm surge, which flooded the Fidalgo Bay Resort Convention Center. Such event was not declared.

Planning Team Members indicate that since 2013, there have been 10 instances where portions of the planning area have lost power, but customarily such events are short-term. The average outage duration at the Longhouse (which serves as the Childcare center and Head Start program) has lasted 106 minutes. The incidents customarily revolve around high winds knocking down trees over power lines, although heavy snow has also caused power outages. Currently, the Samish Nation has no back-up power supplies. The Tribe has identified the potential of seeking additional generators as a potential mitigation strategy.

The lack of power will become more of an issue as the Samish continue to expand and include residential structures, particularly since its intent over the next few years is to develop elder housing, and housing for individuals with disabilities. Both the elderly and citizens with disabilities historically are more vulnerable to the impacts of power outages.

Downed trees do have the potential to impact ingress and egress to certain areas. The primary roadways onto the Fidalgo Bay Resort Road and the Lake Campbell area are (in part) county-owned, with portions of the roadways in the area owned and maintained by the Samish Indian Nation. Those sections of roadway are part of the National Tribal Transportation Facility Inventory. After a significant windstorm event, the Samish assist the City and County to help clear debris from the area and make repairs as necessary.

The following provides a brief synopsis of a few of the severe weather events occurring in the area, some of which did not rise to the level of a disaster declaration, but had significant impact.

- January 1950 – Snow: Heavy accumulations of snow fell throughout western Washington.
- October 1962 – Wind: Columbus Day Windstorm (discussed in detail below) affected areas from northern California to British Columbia and is the windstorm all others since are compared to. Recorded wind gusts between 88 and 150 miles per hour were recorded in Washington State; damage in the area ranged from downed trees, broken windows to collapsed barns.
- February 1979 – Wind: A series of windstorms caused damage throughout western Washington, and in some areas caused more damage than the Columbus Day windstorm due to sustained winds of 25 to 30 miles per hour over a long period of time.
- January 1993 – Wind: Inauguration Day Windstorm caused damage throughout western Washington. Large areas of the state were without electrical power for several days.
- December 2000 – Wind: A series of windstorms with gusts between 60 and 90 miles per hour in the western portion of the county downing trees and power lines and damaging numerous agricultural buildings and barns.
- November 2006 – Wind: A sustained windstorm with high peak gusts caused significant blow-down of large trees on southeast Fidalgo Island, in the vicinity of the Swinomish Reservation, blocking roads and access within the Reservation for 2-3 days and downing power lines. The combination of loss of power and blocked roads for an extended period forced some temporary relocation of residents to emergency shelters.
- November 2006 – Wind: A sustained windstorm with high peak gusts caused significant blow-down of large trees throughout the area.

Figure 10-14 identifies both the magnitude and number of tornadoes occurring within the state since 1950.[18] Review of the data illustrates that the Tribal Planning Area has not experienced any tornadoes. Figure 10-15 identifies the vulnerability to tornadoes statewide, as developed by the Storm Prediction Center.

[18]https://www.seattletimes.com/seattle-news/weather/tornado-touches-down-on-kitsap-peninsula-rips-roof-off-home-weather-service-says/ *NOAA National Weather Service as cited in the Seattle Times*

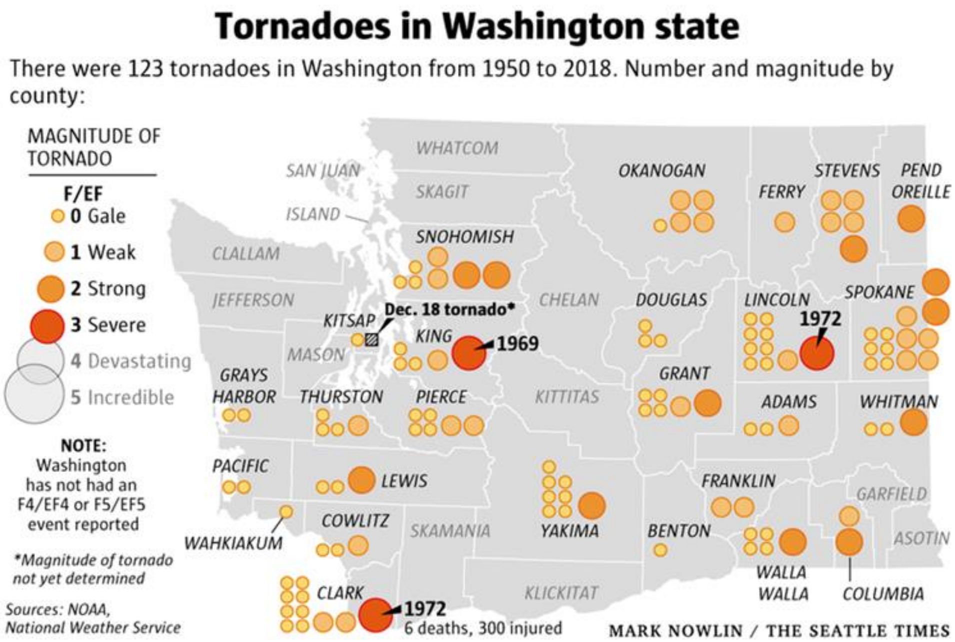


Figure 10-14 Tornado History in Washington 1950-2018

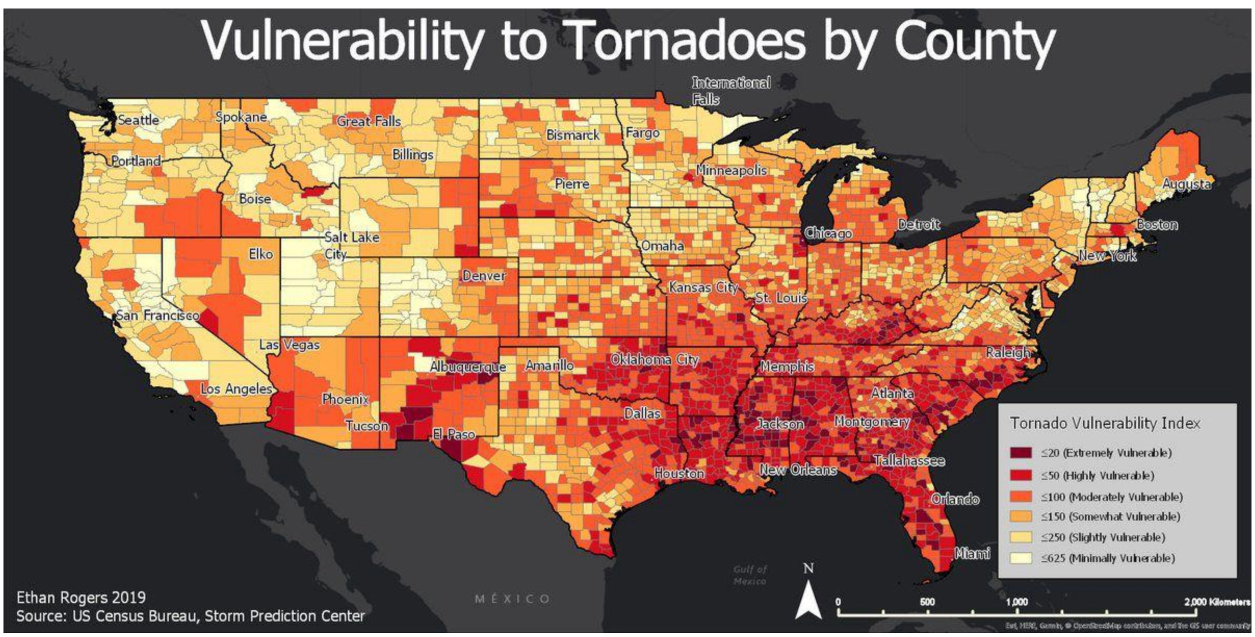


Figure 10-15 Tornado Vulnerability

Source: US Census Bureau, Storm Prediction Center[19]

[19] Accessed 27 July 2020. Available online at: https://dmn-dallas-news-prod.cdn.arcpublishing.com/resizer/xZJRjG5gAZ8DMItIc4v_4Sed52k=/1660x0/smart/filters:no_upscale()/arc-anglerfish-arc2-prod-dmn.s3.amazonaws.com/public/IAZVIDTMVMDMCIXM4YPUGIC54Q.jpg

TABLE 10-1
SEVERE WEATHER EVENTS IMPACTING PLANNING AREA SINCE 1960

Date	Type	Deaths or Injuries	Property Damage
November 1990 (Disaster 896)	Flooding (severe storm and high tides)	1 death – falling tree	$12,013,257 (Skagit)
Description: A series of arctic-air windstorms caused damage throughout western Washington including $12,013,257 in public and private damage in Skagit County. Thousands of trees were downed in the western portion of Skagit County, mostly on Samish Island, Guemes Island, and in the Anacortes/Fidalgo Island area and large areas of the county were without electrical power for several days. Several homes and vehicles were damaged due to downed trees and 1 person was killed when a tree hit the vehicle the victim was driving.			
November 1995 (Disaster 1079)	Flooding, severe storm, and high winds	Unknown	Unknown
Description: Heavy rains lead to flooding throughout the region.			
Dec. 1996—Jan. 1997 (Disaster 1159)	Severe winter storm, flooding, landslides, and mudslides.	24 deaths statewide	Skagit: $6,245,145 Statewide losses $140 million statewide
Description: Saturated ground combined with snow, freezing rain, rain, rapid warming and high winds within a five-day period produced flooding and landslides. 37 counties were impacted, with large power outages throughout the impacted counties. Heavy accumulations of snow fell throughout Skagit County over several days with depths of 2-3 feet in the western portion and depths of 4-5 feet in the eastern portions of the county. This snow event was followed several days later by high winds and rain. Many roads were impassable and road crews worked 24-hour days to plow snow. Damage to barns, agricultural buildings, and commercial greenhouses exceeded 3 million dollars and many residential carports, unattached garages, and storage buildings were destroyed. Marinas in Skagit County received over 1.7 million dollars in damage to docks and roofs and 30 private boats were damaged due to collapsed marina roof structures. The total amount of public and private damage in Skagit County was $6,245,145 as a result of these events.			
October 2003 (Disaster 1499)	Severe Storm and Flooding	Unknown	Statewide losses PA >$9 million; IA >$5.5 million
Description: Heavy rains, severe storms.			
December 2006 (Disaster 1671)	Severe winter storm, flood, landslide, mudslide, tidal surge	Unknown	Statewide PA >$29 million; IA >$5M
Description: Heavy rains from November 2 – 11, 2006 along with high tidal surge caused flooding in several Western Washington counties.			
December 2006 (DR 1682)	Severe winter storm, wind, landslides, and mudslides	One fatality in McCleary	Unknown

TABLE 10-1
SEVERE WEATHER EVENTS IMPACTING PLANNING AREA SINCE 1960

Date	Type	Deaths or Injuries	Property Damage
Description: A severe low-pressure weather event accompanied by high winds and coinciding with high tide created a 100-year tidal surge event within the Town of La Conner and the Swinomish Indian Tribal Community. This event caused damage to homes and other structures adjacent to shorelines on Fidalgo Island and caused a break in the dike along Sullivan Slough in La Conner. The severe winter storm caused landslides and mudslides throughout region. Areas of the state experienced hurricane-force winds and heavy rains with over one million people without power in the State. The "Hanukkah Eve Windstorm of 2006" downed power lines, trees, and building debris which caused many road closures and left the county in a state of emergency. A McCleary man was killed when the top of a tree snapped off in the wind and crashed into his home crushing him in his bed. A woman was injured when a gust blew a light pole down on the Chehalis River Bridge, sending it crashing onto her windshield and trapping her inside her vehicle. Injuries were reported statewide.			
December 2007 (Disaster 1734)	Severe storm, flooding, landslides, and mudslides	Unknown	Unknown
Description: Severe winter storm, including record and near record snowfall and heavy rains and winds. The great Coastal Gale of December 1-3, 2007 impacted the entire western coastline from northern California to Canada. Over a period of three days, two separate storms lashed the area with hurricane-force gusts and heavy rain. Impact from the series of windstorms in the western portion of the county caused damage to the Skagit County dock at Sinclair Island. Warming temperatures caused an avalanche in eastern Skagit County damaging a Skagit County bridge on the Cascade River Road. The region between Newport, OR and Hoquiam, WA received the strongest gale since the great Columbus Day Storm of 1962. **Error! Reference source not found.** below compares winds speeds of the 1962 Columbus Day Storm to the 2007 event.[20]			
December 2008 (Disaster 1825)	Severe winter storm, record and near record snow	Unknown	Public Assistance to all declared counties was over $5.5 million
Description: Severe winter storm, including record and near record snowfall and heavy rains and winds.			
January 2011 (Disaster 1963)	Severe Winter Storm, Flooding, Landslides and Mudslides	Unknown	PA >$870,000
Description: A weather system deposited snow and rain over much of Western Washington. Water and slides impacted roadways in the eastern portion of Skagit County as well as the Samish Flood Plain. Total damage to public assets $879,183.			
IA= FEMA Individual Assistance funds paid as a result of the disaster (loss impact paid to individuals).			
PA=FEMA Public Assistance funds paid as a result of the disaster (loss impact paid to governmental entities).			

10.2.3 Severity

The most common problems associated with severe storms are immobility and loss of utilities. Roads become impassable due to flooding, downed trees, ice or snow, or a landslide, increasing the potential for injuries or death.

Power lines may be downed due to high winds, and services such as water or phone may not be able to operate without power. Lightning can cause severe damage and injury, although no such injuries have been

[20] http://www.climate.washington.edu/stormking/

reported within the tribal planning area. Physical damage to homes and facilities caused by wind do occur, although unless it is a significant windstorm, the impact is usually limited in nature.

The strongest winds are generally from the south or southwest and occur during fall and winter, although severe windstorms are associated with summertime storms. In interior valleys, wind velocities reach 40 to 50 mph each winter, and 75 to 90 mph a few times every 50 years. The highest summer and lowest winter temperatures generally occur during periods of easterly winds.

Due to the amount of snow customarily received in the region, even a small accumulation of ice or snow can, and has, caused havoc on transportation systems due to terrain, the level of experience of drivers to maneuver in snow and ice conditions, and the lack of snow clearing equipment and resources within the region.

Ice storms, especially when accompanied by high winds, can have an especially destructive impact within the planning region, with both being able to close major transportation corridors and bridges, and also its impact on the densely wooded areas. Accumulation of ice on trees, power lines, communication towers and wiring, or other utility services can be crippling, and create additional hazards for residents, motorists, and pedestrians. The Tribe has received no disaster declarations for an ice storm event.

During the last 30 years, Western Washington has had an average annual snowfall of 11.4 inches per year, with the snowfall customarily occurring during November through March, although snow has fallen as late as April. Historical records in Western Washington are as follows:

- January 1950 – One day record for snow accumulation – 21 inches
- January 1950 – One month record for snow accumulation – 57 inches
- 1968-1969 – Winter season record for snow accumulation – 67 inches

Windstorms are common in the planning area, occurring many times throughout the year. The predicted wind speed given for wind warnings issued by the National Weather Service is for a one-minute average, during which gusts may be 25 to 30 percent higher. Windstorms are a threat within the planning area due, in part, to the densely wooded areas, and the potential for falling trees. Windstorm events have included straight-line winds, tornado, and winter storms. The County has sustained two windstorm declarations within ~14 weeks of one another during 2015.

Routine services could be disrupted, and businesses could be forced to close for an extended period, impacting availability of commodities. As a result of the heavily forested areas, debris accumulations would be high, causing additional difficulties with access along major arterials connecting the area to other parts of the area, further impacting logistical support and commodities.

The extent (severity or magnitude) of extreme cold temperatures are generally measured through the wind chill temperature index. Wind Chill Temperature is the temperature that people and animals feel when outside and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop (NWS, 2009).

On November 1, 2001, the NWS implemented a new wind chill temperature index. It was designed to more accurately calculate how cold air feels on human skin. Figure 10-6 shows the new wind chill temperature index[21]. The Index includes a frostbite indicator, showing points where temperature, wind speed and

[21] NWS, 2008

exposure time will produce frostbite to humans. The chart shows three shaded areas of frostbite danger. Each shaded area shows how long a person can be exposed before frostbite develops (NWS, 2009).

The extent of extreme temperatures is generally measured through the heat index (shown above). Created by the NWS, the Heat Index accurately measures apparent temperature of the air as it increases with the relative humidity. The Heat Index can be used to determine what effects the temperature and humidity can have on the population (NCDC, 2000).

10.2.4 Frequency

The severe weather events are often related to high winds and associated other winter storm-type events such as heavy rains and landslides, and snow. Severe storms (which include flooding) are the most declared event for the Samish Nation. The Samish experiences some form of a severe storm annually, although in most cases, such events do not rise to the level of a declared disaster. While snow events do occur, they customarily are not significant, nor last for extended periods of time.

The National Weather Service reports that Washington state averages 2.5 tornadoes per year, which ranks in the bottom ten states.[22] Washington State Department of Ecology has estimated frequency intervals for wind speed as follows:

WIND SPEEDS EXCEED	FREQUENCY
55 MPH	Annually
76 MPH	~ 5 years
83 MPH	~10 years
92 MPH	~25 years
100 MPH	~50 years
108 MPH	~100 years

10.3 VULNERABILITY ASSESSMENT

10.3.1 Overview

Severe weather incidents can and regularly do occur throughout the entire planning area. Similar events impact areas within the planning region differently, even though they are part of the same system. While in some instances some type of advanced warning is possible, as a result of climatic differences, topographic and relative distance to the coastline, the same system can be much more severe in certain areas than others. Therefore, preparedness plays a significant contributor in the resilience of the citizens to withstand such events.

Warning Time

Meteorologists can often predict the likelihood of some severe storms. In some cases, this can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm, and the rapid changes which can also occur significantly increasing the impact of a weather event.

[22] http://mynorthwest.com/1220169/common-tornadoes-washington-state/

10.3.2 Impact on Life, Health, and Safety

The entire planning area is susceptible to severe weather events. Populations living at higher elevations with large stands of trees or above-ground power lines may be more susceptible to wind damage and black out conditions, while populations in low-lying areas are at risk for possible flooding and landslides associated with the flooding as a result of heavy rains. Increased levels of precipitation in the form of snow also vary by area, with higher elevations being more susceptible to increased accumulations. Resultant secondary impacts from power outages during cold weather event, when combined with the high population elderly residents significantly impacts response capabilities and the risk factor associated with such weather incidents. Within the densely wooded areas, increased fire danger during extreme heat conditions increases the likelihood of fire, which increases fire danger.

Particularly vulnerable populations are the elderly and very young, low income, linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Currently, the Samish have approximately 70 registered Citizens between the ages of 0-5 and 65 and over. Extreme temperature variations, either heat or cold, are of significant concern for both the elderly and the young, increasing vulnerability of those populations.

The National Severe Storms Laboratory states that of injuries related to ice and snow[23]:

    - About 70% occur in automobiles.
    - About 25% are people caught out in the storm.
    - Majority are males over 40 years old.

- Of injuries related to exposure to cold:
    - 50% are people over 60 years old.
    - Over 75% are males.
    - About 20% occur in the home.

Due to the somewhat limited roadways to structures owned by the Samish via primary transportation routes, even minor incidents have the potential to impact ingress and egress. Such issues are of concern as a result of limited access for evacuation purposes by first responder if vital Advanced Life Support is required, as well as for general evacuation purposes during a period where power is out, and individuals attempt to leave the area. While there currently are no residential structures owned by the Samish, over the course of the life cycle of this plan, the Samish are constructing new residential facilities specifically for the Tribal Elders, as well as housing for both tribal and non-tribal citizens with disabilities. As such, accessibility during severe weather events will become an even greater concern.

10.3.3 Impact on Property

Loss estimations for severe weather hazards are not based on modeling utilizing damage functions, as no such functions have been generated. For planning purposes, all properties and buildings within the planning area are considered to be exposed to the severe weather hazard, but structures in poor condition or in particularly vulnerable locations (hilltops or exposed open areas, or low-lying coastal areas) may be at risk for the most damage. Potential loss estimation for the Samish Indian Nation for structure value is $15.7 million.

[23] http://www.nssl.noaa.gov/education/svrwx101/winter/

The frequency and degree of damage will depend on specific locations and severity of the weather pattern impacting the region. It is improbable to determine the exact number of structures susceptible to a weather event, and therefore emergency managers and public officials should establish a maximum threshold, or worst-case scenario, of susceptible structures.

10.3.4 Impact on Critical Facilities and Infrastructure

It should be assumed that all critical facilities are vulnerable to some degree, with the older structures built pre-code being more susceptible to impact from a severe weather event. As many of the severe weather events include multiple hazards, information such as that identifying facilities exposed to flooding or landslides (see Flood and Landslide profiles) are also likely exposed to severe weather. Additionally, facilities on higher ground may also be exposed to wind damage or damage from falling trees. The most common problems associated with severe weather are loss of utilities. Downed power lines can cause blackouts, leaving large areas isolated. While historically not a significant problem due to the rapid response by Puget Sound Energy to re-establish power, as population continues to increase into more rural areas, that may not always be the case.

Within the planning region, hydroelectric energy from dams produce a significant amount of power to areas falling well outside of the planning area. Major power lines travel from the dam through a large swath of the area in general. As such, wind events also have the potential to impact power supplies in large metropolitan areas well outside of the tribal planning area.

In addition, power, phone, water, and sewer systems may also not function properly during severe weather events. Cell towers may be damaged; landlines may be impacted via flood or landslide event. Power outages may impact both wells and municipal water and sewer systems. The primary water and sewer services to Samish structures are supplied by the City of Anacortes. There is one structure for which the Tribe provides water via a well. That well provides water for agricultural purposes (both crops and livestock) at the leased barn in Burlington. A power outage may impact the Tribe's ability to provide that water.

Roads may become impassable due to ice or snow or from secondary hazards such as landslides. Incapacity and loss of roads are the primary transportation failures, most of which are associated with secondary hazards. Landslides that block roads are caused by heavy prolonged rains. High winds can cause significant damage to trees and power lines, with obstructing debris blocking roads, incapacitating transportation, isolating population, and disrupting ingress and egress. Snowstorms at higher elevations can impact the transportation system, impacting not only commodity flow, but also the availability of public safety services into impacted areas. Of particular concern are roads providing access to isolated areas and to the elderly, or areas where there is only one primary access route.

Severe windstorms, downed trees, and ice can create serious impacts on power and above-ground communication lines. Freezing of power and communication lines can cause them to break, disrupting both electricity and communication for households. Loss of electricity and phone connection would result in isolation because some residents will be unable to call for assistance.

10.3.5 Impact on Economy

Prolonged obstruction of major routes due to severe weather can disrupt the shipment of goods and other commerce, both on and off the reservation. With a large portion of the economic base for the Samish being the Fidalgo Bay Resort, which is open year-round, severe weather events would impact the economy of the Samish Indian Nation.

Severe windstorms, downed trees, and ice can create serious impacts on power and above-ground communication lines. Freezing rain/snow on power and communication lines can cause them to break, disrupting electricity and communication, further impacting business within the region. Prolonged outages would impact consumer spending and lost revenue, (food) spoilage, lack of production/manufacturing, etc. Large, prolonged storms can have negative economic impacts for an entire region. All severe weather events have the potential to also impact tourism, including visitors to the various business ventures owned by the Samish. Accommodation services account for a large percentage of the Tribe's economy, both employee-based and as the employer/owner, with entertainment and recreation also a significant contributor.

Combined, these categories account for most of the Tribe's economy. Each of these occupation classes are highly vulnerable to impacts from severe weather events, and as such, would have a significant impact on the economy, particularly if an event lasted for several days, or the resulting impacts continued for significant periods of time.

10.3.6 Impact on Environment

The environment is highly exposed to severe weather events. Natural habitats such as streams and trees are exposed to the elements during a severe storm and risk major damage and destruction. Prolonged rains can saturate soils and lead to slope failure. Flooding events caused by severe weather or snowmelt can produce river channel migration or damage riparian habitat, also impacting spawning grounds and fish populations for many years. The Tribe does maintain an active fish hatchery, which could also be potentially impacted by various severe weather events. Storm surges can erode bluffs and redistribute sediment loads. Extreme heat can raise temperatures of rivers, impacting oxygen levels in the water, threatening aquatic life.

10.3.7 Impact from Climate Change

Climate change presents a challenge for risk management associated with severe weather. The frequency of severe weather events has increased steadily over the last century. The number of weather-related disasters during the 1990s was four times that of the 1950s, and cost 14 times as much in economic losses. Historical data shows that the probability for severe weather events increases in a warmer climate. According to the EPA, "Since 1901, the average surface temperature across the contiguous 48 states has risen at an average rate of 0.14°F per decade. Average temperatures have risen more quickly since the late 1970s (0.36 to 0.55°F per decade). Seven of the top 10 warmest years on record for the contiguous 48 states have occurred since 1998, and 2012 was the warmest year on record (U.S. EPA, 2013)." This increase in average surface temperatures can also lead to more intense heat waves that can be exacerbated in urbanized areas by what is known as urban heat island effect. Additionally, the changing hydrograph caused by climate change could have a significant impact on the intensity, duration, and frequency of storm events. All of these impacts could have significant economic consequences.

With the increase in average ambient temperatures, since the 1980s, unusually cold temperatures have become less common in the contiguous 48 states (U.S. EPA, 2013). This trend is expected to continue, and the frequency of winter cold spells will likely decrease. As ambient temperatures increase, more water evaporates from land and water sources. The timing, frequency, duration, and type of precipitation events will be affected by these changes. In general, more precipitation will fall as rain rather than snow.

10.4 FUTURE DEVELOPMENT TRENDS

All future development will be affected by severe storms. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. The Tribe does not have extensive land use regulations in place, but does adhere to strict implementation of the

International Building Codes as well as additional land use authority as established within the City of Anacortes and Skagit County, depending on where construction occurs. These codes are equipped to deal with the impacts of severe weather incidents by identifying construction standards which address wind speed, roof load capacity, elevation, and setback restrictions.

While under the Growth Management Act, public power utilities are required by law to supply safe, cost effective and equitable service to everyone in the service area requesting service, most lines in the area are above-ground, causing them to be more susceptible to high winds or other severe weather hazards. However, growth management is also a constraint, which could possibly lead to increased outages or even potential shortages, as while most new development expects access to electricity, they do not want to be near substations. The political difficulty in sighting these substations makes it difficult for the utility to keep up with regional growth. The Tribe does not generate its own power.

Land use policies currently in place, when coupled with informative risk data such as that established within this mitigation plan will also address the severe weather hazard. In addition to the local land use authority, the Samish Indian Nation must also address Federal land use requirements for any projects funded with federal dollars. That, when coupled with the land use tools currently in place, the Tribe will be well-equipped to deal with future growth and the associated impacts of severe weather.

10.5 ISSUES

Important issues associated with a severe weather in the planning area include the following:

- Older building stock in the planning area are built to low code standards or none at all. These structures could be highly vulnerable to severe weather events such as windstorms. While many structures owned by the Samish are newer (post-1975), and built to higher code standards, tribal citizens living throughout the planning area could be impacted as a result of the lower building code standards in their residential structures.
- Redundancy of power supply must be evaluated and increased planning-region wide in order to understand the vulnerabilities more fully in this area.
- The capacity for backup power generation is limited and should be enhanced, especially in areas of potential isolation due to impact on major thoroughfares or evacuation routes, or structures which ensure continuity of government.
- Isolated population centers could exist if roadways are impacted.
- Climate change may increase the frequency and magnitude of winter flooding or storm surges, thus exacerbating severe winter events.
- Proximity to the coastline enhances flooding potential through storm surges, erosion, and severe storms in general.

10.6 IMPACT AND RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for impact from a severe weather event throughout the area is highly likely, but the impact is more limited when removing resulting flood and landslide events from the severe weather category (those hazards are analyzed separately).

The entire area experiences some severe storm or weather event annually, be it wind, rain, snow, fog, extreme heat, or thunderstorms. When severe weather events occur, the storms do have the ability to impact the area, posing a danger to life and property, as well as possibly causing economic losses, such as that occurred in November 2012, which damaged an economic hub for the Samish Nation. While snow and ice do occur, impact and duration are somewhat limited, reducing life safety dangers as advanced warning many times allow residents to take precautionary measures (extra food, not driving, etc.).

Wind is a very significant factor, which can cause power outages, as well as impacting transportation to transport citizens and goods. While the local PUD/utilities maintain excellent records for low incidents of long-term power outages, the possibility does exist. Historically, severe weather events that occur are of a relatively short duration, with more localized impacts, and thankfully, power outages have not been for extended periods of time, but shorter in duration.

Based on the potential impact, the Planning Team determined the CPRI score to be 3.05, with overall vulnerability determined to be a high level.

CHAPTER 11.
TSUNAMI

A tsunami is a series of high-energy waves radiating outward from a disturbance. Earthquakes may produce displacements of the sea floor that can set the overlying column of water in motion, initiating a tsunami.

Tsunamis are classified as local or distant. Distant tsunamis may travel for hours before striking a coastline, giving a community a chance to implement evacuation plans. Local tsunamis have minimal warning times, leaving few options except to run to high ground. They may be accompanied by damage resulting from the triggering earthquake due to ground shaking, surface faulting, liquefaction, or landslides. As a result of the high probability of a Cascadia Subduction Zone-type earthquake, occupants of many parts of Washington's coastlines have minimal time to reach high ground, in some areas only 20-30 minutes.

DEFINITIONS

Tsunami—A series of traveling ocean waves of extremely long wavelength usually caused by displacement of the ocean floor and typically generated by seismic or volcanic activity or by underwater landslides.

Tidal bore – A tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the river or bay's current.

Tsunami Advisory - The purpose of a Tsunami Advisory is to keep people away from rivers, beaches, and harbors for their own personal safety. Tsunami waves during a Tsunami Advisory can also appear as "sneaker waves."

Sneaker wave – A term used to describe disproportionately large coastal waves that can sometimes appear in a wave train without warning.

11.1 GENERAL BACKGROUND

11.1.1 Physical Characteristics of Tsunamis

All waves, including tsunamis, are defined by the following characteristics (see Figure 11-1; Earth Science, 2012, Tulane University[24]):

- **Wavelength** is defined as the distance between two identical points on a wave (i.e., between wave crests or wave troughs). Normal ocean waves have wavelengths of about 300 feet. Tsunamis have much longer wavelengths, up to 300 miles.
- **Wave height** is the distance between the trough of a wave and its crest or peak.
- **Wave amplitude** is the height of the wave above the still water line; usually this is equal to 1/2 the wave height. Tsunamis can have variable wave height and amplitude that depends on water depth.
- **Wave frequency or period** is the amount of time it takes for one full wavelength to pass a stationary point.
- **Wave velocity** is the speed of a wave. It is equal to the wavelength divided by the wave period. Velocities of normal ocean waves are about 55 mph while tsunamis have velocities up to 600 mph (about as fast as jet airplanes).

Tsunamis are different from the waves most of us have observed on the beach, which are caused by the wind blowing across the ocean's surface. Wind-generated waves usually have periods of 5 to 20 seconds and a wavelength of 300 to 600 feet. A tsunami can have a period in the range of 10 minutes to 2 hours and

[24] http://www.tulane.edu/~sanelson/Natural_Disasters/tsunami.htm

wavelengths greater than 300 miles. Tsunamis are shallow-water waves, which are waves with very small ratios of water depth to wavelength.

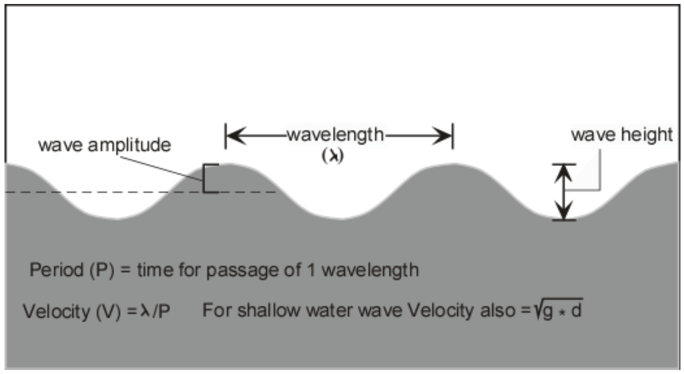


Figure 11-1 Physical Characteristics of Waves

The rate at which a wave loses its energy is inversely related to its wavelength. Since a tsunami has a very large wavelength, it loses little energy as it propagates. Thus, in very deep water, a tsunami will travel at high speeds with little loss of energy. For example, when the ocean is 20,000 feet deep, a tsunami will travel about 600 mph, and thus can travel across the Pacific Ocean in less than one day.

As a tsunami leaves the deep water of the open sea and arrives at shallow waters near the coast, it undergoes a transformation (see Figure 11-2; Earth Science, 2012). Since the velocity of the tsunami is also related to the water depth, as the depth of the water decreases, the velocity of the tsunami decreases. The change of total energy of the tsunami, however, remains constant. Furthermore, the period of the wave remains the same, so more water is forced between the wave crests, causing the height of the wave to increase.

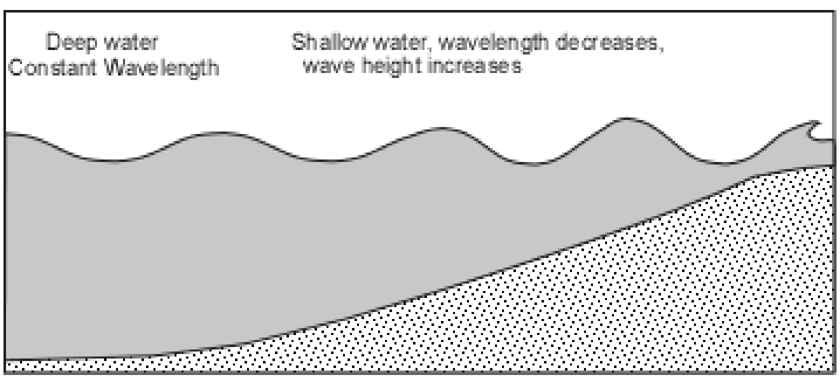


Figure 11-2 Change in Wave Behavior with Reduced Water Depth

Because of this “shoaling” effect, a tsunami that was imperceptible in deep water may grow to have wave heights of several meters. As a tsunami enters the shoaling waters near a coastline, its speed diminishes, its wavelength decreases, and its height increases greatly. The first wave usually is not the largest. Several larger and more destructive waves often follow. As tsunamis reach the shoreline, they may take the form of a fast-rising tide, a cresting wave, or a bore (a large, turbulent wall-like wave). The bore phenomenon resembles a step-like change in water level that advances rapidly (from 10 to 60 miles per hour).

The configuration of the coastline, the shape of the ocean floor, and the characteristics of advancing waves play roles in the destructiveness of tsunamis. Offshore canyons can focus tsunami wave energy and islands can filter the energy. The orientation of the coastline determines whether the waves strike head-on or are refracted from other parts of the coastline. A wave may be small at one point on a coast and much larger at other points. Bays, sounds, inlets, rivers, streams, offshore canyons, islands, and flood control channels may cause various effects that alter the level of damage. It has been estimated, for example, that a tsunami wave entering a flood control channel could reach a mile or more inland, especially if it enters at high tide.

The first indication of a tsunami to reach land may be a trough—called a drawdown—rather than a wave crest. The water along the shoreline recedes dramatically, exposing normally submerged areas. Drawdown is followed immediately by the crest of the wave, which can catch people observing the drawdown off guard. Rapid drawdown can create strong currents in harbor inlets and channels that can severely damage coastal structures due to erosive scour around piers and pilings. As the water's surface drops, piers can be damaged by boats or ships straining at or breaking their mooring lines. The vessels can overturn or sink due to strong currents, collisions with other objects, or impact with the harbor bottom.

Conversely, the first indication of a tsunami may be a rise in water level. The advancing tsunami may initially resemble a strong surge increasing the sea level like the rising tide, but the tsunami surge rises faster and does not stop at the shoreline. Even if the wave height appears to be small, 3 to 6 feet for example, the strength of the accompanying surge can be deadly. Waist-high surges can cause strong currents that float cars, small structures, and other debris. Boats and debris are often carried inland by the surge and left stranded when the water recedes.

When the crest of the wave hits, sea level rises (called run-up). Run-up is usually expressed in height above normal high tide. Run-ups from the same tsunami can vary with the shape of the coastline. One coastal area may see no damaging wave activity while in another area destructive waves can be large and violent. The flooding of an area can extend inland by 1,000 feet or more, covering large areas of land with water and debris. Tsunami waves tend to carry loose objects and people out to sea when they retreat. Tsunamis may reach a vertical height onshore of 100 feet above sea level.

At some locations, the advancing turbulent wave front will be the most destructive part of the wave. In other situations, the greatest damage will be caused by the outflow of water back to the sea between crests, sweeping all before it and undermining roads, buildings, bulkheads, and other structures. This outflow action can carry enormous amounts of highly damaging debris with it, resulting in further destruction. Ships and boats, unless moved away from shore, may be dashed against breakwaters, wharves, and other craft, or be washed ashore and left grounded after the withdrawal of the seawater.

Because the wavelengths and velocities of tsunamis are large, their period is also large. It may take several hours for successive crests to reach the shore. (For a tsunami with a wavelength of 125 miles traveling at 470 mph, the wave period is about 16 minutes). Thus people are not safe after the passage of the first large wave, but must wait several hours for all waves to pass. The first wave may not be the largest in the series of waves. For example, in several recent tsunamis, the first, third, and fifth waves were the largest.

11.2 HAZARD PROFILE

11.2.1 Extent and Location

Tsunamis affecting Washington may be induced by local geologic events or earthquakes at a considerable distance, such as in Alaska or South America. Approximately 80 percent of tsunamis originate in the Pacific Ocean and can strike distant coastal areas in a matter of hours, such as the 2011 earthquake and ensuing tsunami occurring in Japan which impacted Washington's coastlines, including within the planning area.

Most recorded tsunamis affecting the Pacific Northwest originated in the Gulf of Alaska. The landslide-generated tsunami in Lituya Bay, Alaska in 1958 produced a 200-foot-high wave. There is also geological evidence of significant impacts from tsunamis originating along the Cascadia subduction zone, which extends from Cape Mendocino, California to the Queen Charlotte Islands in British Columbia.

There is no written historical record of a damaging tsunami occurring in or affecting Skagit County (Skagit County HMP, 2015, 2020). Geologic evidence of tsunamis has been found at Cultus Bay on Whidbey Island and at West Point in Seattle. Researchers believe these tsunami deposits are evidence of earthquake activity along the Seattle Fault or other shallow crustal faults located in the Puget Sound area.

Although there is no written record of a tsunami affecting Skagit County, scientific studies conclude that tsunami inundation resulting from a large-magnitude Cascadia Subduction Zone earthquake does pose a hazard to some areas of Skagit County, including in the Anacortes area.

Studies indicate that about a dozen very large earthquakes with magnitudes of 8 (Richter) or more have previously occurred in the Cascadia Subduction Zone off the coast of Washington. Computer models indicate that tsunami waves from such an event could be up to 30 feet in height and could affect the entire coast of Washington at varying degrees and depths. Such a tsunami would most likely impact the Pacific coastal areas of Washington, but inlets like the Strait of Juan de Fuca, could also be impacted. In addition to the direct impact of the tsunami, such an event could produce extensive seiche action of nearby waters resulting in additional damage to nearby shoreline areas not directly impacted by the tsunami (SCHMP, 2015).

If a tsunami were to strike the coast of Washington and Vancouver Island in such a way that a portion of the tsunami directly enters the Strait of Juan de Fuca, a large tsunami wave could travel easterly thereby directly striking the west shore of Whidbey Island (Island County) and would most likely also impact the west shore of Fidalgo Island portions of the City of Anacortes, and other low-lying shoreline areas within Skagit County.

2016 NOAA and Joint Institute for the Study of Ocean and Atmosphere (JISAO) Study

The State of Washington has partnered with University of Washington/Joint Institute for the Study of Atmosphere and Ocean/NOAA Center for Tsunami Research/Pacific Marine Environmental Laboratory in conducting a study to determine, using a local earthquake scenario, the level of tsunami energy and impact of tsunami waves as they propagate along the Strait of Juan de Fuca and into Puget Sound. Those studies focused on various coastal areas, including on-going efforts in Skagit, Island, and Whatcom Counties. Information from that study, referenced as *2016 Study*, will be utilized to supplement information within this hazard profile. The Tsunami Source used in the 2016 Study is based on that of Witter *et al*. (2011). The rupture scenario (referred to as L1), represents a M9.0 scenario, known as the 2,500-year event, which occurs along the Cascadia subduction zone. The study was specifically selected from 15 rupture scenarios because it generates the highest moment magnitude, due to a higher maximum and average slip values.

It is noted that the study was not re-created for these planning purposes, but rather existing data utilized. Reviewers wishing greater detail on this and other reports may access the information on Washington State Department of Natural Resources' webpage at: https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/publications-and-maps#wgs-publication-catalog.

Based on the 2016 Study, it is anticipated that within Anacortes, significant inundation occurs on the southwest side, particularly in the community of Flounder Bay. The shores of Cannery Lake and the western portion of Ship Harbor Interpretive Preserve are also inundated. Based on the 2016 simulation, the flow depth around Flounder Bay ranges from 0.30 m to as high as 5 m. A flow depth of at least 2 m and at least 3.5 m could occur at Cannery Lake and west of Ship Harbor Interpretive Preserve, respectively. The northern coast is also inundated, especially at the pier area from Georgia Avenue to Dakota Avenue and from Guemes Island Ferry Terminal eastward beyond R Avenue. The extent of inundation covers several blocks inland, with a flow depth ranging from 0.01 m to as high as 2 m. Cap Sante Marina and an area to its south are also inundated. The parking lots south of Fidalgo Marina and near Weavering Spit and the coast along the southeast end of Fidalgo Bay are also affected.

From the simulated results, the tsunami wave front first hits the southwest coast of Anacortes, specifically along the coast of Flounder Bay. In Anacortes, the community of Flounder Bay is the hardest hit, in terms of inundation extent and flow depth. The tsunami wave amplitude drops as it proceeds along the northern coast through Guemes Channel and moves into Fidalgo Bay.

The maximum current is high offshore Flounder Bay and slowly declines as it rounds the northern shore of Anacortes. It picks up speed along the Guemes Channel, dropping again as it passes Cap Sante Marina and enters Fidalgo Bay. In terms of inundation, the pier/port and marina area of Anacortes is flooded. At Flounder Bay, the flooding extends into the residential area. Mapped results are illustrated in Figure 11-3, completed by the Washington State Geological Survey (2018).

It should be noted that the data referenced in this document is for planning purposes only as much of the data will be refined and will undoubtedly change, as well as expanded as additional geographic areas are studied. Readers should use this information as intended, for planning purposes only, and not life safety measures prior to verifying the information as the study continues. There are also significant variations in the data, as well as unknown factors which may lead to different outcomes, including:

- The Digital Elevation Model used in the 2016 Study is based on Mean High Water.
- The study does not take into account the effects of tides, particularly at the time of tsunami arrival, which has the potential to greatly impact the inundation area.
- While some models show no co-seismic deformation, such does not suggest nor imply that no such deformation will actually occur. The 2016 Study is based on best available science at the time completed, and variations will occur based on the actual placement of the epicenter, and the size of the earthquake.

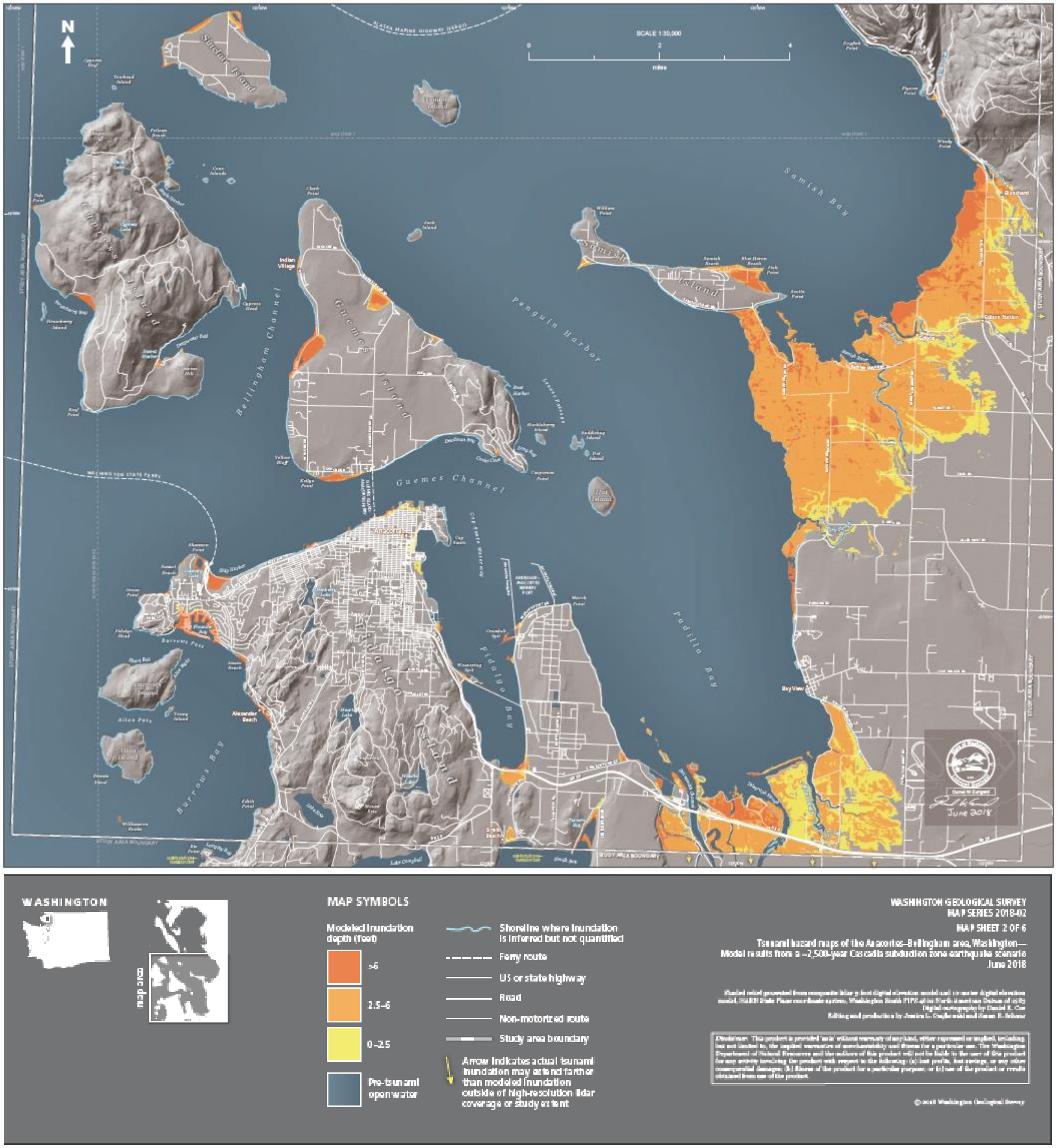


Figure 11-3 Inundation Area Based on Washington Geological Survey Map Series (2018)

Skagit County's 2015 Hazard Mitigation Plan also utilized previous data to identify areas of potential impact, which the Planning Team also determined to be relevant. That study includes the *Tsunami Hazard Map of the Anacortes-Whidbey Island Area, Washington*, which was produced in January 2005 by the Washington State Department of Natural Resources (DNR), Division of Geology and Earth Resources in cooperation with the Washington State Military Department, Emergency Management Division. That map was the result of an extensive computer modeling study conducted by the Center for the Tsunami Inundation Mapping Efforts (TIME) at the National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory in Seattle, Washington, and was considered a benchmark document. Due to its size, the map is available for viewing online at: http://www.dnr.wa.gov/Publications/ger_ofr2005-1_tsunami_hazard_anacortes_whidbey.pdf.

Review of the results from the studies referenced above indicate that a tsunami induced by a Cascadia Subduction Zone earthquake could generate waves of sufficient height to inundate shorelines and adjacent low-lying areas with water up to 2 meters in depth. Certain isolated shoreline areas could receive water greater than 2 meters in depth. Based on the 2005 study, those areas are identified in Table 11-1 and Table 11-2.

TABLE 11-1
AREAS WITH POSSIBLE INUNDATION DEPTHS OF 2 METERS OR LESS

Bay View	March Point
Cypress Island - Strawberry Bay and Secret Harbor	Padilla Bay
Dewey Beach	Samish Bay
Easterly shoreline of Guemes Island	Samish Flats north of Joe Leary Slough
Edison	Samish Island – Camp Kirby and Blue Heron Beach
Fidalgo Bay	Similk Bay
Fir Island	Snee-oosh Beach
Guemes Channel	Swinomish Channel
	Western Shoreline of Fidalgo Island

TABLE 11-2
AREAS WITH POSSIBLE INUNDATION DEPTHS OF GREATER THAN 2 METERS

Alexander Beach	Fidalgo Head and Washington Park
Allen Island	Rosario Beach
Biz Point	Skyline
Bowman's Bay	Southern shoreline of Padilla Bay
Burrows Island	West Beach, Guemes Island
Eastern shoreline of Fidalgo Bay near Anacortes Marina	

The studies also identify deficiencies with respect to the fact that several of the potential inundation areas "protected by salt-water dikes… were not resolved in the grid used for the modeling [in the study], but the height of the dikes suggest they would be overtopped by the model tsunami" (Tsunami Hazard Map of the Anacortes–Whidbey Island Area, Washington: Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake, 2005) (Skagit County HMP, 2015). As such, viewers should take such findings into consideration. Realizing this potential issue, the Samish Indian Nation has identified future studies or technical assistance as a potential mitigation strategy for future consideration. Utilizing the Tsunami Inundation Zone as updated by Washington State Department of Natural Resources in October 2019, Figure 11-4 illustrates the Tsunami's impact to the Samish critical facilities.

In total, nine structures are impacted in the Fidalgo Bay area; however, in addition, there are several hazardous materials sites (not owned by the Samish) identified in Figure 11-4 which would also be impacted, causing potential environmental concerns.

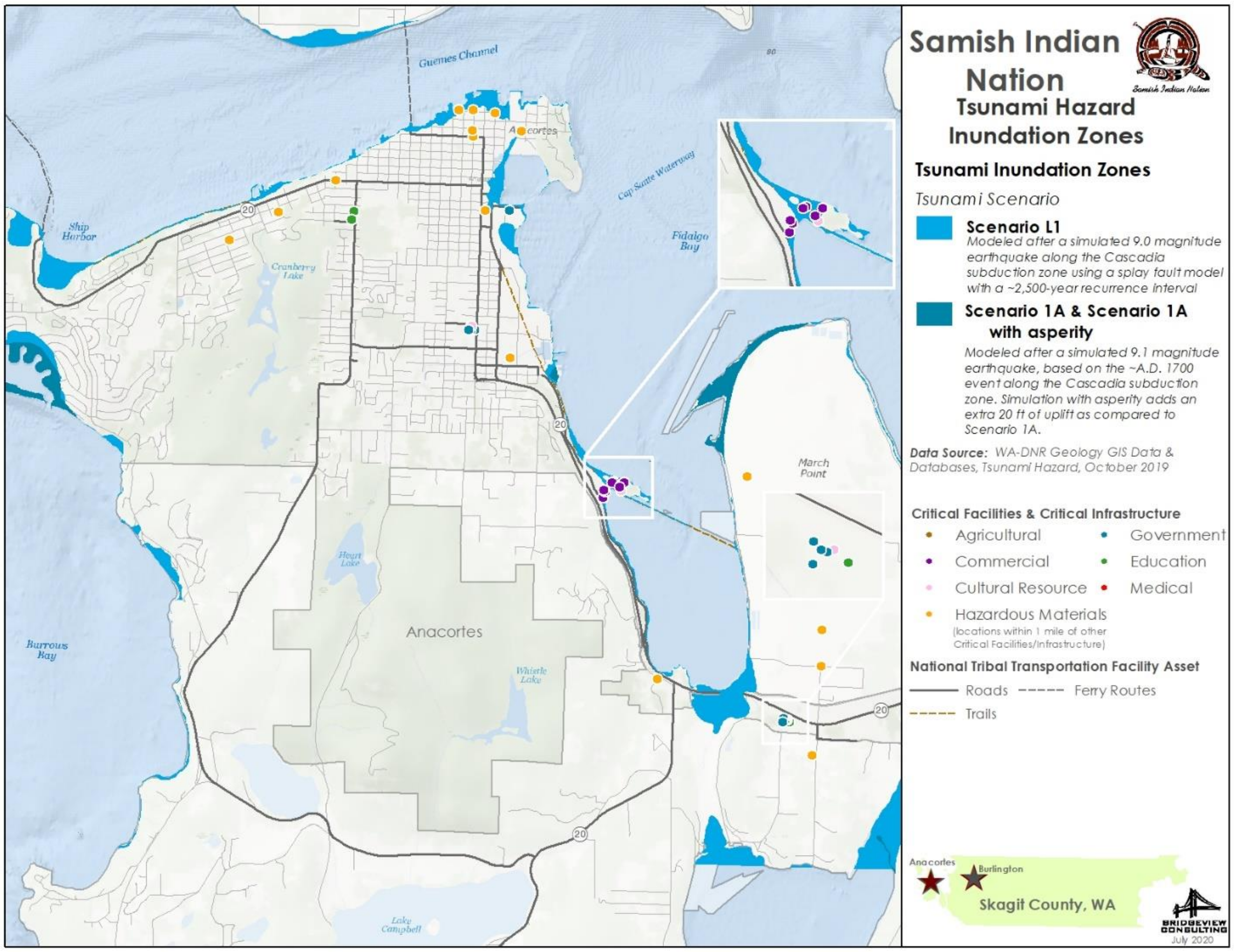


Figure 11-4 Tsunami Inundation Zones Impact to Samish Critical Facilities

11.2.2 Previous Occurrences

According to data captured from NOAA, SHELDUS and historical records, there is no record that Skagit County has ever been impacted by tsunami wave events. However, geologic evidence of tsunamis has been found at Cultus Bay on Whidbey Island and at West Point in Seattle. Researchers believe these tsunami deposits are evidence of earthquake activity along the Seattle Fault or other shallow crustal faults located in the Puget Sound area. Other historic incidents that have impacted areas of Washington State as a whole include:

- On May 22, 1960, the biggest earthquake ever recorded at the time occurred just off the coast of Chile, South America. The earthquake measured 9.5 (Richter) with swarms of aftershock earthquakes that measured as large 8.0 (Richter). The earthquakes triggered the creation of a tsunami, which was responsible for most of the ensuing devastation and death. The tsunami, together with the coastal subsidence and flooding, caused tremendous damage along the Chile coast, where about 2,000 people died. The waves spread outwards across the Pacific and fifteen (15) hours after the earthquake, tsunami waves flooded Hilo, on the island of Hawaii, where they built up to thirty (30) feet in height and caused 61 deaths along the waterfront. Seven hours later, the waves flooded the coastline of Japan where waves at least ten (10) feet in height caused 200 deaths. Tsunami waves also caused damage in the Marquesas, Samoa, and New Zealand.

- The 1964 Magnitude-9.2 earthquake in Prince William Sound, Alaska which caused a tsunami that struck Washington, Oregon, and California, killing 139 people, mostly in Alaska. There were no reported deaths in Washington, but there were reports of damaged roads, bridges, boats, and houses along the coastline in the more southwestern portions of the state.[25]
- On July 17, 1998, an earthquake measuring 7.1 (Richter) occurred about 15 miles off the coast of New Guinea in the southwestern Pacific Ocean. While the magnitude of the quake was not large enough to create the tsunami directly, it is believed the earthquake generated an undersea landslide, which in turn caused the tsunami that generated waves reaching 40 feet killing an estimated 2,200 people.
- On December 26, 2004, a massive earthquake measuring over 9.0 (Richter) occurred under the Indian Ocean floor just of the coast of the Indonesian island of Sumatra. Violent movement of the Earth's tectonic plates in this area displaced an enormous amount of water, sending powerful tsunami waves in every direction. Within hours, tsunami waves radiating from the earthquake's epicenter slammed into the coastline of 12 Indian Ocean countries with wave heights reaching up to 50 feet. As many at 250,000 persons were either killed or listed as missing and presumed dead. As many as 1,125,000 people were displaced by the earthquake and subsequent tsunami. The economic losses exceed $10 billion.
- The February 27, 2010 Chilean Magnitude-8.8 earthquake generated a small tsunami with no reported damage in Washington. NOAA reported increased wave heights above sea level as 5.5 inches in Westport, 7.5 inches in Port Angeles, 8.5 inches in La Push, and 9 inches in Neah Bay. (NOAA, 2011).
- The March 2011 tsunami that resulted from a Magnitude-9.0 earthquake in Japan caused increased wave heights along the California, Oregon, and Washington coastlines. Major declarations were issued in California and Oregon, but Washington sustained much less damage. Washington coastline wave heights above sea level were reported at La Push at 28 inches; Port Angeles at 23 inches; Westport at 18 inches; Toke Point at 13 inches; Port Townsend at 6 inches; and Neah Bay at 17 inches. No significant damage was reported, but this incident had the potential to be much worse.
- As a result of the Queen Charlotte Island M7.7 Earthquake which occurred on October 28, 2012 Toke Point and Westport experienced a tsunami, with maximum water height at Toke Point .04m and Westport .08m.[26]

11.2.3 Severity

Tsunamis are a threat to life and property to anyone living near the ocean. According to the National Centers for Environmental Information (NCEI), tsunamis took the lives of more than 290,000 million people in the

[25] USC Tsunami Research Group http://cwis.usc.edu/dept/tsunamis/alaska/1964/webpages/index.html
[26] NOAA National Centers for Environmental Information Accessed 25 July 2019. Available online at: https://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=167&d=166

past 100 years.[27] From 1950 to 2007 alone, 478 tsunamis were recorded globally. Fifty-one events caused fatalities, to a total of over 308,000 coastal residents. The overwhelming majority of these events occurred in the Pacific basin. Recent tsunamis have struck Nicaragua, Indonesia, Thailand, and Japan, killing several hundred thousand people. Property damage due to these waves was nearly $1 billion. Historically, tsunamis originating in the northern Pacific and along the west coast of South America have caused more damage on the west coast of the United States than tsunamis originating in Japan and the Southwest Pacific.

The Cascadia subduction zone will produce the state's largest tsunami. The Cascadia subduction zone is similar to the Alaska-Aleutian trench that generated the Magnitude-9.2 1964 Alaska earthquake and the Sunda trench in Indonesia that produced the Magnitude-9.3 December 2004 Sumatra earthquake. Native American accounts of past Cascadia earthquakes suggest tsunami wave heights on the order of 60 feet, comparable to water levels in Aceh Province Indonesia during the December 2004 tsunami there. The Cascadia subduction zone last ruptured on January 26, 1700, creating a tsunami that left markers in the geologic record from Humboldt County, California, to Vancouver Island in Canada and is noted in written records in Japan. Water heights in Japan produced by the 1700 Cascadia earthquake were over 15 feet, comparable to tsunami heights on the African coast after the Sumatra earthquake. At least seven ruptures of the Cascadia subduction zone have been observed in the geologic record.

A Cascadia Subduction Zone earthquake is expected to lower the ground surface along much of the coast of Washington. Maximum flooding depth, velocity, and extent will depend greatly on the tide height at the time of the tsunami arrival.

Although there is no record of a tsunami affecting Skagit County as a whole, scientific studies conclude that tsunami inundation resulting from a large-magnitude Cascadia Subduction Zone earthquake does pose a hazard to some areas of Skagit County. Such a tsunami would most likely impact the Pacific coastal areas of Washington and also inlets like the Strait of Juan de Fuca.

If a tsunami were to strike the coast of Washington and Vancouver Island in such a way that a portion of the tsunami directly enters the Strait of Juan de Fuca, a large tsunami wave could travel easterly thereby directly striking the west shore of Whidbey Island (Island County) and would also impact not only the west shore of Fidalgo Island, but additional areas of the City of Anacortes and other low-lying shoreline areas within Skagit County.

11.2.4 Frequency

Unlike many natural hazards, the number of tsunamis is low. In the last 100 years, slightly over 100 fatal tsunamis struck coastlines around the globe.[28] Generally four or five tsunamis occur every year in the Pacific Basin, and those that are most damaging are generated off South America rather than in the northern Pacific. Pacific-wide tsunamis are rare, occurring every 10 to 12 years on average. Most of these tsunamis are generated by earthquakes that cause displacement of the seafloor, but a tsunami can also be generated by volcanic eruptions, landslides, underwater explosions, and meteorite impacts (Nelson, undated). The frequency of tsunamis is related to the frequency of the event that causes them, which would include seismic, volcanic, or landslide events.

[27] https://www.ncei.noaa.gov/news/november-5-world-tsunami-awareness-day
[28] https://www.ncei.noaa.gov/news/november-5-world-tsunami-awareness-day

11.3 VULNERABILITY ASSESSMENT

11.3.1 Overview

Results from several studies conducted over the course of the last several years vary in some degree to impact; however, most reports are consistent in several factors. Due to the close proximity to the earthquake source, subsidence may occur, which will result in long-term inundation (Gica, 2014). Short-term inundation is expected to be caused by the generated tsunami waves. While the 2016 Study indicates that the long-term inundation generated by co-seismic displacement may not occur based on the L1 scenario, the epicenter and size of the earthquake source may in fact generate co-seismic displacement, thereby causing long-term inundation. There are additional factors which would also influence the potential co-seismic displacement.

Studies based on scenarios developed by PMEL and NOAA have illustrated inundation in the planning area. Extensive flooding is primarily caused by the initial tsunami waves that hit the coasts, with later waves also deemed to be damaging, with some area's amplitudes almost matching the initial waves occurring hours after the earthquake.

As a result of the offshore continental shelf margin and wave refractions and reflections along the coast, tsunami time series models indicate that it will take several hours before the generated tsunami waves begin to die out (Gica, 2014). Wave height also varies by study (Gica, 2014).

Aside from the tremendous hydraulic force of the tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and destroy inland structures. Ships moored at piers and in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes because of scouring actions that sweep away their foundation material and sometimes because of the sheer impact of the waves. Railroad yards and oil tanks situated near the waterfront are particularly vulnerable. Oil fires frequently result and are spread by the waves.

Methodology

The majority of data utilized within this process is the result of on-going projects by Washington State Department of Natural Resources' Tsunami Inundation Modeling project, and various studies, as they remain the subject matter experts in the field. Working in conjunction with FEMA, NOAA and others, WDNR developed the tsunami model for Skagit County, which is based on a Cascadia M9.0 earthquake, and was originally developed by Priest and others (1997) and designated Scenario 1A (also see Myers and others, 1999). It should be noted that in some cases, discrepancies in data results will exist due to the variations in the methods used (different Hazus models), as well as different data sources, such as topography, and the use of the various water tables (e.g., Mean High Water, wave height, source of the tsunami, etc.), as well as the actual results of a Cascadia event, including uplift (topographic changes), the existing tide stage at the time of the event, and liquefaction, among others. While this model is a useful tool for planning purposes, it should not be utilized for life-safety considerations, as such determinations are outside the scope of this hazard mitigation plan.

An exposure analysis was also conducted during this HMP update process outside of Hazus utilizing the critical facilities identified by the HMP Planning Team in conjunction with WDNR outputs. The results are on the same Cascadia M9.0 earthquake event as utilized by WDNR and FEMA.

As the Samish's building layer data is refined, increased accuracy with respect to the number of structures at risk will be modified. Readers requiring additional data on the methodology utilized in the various studies referenced should obtain such information from FEMA Region X, or from Washington State Department of Natural Resources for a full copy of the findings. Information presented is for hazard mitigation planning purposes only, and should not be considered for life-safety measures.

Warning Time

Typical signs of a tsunami hazard are earthquakes and/or sudden and unexpected rise or fall in coastal water. The large waves are often preceded by coastal flooding and followed by a quick recession of the water. Tsunamis are difficult to detect in the open ocean, with waves less than 3 feet high. The tsunami's size and speed, as well as the coastal area's form and depth, affect the impact of a tsunami. In general, scientists believe it requires an earthquake of at least a magnitude 7 to produce a tsunami. Figure 10-4 shows typical time for a tsunami to travel across the Pacific Ocean, based on the 1964 Alaska and 1960 Chile earthquakes and resulting tsunamis.

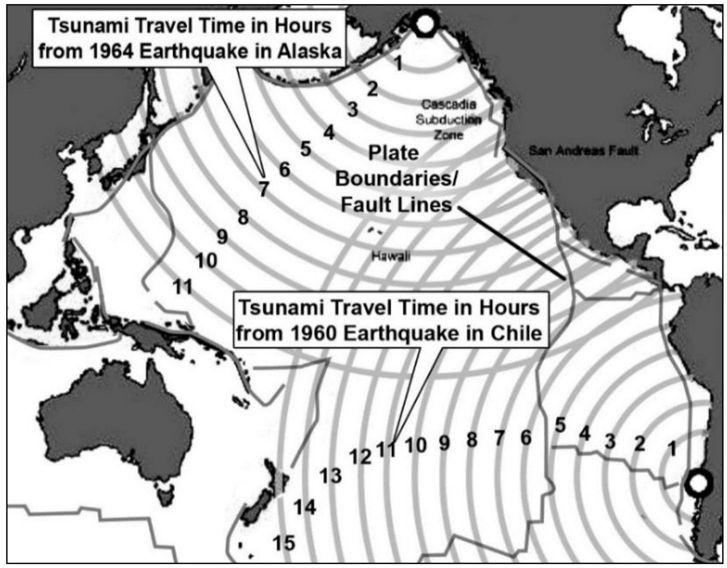


Figure 11-5 Tsunami Travel Times in the Pacific Ocean

According to Washington State's Hazard Mitigation Plan (2013) at least thirteen (13) of Washington State's Pacific Ocean coastal communities and tribal reservations lack natural high ground that is of sufficient elevation to escape a 30+ foot tsunami triggered by a Cascadia Subduction Zone earthquake.

The lack of natural high ground coupled with preceding earthquake damage, close proximity to the fault (~50-100 miles), and limited time for evacuation (15-30 minutes) preclude the use of traditional horizontal or vehicular evacuation strategies. These limiting factors make the 13 outer coastal communities in Washington extremely vulnerable to significant loss of life from such an incident. However, this situation is not unique to Washington State, as many low-lying coastal areas within U.S. states, commonwealths, and territories are also constrained by similar geographic factors.

To address this unique challenge, the concept of vertical evacuation was established. This evacuation strategy allows residents and visitors to move upwards to safety in man-made structures (buildings, towers, or berms) and is particularly important on peninsulas where traditional evacuation measures are not viable options for life safety. In 2008, FEMA collaborated with the National Oceanic and Atmospheric Association and published engineering guidance entitled "*Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*" to promote the planning and development of life safety refuges in the United States (FEMA P646). In 2011, the vertical evacuation concept was tested to its fullest extent and successfully saved thousands of lives in Japan during the March 11, 2011 tsunami. Within Washington State, Grays Harbor County was successful in constructing our nation's first vertical evacuation at the Ocosta School – Project Safe Haven. More recently, the Shoalwater Bay Tribe has also been awarded funds to build a vertical evacuation on a parking structure adjacent to their casino.

The arrival time and duration of flooding are key factors to be considered in evacuation strategies. For some locations on Washington's outer coast, the first wave crest is generally predicted to arrive between 25 and 40 minutes after the earthquake (Gica, 2014). However, significant flooding can occur before the first crest arrives because a Cascadia Subduction Zone earthquake is expected to lower the ground surface along the coastlines. This will effectively render evacuation times short not only for people on the beach, but also along coastal roadways, including major transportation corridors traversing the coastline.

Washington State Department of Natural Resources recently completed a study within several different areas of the state to determine the timelines within which waves are expected to begin reaching the shorelines, as well as the anticipated walking time required to evacuate those areas. The study is intended to last for several more months, well beyond the time associated with the update of this plan; however, some maps for the planning area have been completed.

Figure 11-6 illustrates travel times/ evacuation routes and reference points out of hazards zones in the planning area. Figure 11-7 identifies the same data in conjunction with Samish owned facilities, and reference points. Additional data (as it is developed) is available online at https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/Tsunamis#tsunami-hazard-maps and https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/Tsunamis#.6

Readers should continue to check the site to view new data as it becomes available. The next phase of the study was anticipated to be released during the springtime of 2020, but the COVID pandemic has delayed release.

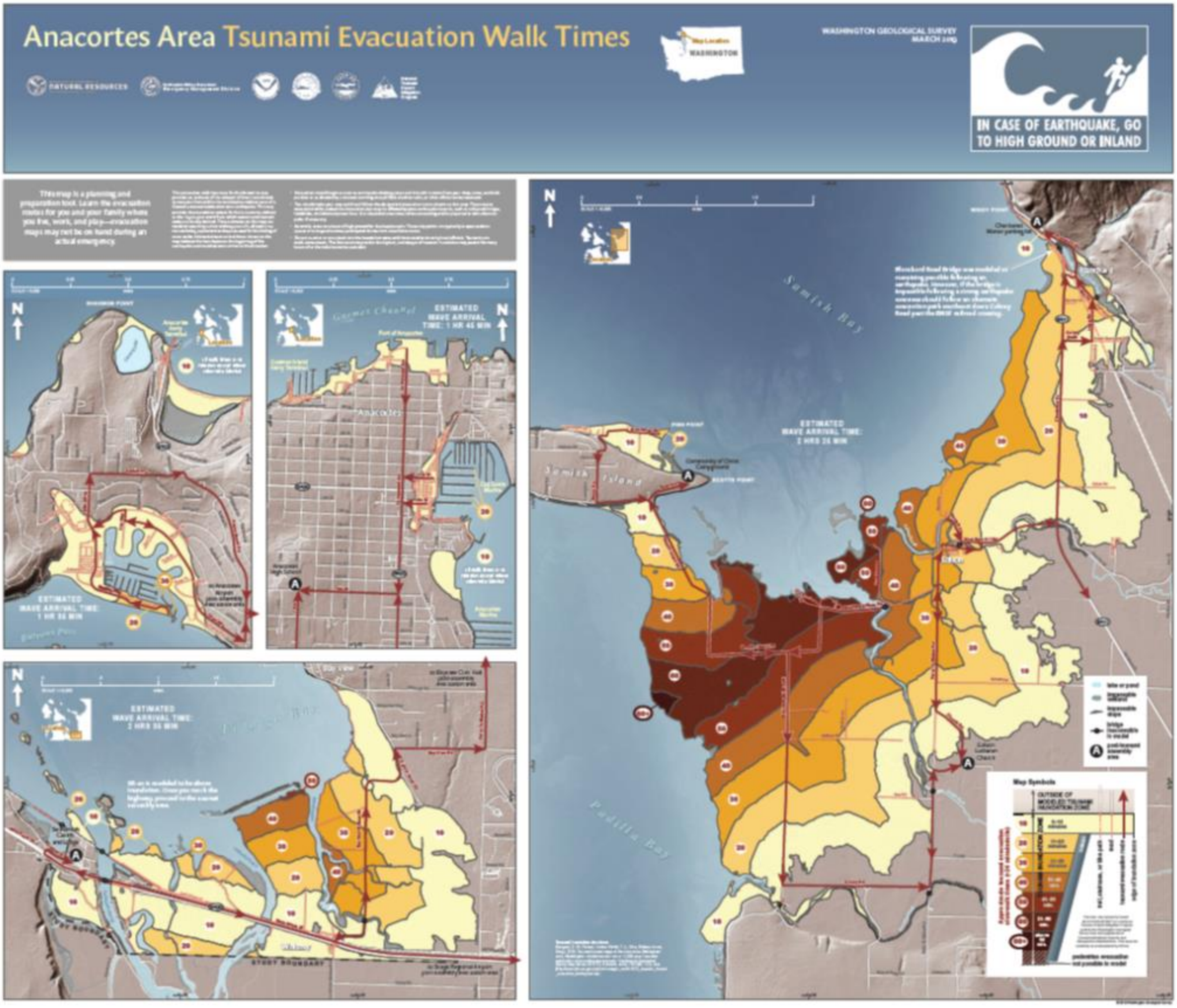


Figure 11-6 Travel Time out of Tsunami Hazard Zone in Minutes (WDNR, 2016)

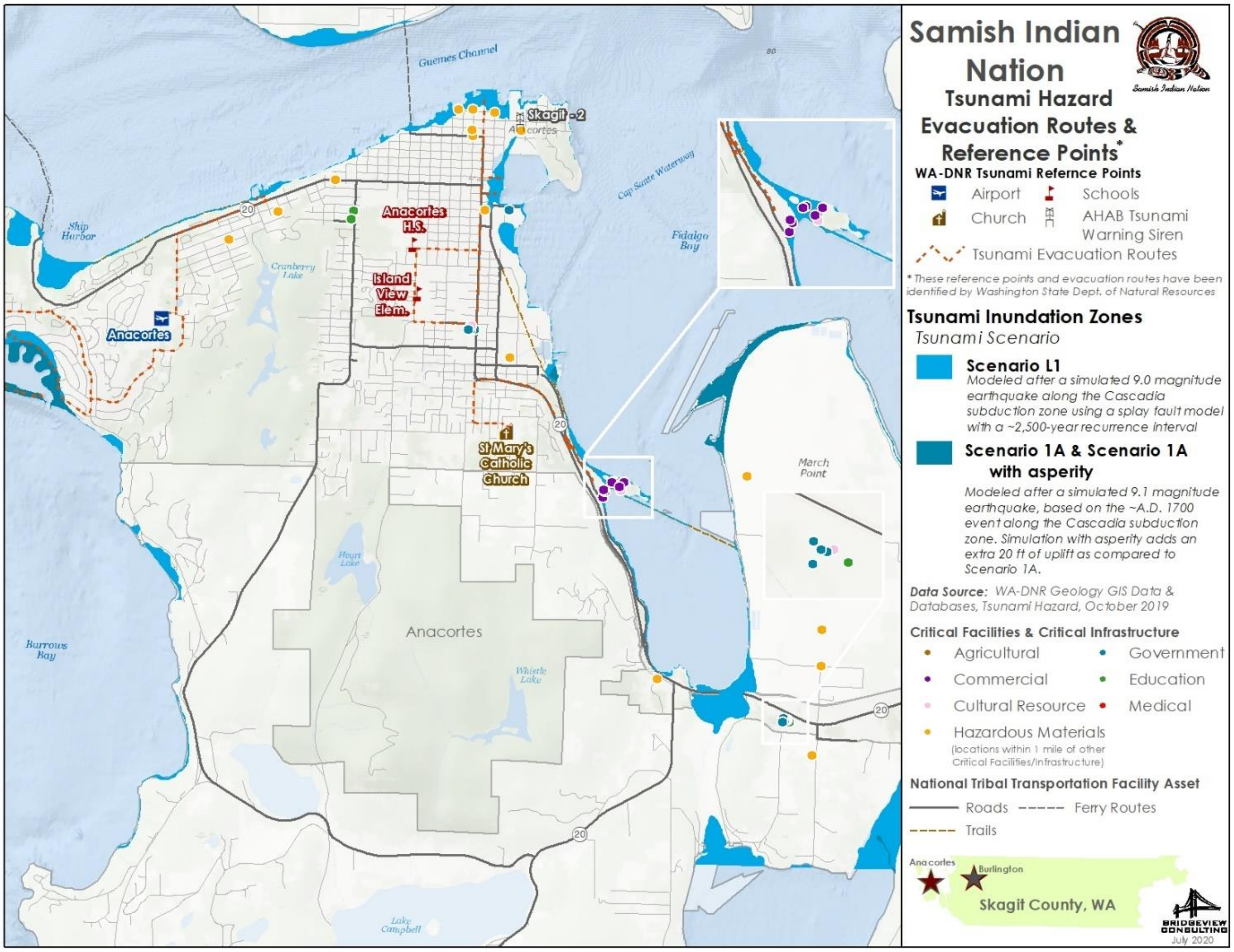
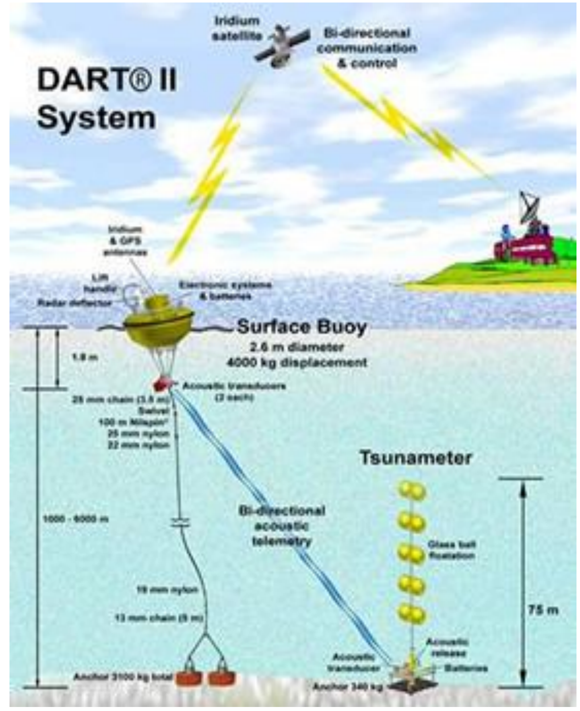


Figure 11-7 Evacuation Routes and Reference Points (WADNR, 2019)

Deep-Ocean Assessment and Reporting of Tsunamis

NOAA's Deep-ocean Assessment and Reporting of Tsunamis system (see Figure 11-8) collects data that is relayed to the Pacific Tsunami Warning Center. These units generate computer models that predict tsunami arrival, usually within minutes of the arrival time. This information is relayed in real time. This system is not considered to be as effective for communities close to the tsunami because the first wave would arrive before the data were processed and analyzed. In this case, strong ground shaking would provide the first warning of a potential tsunami.

Figure 11-8 Deep-Ocean Assessment and Reporting of Tsunamis System (DART)



Pacific Tsunami Warning System

The Pacific Tsunami Warning System evolved from a program initiated in 1946. It is a cooperative effort involving 26 countries along with numerous seismic stations, water level stations and information distribution centers. The National Weather Service operates two regional information distribution centers. One is located in Ewa Beach, Hawaii, and the other is in Palmer, Alaska. The Ewa Beach center also serves as an administrative hub for the system. When a Pacific basin earthquake of magnitude 6.5 or greater occurs, the following sequence of actions begins:

- Data is interpolated to determine epicenter and magnitude of the event.
- If the event is magnitude 7.5 or greater and located at sea, a TSUNAMI WATCH is issued.
- Participating tide stations in the earthquake area are requested to monitor their gauges. If unusual tide levels are noted, the tsunami watch is upgraded to a TSUNAMI WARNING.
- Tsunami travel times are calculated, and the warning is transmitted to the disseminating agencies and thus relayed to the public.
- The Ewa Beach center will cancel the watch or warning if reports from the stations indicate that no tsunami was generated or that the tsunami was inconsequential.

All-Hazard Alert Broadcasting Network

Currently, Skagit County is in the process of installing All-Hazard Alert Broadcast sirens in the area. It is anticipated that installation of those sirens will occur during the life cycle of this plan, as the County is in the process of working with Washington State Department of Emergency Management to for installation of those sirens. Once installed, those sirens will provide warnings of tsunamis to outdoor populations. The system will provide rapid alert to citizens and visitors who are in the hazard zone, giving advanced warning for evacuation.

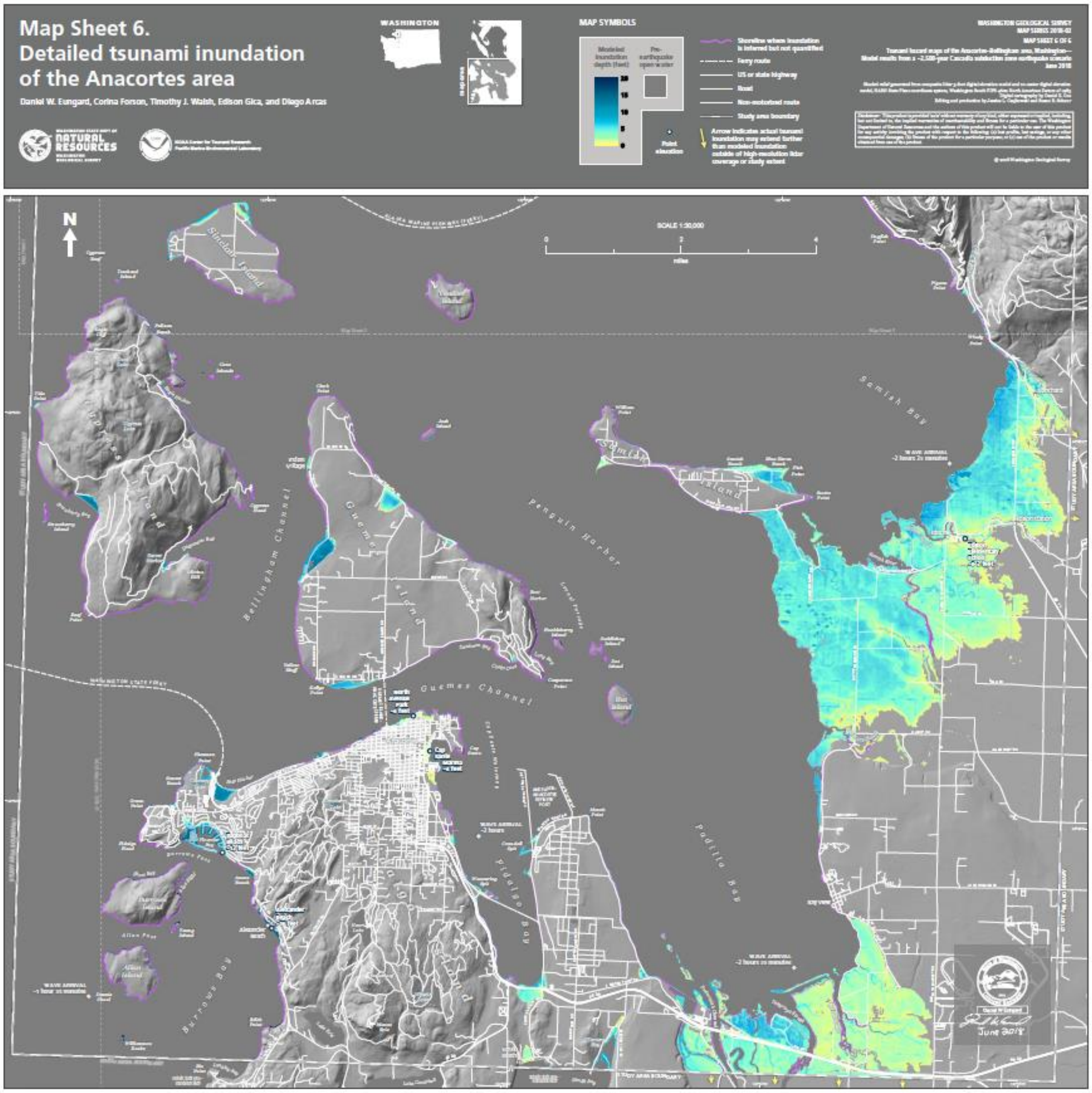


Figure 11-9 WDNR Tsunami Inundation Area (WDNR, 2016).

11.3.2 Impact on Life, Health, and Safety

Several factors are considered when determining the impact to the population from the Tsunami hazard. The arrival time and duration of flooding are key factors to be considered in evacuation strategies. For a Cascadia Subduction Zone tsunami, the first wave crest is generally predicted to arrive at the City of Anacortes approximately 90 minutes after the earthquake; however, a Seattle fault-generated tsunami would begin arriving in Skagit County within 60 minutes (FEMA 2017 Risk Report). Maximum flooding depth, velocity, and extent will depend on tide height at the time of tsunami arrival, but it is important for readers to evacuate to higher ground immediately after the ground stops shaking.

The populations most vulnerable to the tsunami hazard are the elderly, disabled and very young who reside near beaches, low-lying coastal areas, tidal flats, and river deltas that empty into ocean-going waters. In the event of a local tsunami generated in or near the planning area, there would be limited warning time, so more of the population would be vulnerable.

The degree of vulnerability of the population exposed to the tsunami hazard event is based on a number of factors:

- Is there a warning system?
- What is the lead time of the warning?
- What is the method of warning dissemination?
- Will the people evacuate when warned?

Also for consideration within the planning area is the high population of tourists, which not only traverse the area en route for other destinations, but also who stay in the Fidalgo Bay Resort, as well as other local hotel and motels in areas along the coastline. Those population numbers should also be factored into the potential population impacted.

11.3.3 Impact on Property

All structures along beaches, low-lying coastal areas, tidal flats, and river deltas would be vulnerable to a tsunami, especially in an event with little or no warning time. The impact of the waves and the scouring associated with debris that may be carried in the water could be damaging to structures in the tsunami's path. Those that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound. Within the planning area, there are ports, business, and structures which store or use chemicals. This could also render property unusable based on the type of chemical, while also increasing the level of damage. Based on FEMA's 2017 Risk Report, the M9.0 Scenario would generate a wave height of approximately seven feet (Walsh et al., 2005). Countywide, 478 buildings would be impacted. Based on existing data, nine structures at Fidalgo Bay Resort would be impacted. Figure 11-10 is an aerial imagery of the potential inundation area. A significant area of the RV park is also impacted.

Figure 11-10 Aerial Imagery of Tsunami Inundation Zones Building Impact

11.3.4 Impact on Critical Facilities and Infrastructure

Roads or railroads that are blocked or damaged can prevent access and can isolate residents and emergency service providers needing to get to vulnerable populations or to make repairs. Bridges washed out or blocked by tsunami inundation or debris from flood flows also can cause isolation. Water and sewer systems can be flooded or backed up, causing further health problems. Underground utilities can also be damaged during flood events.

A total of nine facilities owned by the Samish are impacted, as indicated above. This includes several structures and the Convention Center at Fidalgo Bay Resort. Total structure and content loss totals approximately $4.2 million. In addition, roadways for which BIA funding have been utilized are also impacted.

Within Skagit County, government-owned infrastructure owned by the Port of Anacortes and the Port of Skagit County as well as the Washington State Department of Transportation Anacortes Ferry Terminal may be vulnerable to tsunami. In addition, the numerous marina facilities as well as the downtown commercial and industrial/manufacturing areas of the City of Anacortes could be vulnerable to tsunami or severe seiche action. Certain portions of the refineries may also be inundated. Such structures provide service to Tribal Citizens in the area.

Roads

Roads are the primary resource for evacuation to higher ground before and during a tsunami event. For low depth, low velocity flood events, roads can act as levees or berms and divert or contain flood flows. Several major transportation corridors will be impacted by tsunami events, due to its proximity to the coastline. Likewise, bridges will also be impacted. These factors are of significant concern for evacuation purposes as these are the only thoroughfares out of the area and to higher ground. This is particularly true in the area of the Fidalgo Bay Resort, including portions of the Pacific Northwest Scenic Trail.

Docks

Docks exposed to tsunami events can be extremely vulnerable due to forces transmitted by the wave run-up and by the impact of debris carried by the wave action. Many docks are old and unstable, with rotting pilings. During an earthquake, there is a high probability that such structures could collapse or be severely weakened. Any ensuing tsunami would collapse the dock through the force of the water. The debris from the collapsed dock would then be pushed ashore, potentially injuring individuals and damaging structures and facilities. The Port of Skagit County, Washington State Ferry System and private businesses operate marine terminals, marinas, airports, and business parks in various areas throughout the County, all of which would sustain some impact from a Tsunami event.

Water/Sewer/Utilities

Water and sewer systems can be affected by the flooding associated with tsunami events. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can be backed up, causing wastes to spill into homes, neighborhoods, rivers, and streams. The forces of tsunami waves can impact above-ground utilities by knocking down power lines and radio/cellular communication towers. Power generation facilities can be severely impacted by both the impact of the wave action and the inundation of floodwaters. This would also impact facilities that are outside of the actual tsunami inundation area.

11.3.5 Impact on Economy

Port facilities, marinas, ferry terminals (both County and state), and public utilities are often the backbone of the economy of the affected areas, and these are the resources that generally receive the most severe damage. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and other economic hubs reconstituted, communities may find themselves without fuel, food, and employment. Wherever water transport is a vital means of supply, disruption of coastal systems caused by tsunamis can have far-reaching economic effects. With the major fuel pipelines in the area, economies outside of the planning area would also be impacted.

Many Samish businesses in the impacted areas are related to tourism, and are highly dependent on the visitors to the area annually. While the Fidalgo Bay Resort is open year-round, depending on the season, large numbers of visitors and tourists may be in the area, increasing response requirements. Those visitors and tourists will require some type of educational outreach with respect to what to do and where to go if an earthquake and tsunami occur. A tsunami would also damage economically important natural resources, such as crab, clams, salmon and other fish, restoration projects, and outdoor recreation areas.

When considering the total area, the inundation zone for the planning region is somewhat limited, but the impact to the commercial hub for the Samish nonetheless would have a significant impact on the Nation’s economy. Loss of revenue, destruction of tribal facilities, destruction of private businesses, loss of land-base, loss of marine vessels for the fishing industry, among other items, all would be significant impacts to overcome to allow the economy to sustain itself. In addition all of Washington would be impacted as a result of the loss of connectivity with Canada to Washington, as well as the impact on major highways, the Port system, ferry systems, and the travel time associated with loss of the transportation infrastructure.

11.3.6 Impact on Environment

The vulnerability of agricultural and aquatic habit and associated ecosystems would be highest in low-lying areas close to the coastline. Areas near gas stations, railcars carrying oil, industrial areas, and Tier II facilities would be vulnerable due to potential contamination from hazardous materials. Refineries in the area could be impacted by a tsunami waive if in no other way than railcars traveling along the coastal rail lines. The refineries themselves, depending on the size of the waive, may also be impacted, although review of FEMA data does not indicate the waive height to inundate the refineries directly.

Tsunami waves can carry destructive debris and pollutants that can have devastating impacts on all facets of the environment. Millions of dollars spent on habitat restoration and conservation in the planning area could be wiped out by one significant tsunami. There are currently no tools available to measure these impacts. However, it is conceivable that the potential financial impact of a tsunami event on the environment could equal or exceed the impact on property. Planners and emergency managers should take this into account when preparing for the tsunami hazard.

11.3.7 Impact from Climate Change Tsunami

The impacts of climate change on the frequency and severity of tsunami events could be significant in regions with vulnerable coastline. Global sea-level rise will affect all coastal societies, especially densely populated low-lying coastal areas. Sea level rise has two effects on low-lying coastal regions: any structures located below the new level of the sea will be flooded; and the rise in sea level may lead to coastal erosion that can further threaten coastal structures.

11.4 FUTURE DEVELOPMENT TRENDS

The Samish Indian Nation does not currently have a defined Land Use Plan, but does have improvement plans for existing developed areas and several undeveloped parcels. On lands not yet in trust, the Samish utilizes either City of Anacortes or Skagit County building codes, as appropriate.

The County does address velocity with respect to wave force in their Comprehensive Land Use Plan and Floodplain ordinance based on storm surge, although standard floodplain development regulation may not provide adequate risk protection for new development. As the tsunami inundation study is applied to official mapping with assigned probabilities of occurrence countywide, a review of existing regulatory provisions in place will require revisions to identify development in high-risk tsunami inundation areas.

Of additional concern is the potential for erosion and bluff washout as a result of Tsunami waves. The planning area does have a significant amount of bluffs and steep hillsides. While the direct impact may not be from the wave flooding a structure, the direct influence of the wave on the shoreline could cause additional landslide and erosion, causing structures to slide which otherwise would not be impacted by Tsunami waves.

The Samish Indian Nation is also continuously improving transportation routes and facilities around existing developed areas, such as the Administration and Summit Park complexes, the Health and Human

Services complex, the Longhouse, and the Fidalgo Bay RV Resort area. Information from this plan will be utilized to address areas of concern as the Samish continue such improvements.

11.5 ISSUES

The worst-case scenario for the planning area is a local tsunami event triggered by a seismic event off the coast (a Cascadia scenario). Portions of residents in the area can expect waves to reach their boundaries within approximately 1.5-2.5 hours depending on the type of earthquake triggering the tsunami. This could result in loss of life due to residents' inability to evacuate quickly enough. This can also cause severe economic and environmental impacts.

The Planning Team has identified the following issues related to the tsunami hazard for the planning area:

- As tsunami warning technologies evolve, the tsunami warning capability within the planning area will need to be enhanced to provide the highest degree of warning to citizens with tsunami risk exposure. Skagit County has already taken some proactive measures with the pending installation of the All Hazards Alert Broadcast (AHAB) system. Funding for weather radios, additional sirens, or notification systems which could be strategically located will allow for advanced warning in areas of concern.
- Additional elevated tsunami evacuation points throughout the area of inundation need to be constructed, which will require additional funding sources.
- With the possibility of climate change, the issue of sea level rise may become an important consideration as probable tsunami inundation areas are identified through future studies.

11.6 IMPACTS AND RESULTS

Based on review and analysis of the data, the Planning Team has determined that the probability for some level of impact from Tsunami throughout the area is of a medium to high nature with respect to geographic extent, but the risk to lives does increase in severity due to Fidalgo Bay Road, and the potential impact to it which would restrict ingress and egress. There have been no recorded events within Skagit County. However, due to the fact that we are well over-due for a Cascadia type earthquake event, which undoubtedly will generate a tsunami within the region (from Canada to California), the probability of occurrence is possible (medium). Economic impact as a result of the tsunami would reach well beyond that of the inundation zone and would have impact statewide. A tsunami would also be a more sudden-impact event, with evacuation times varying depending on where the earthquake occurred. Implementation of mitigation strategies for vertical evacuation sites will help protect some lives, but not all. Based on the potential impact, the Planning Team determined the CPRI score to be 2.10, with overall vulnerability determined to be a medium level.

CHAPTER 12. VOLCANO

The Cascade Range of Washington, Oregon, and California places volcanoes in close proximity. The primary effect of the Cascade volcanic eruptions would be potential lahar inundation and ash fall, with additional disruption of service due to impact on surrounding counties. Mount Baker lies to the North in Whatcom County and Glacier Peak lies in Snohomish County. Samish lands are located in the lahar zone of Glacier Peak, and in a potential debris flow from Mont Baker.

The distribution of ash from a violent eruption is a function of wind direction and speed, atmospheric stability, and the duration of the eruption. As the prevailing wind in this region is generally from the west, ash is usually spread eastward from the volcano. Exceptions to this rule do, however, occur. Ash fall, because of its potential widespread distribution, suggests some limited volcanic hazards.

DEFINITIONS

Ash—Ash is a harsh acidic with a sulfuric odor, consisting of small bits of pulverized rock and glass, less than 2 millimeters (0.1 in) in diameter. Ash may also carry a high static charge for up to two days after being ejected from a volcano. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with the rainwater to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat.

Lahar—A rapidly flowing mixture of water and rock debris that originates from a volcano. While lahars are most commonly associated with eruptions, heavy rains, and debris accumulation, earthquakes may also trigger them.

Lava Flow—The least hazardous threat posed by volcanoes. Cascades volcanoes are normally associated with slow moving andesite or dacite lava.

Stratovolcano—Typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs, rising as much as 8,000 feet above their bases. The volcanoes in the Cascade Range are all stratovolcanoes.

Tephra—Ash and fragmented rock material ejected by a volcanic explosion

Volcano—A vent in the planetary crust from which magma (molten or hot rock) and gas from the earth's core erupts.

12.1 GENERAL BACKGROUND

Hazards related to volcanic eruptions are distinguished by the different ways in which volcanic materials and other debris are emitted from the volcano (see Figure 12-1). The molten rock that erupts from a volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles. Ash and fragmented rock material can become airborne and travel far from the erupting volcano to affect distant areas.

Monitored volcanoes generally give signs of reawakening (volcanic unrest) before an eruption because it takes time for magma to move from its storage area, several miles beneath the volcano, to the surface. As magma moves to the surface, it breaks open a pathway, which produces earthquakes; it goes from higher to lower pressures, resulting in the release of volcanic gases; and as the amount of magma decreases in the storage area and temporarily pools at shallower levels it deforms the earth. All these processes can be monitored, although none can be measured directly.

Volcanic events often differ from other natural hazards because the duration of unrest and eruptive activity are generally longer. Although volcanic unrest prior to eruptions can be only hours, these short timescales most frequently occur at volcanoes that have erupted in the recent past (years to decades). At volcanoes like Mount Baker and Glacier Peak, their conduit systems which convey magma to the surface have solidified and will have to be fractured and reopened for the next magma batch to reach the surface. Thus, it is anticipated that several days to weeks of warning will occur before an eruption, although hazardous events such as small steam and ash explosions and expulsion of water to form lahars may occur before an eruption begins. While Mount St. Helens has continued to emit steam on occasion since its last eruption, scientists feel that advanced warning of a significant magnitude would provide some level of advanced notice.

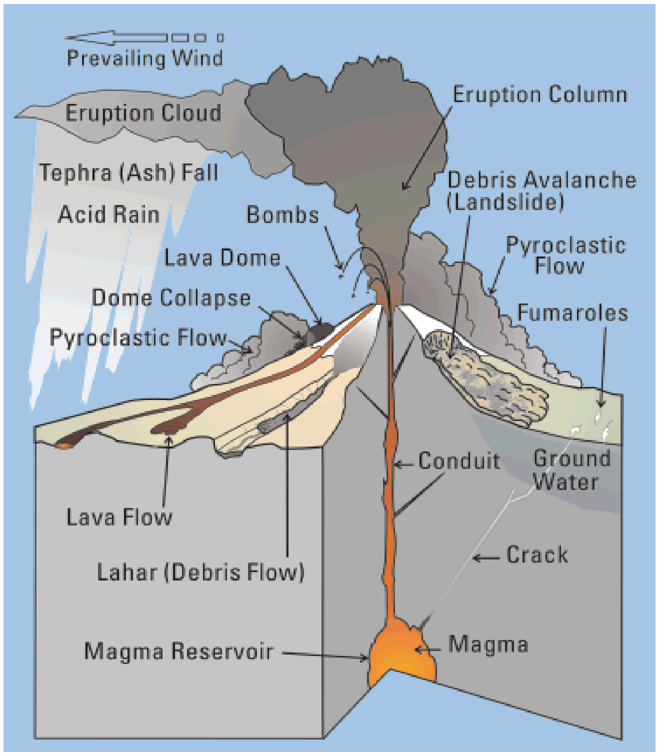


Figure 12-1 Volcano Hazard

The most recent eruption in Washington State, the eruption of Mount St. Helens in 1980, is identified as a Plinian eruption, which are the most violent of types, including violent ejection of very large columns of ash, followed by a collapse of the central portion of the volcano. It should be noted that a volcano has the potential to exhibit various styles of eruption at different intervals, changing from one form or type to another as the eruption progresses.

12.2 HAZARD PROFILE

12.2.1 Extent and Location

The Cascade Range extends more than 1,000 miles from southern British Columbia into northern California and includes 13 potentially active volcanic peaks in the U.S. Figure 12-2 shows the location of the Cascade Range volcanoes, most of which have the potential to produce a significant eruption.

Geologic evidence indicates that both Mount Baker and Glacier Peak have erupted in the past and will no doubt erupt again in the foreseeable future. Due to the topography of the region and the location of drainage basins and river systems, eruption events on either Mount Baker or Glacier Peak resulting in lahar's, pyroclastic flows, tephra or ash fall, lava flows, or debris flows could impact the tribal planning area. While not in the direct flow from Mount Baker's lahar zone, the watershed(s) in the area and the various streams and tributaries would be impacted, and there is the potential for a debris flow impacting the Thomas Creek area of Burlington, where the Samish have properties. The Glacier Peak lahar zone would also impact the planning area in the same location. Ash from either Mount Baker or Glacier Peak would also impact the area.

Mt. Baker is one of the youngest volcanoes in the Cascade Range. Glacier Peak is the most remote of the five active volcanoes in Washington, not visibly prominent from any major population center, although in previous times, it produced some of the largest and most explosive eruptions in the state.

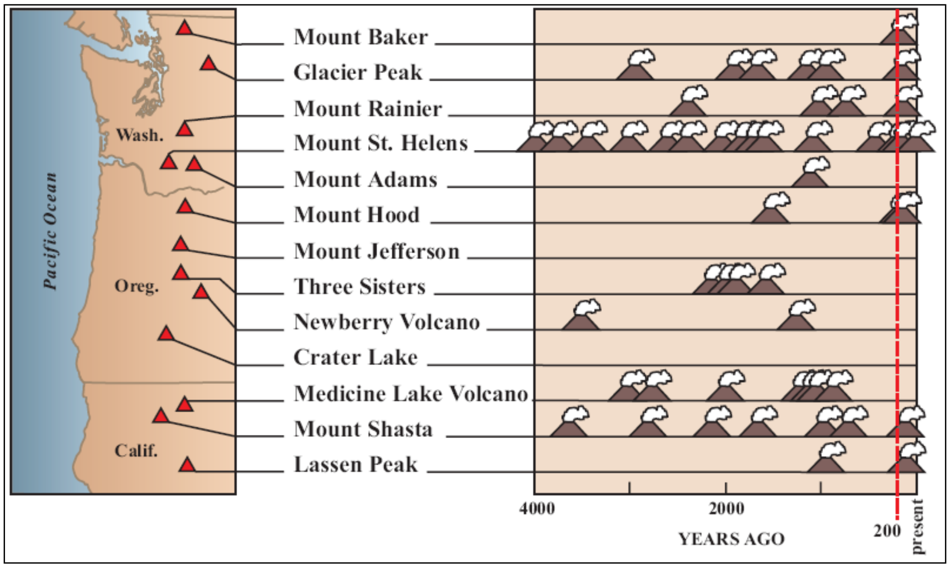


Figure 12-2 Past Eruptions of Cascade Volcanoes

Mount Baker

Figure 12-3 Mount Baker
(Source: Schurlock, 2002-2014)

Mount Baker is an ice-clad stratovolcano located in Whatcom County. USGS research in the last decade shows Mount Baker to be one of the youngest volcanoes in the Cascade Range. At 10,781 feet it is the third highest volcano in Washington State. After Mount Rainier, Mount Baker is the most heavily glaciated of the Cascade volcanoes: the volume of snow and ice on Mount Baker (about 0.43 cubic miles) is greater than that of all the other Cascades volcanoes (except Rainier) combined. Isolated ridges of lava and hydrothermally altered rock, especially in the area of Sherman Crater, are exposed between glaciers on the upper flanks of the volcano; the lower flanks are steep and heavily vegetated. The volcano rests on a foundation of non-volcanic rocks in a region that is largely non-volcanic in origin.

Historical activity at Mount Baker includes several explosions during the mid-19th century, which were witnessed from the Bellingham area. Sherman Crater (located just South of the summit) probably originated with a large hydrovolcanic explosion. In 1843, explorers reported a widespread layer of newly fallen rock fragments and several rivers south of the volcano were clogged with ash. A short time later, two collapses of the East side of Sherman Crater produced two lahars, the first and larger of which flowed into the natural Baker Lake, raising its water level at least 10 feet.

In 1975, increased fumarolic activity in the Sherman Crater area caused concern that an eruption might be imminent. Additional monitoring equipment was installed, and several geophysical surveys were conducted to try to detect the movement of magma. The level of the present day Baker Lake reservoir (located to the east and south of the mountain) was lowered and people were restricted from the area due to concerns that an eruption-induced debris avalanche or debris flow might enter Baker Lake and displace enough water to either cause a wave to overtop the Upper Baker Dam or cause complete failure of the dam. However, few anomalies other than the increased heat flow were recorded during the surveys nor were any other precursory activities observed to indicate that magma was moving up into the volcano. This volcanic activity gradually declined over the next two years but stabilized at a higher level than before 1975. Several small lahars formed from material ejected onto the surrounding glaciers and acidic water was discharged into Baker Lake for many months.

Glacier Peak

Figure 12-4 Glacier Peak from the Northeast
Source: Schurlock, Glacier Peak, 2007

Glacier Peak is a small stratovolcano and is the most remote of the five active volcanoes in Washington State. At 10,541 feet elevation, it is, next to Mount St Helens, the shortest of the major Washington volcanoes. Glacier Peak is not prominently visible from any major population center, and so its hazards tend to be over-looked. Erupting more than 6 times, this volcano has produced some of the largest and most explosive eruptions in the continuous United States since the last ice age.

Glacier Peak and Mount St. Helens are the only volcanoes in Washington State that have generated large, explosive eruptions in the past 15,000 years. Their violent behavior results from the type of magma they produce which is too viscous to flow easily out of the eruptive vent and must be pushed out under high pressure. As the magma approaches the surface, expanding gas bubbles within the magma burst and break into countless fragments of tephra and ash. The largest of these eruptions occurred about 13,000 years ago and ejected more than five times as much tephra as the May 18, 1980, eruption of Mount St. Helens.

During most of Glacier Peak's eruptive episodes, lava domes have extruded onto the volcano's summit or steep flanks. Parts of these domes collapsed repeatedly to produce pyroclastic flows and ash clouds. The remnants of prehistoric lava domes make up Glacier Peak's main summit as well as its "false summit" known as Disappointment Peak. Pyroclastic flow deposits cover the valley floors east and west of the volcano. Deposits from ash clouds mantle ridges East of the summit.

There is definite evidence that pyroclastic flows have mixed with melted snow and glacial ice to form lahars that have severely affected river valleys that head on Glacier Peak. Approximately 13,000 years ago, dozens of eruption-generated lahars descended down the White Chuck, Suiattle, and Sauk Rivers, inundating valley floors.

Geologic evidence indicates that lahars flowed down both the North Fork Stillaguamish (then an outlet of the upper Sauk River) and the Skagit River to Puget Sound. These lahars deposited more than seven feet of material as far away as 60 miles from Glacier Peak. The Sauk River's course via the Stillaguamish was abandoned and the Sauk River began to drain only into the Skagit River as it still does today.

12.2.2 Previous Occurrences

Table 12-1 summarizes past eruptions in the Cascades. During the 1980 Mount St. Helens eruption, 23 square miles of volcanic material buried the North Fork of the Toutle River and there were 57 human fatalities. During the last 4,000 years, Mount St. Helens has erupted more frequently than any other volcano in the Cascade Range (see Figure 12-2).

Geologic evidence indicates that both Mount Baker and Glacier Peak have erupted in the past and will no doubt erupt again in the foreseeable future. Due to the topography of the region and the location of drainage basins and river systems, eruption events on either Mount Baker or Glacier Peak resulting in lahar's, pyroclastic flows, tephra or ash fall, and lava and debris flows could impact the area.

TABLE 12-1
PAST ERUPTIONS IN WASHINGTON

Volcano	Number of Eruptions	Type of Eruptions
Mount Adams	3 in the last 10,000 years, most recent between 1,000 and 2,000 years ago	Andesite lava
Mount Baker	5 eruptions in past 10,000 years; mudflows have been more common (8 in same time period)	Pyroclastic flows, mudflows, ash fall in 1843.
Glacier Peak	8 eruptions in last 13,000 years	Pyroclastic flows and lahars
Mount Rainier	14 eruptions in last 9000 years; also 4 large mudflows	Pyroclastic flows and lahars
Mount St Helens	19 eruptions in last 13,000 years	Pyroclastic flows, mudflows, lava, and ash fall

12.2.3 Severity

Eruption durations are quite variable, ranging from hours to decades. At present, when an eruption begins scientists cannot foretell when it will end or whether the activity will be intermittent or continuous. Worldwide, the average eruption duration is about two months, although the most recent eruptions in the Cascades have been of greater duration (Mount St. Helens, Washington: intermittent activity from 1980 to 1986 and continuous activity from late 2004 to early 2008; Lassen Peak, California: intermittent activity from 1914 to 1917).

The explosive disintegration of Mount St. Helens' north flank in 1980 vividly demonstrated the power that Cascade volcanoes can unleash. The thickness of tephra sufficient to collapse buildings depends on construction practices and on weight of the tephra (tephra is much heavier wet than dry). Past experience in several countries shows that tephra accumulation near 10 cm is a threshold above which collapses tend to escalate. A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse.

Ash is harsh, acidic, and gritty, and it has a sulfuric odor. Ash may also carry a high static charge for up to two days after being ejected from a volcano. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with the rainwater to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat. Westerly winds dominate in the Pacific Northwest sending volcanic ash east and north–eastward about 80–percent of the time, though ash can blow in any direction.

Figure 12-5 shows probabilities of tephra accumulation from Cascade volcanoes in the Pacific Northwest (tephra is fragmented rock material ejected by a volcanic explosion). Wind in western Washington blows to the west, northwest and southwest only 10 percent of the time, so tephra from eruptions of Mount St. Helens or Mt. Rainier customarily would be far more likely on the east side of the volcano. Glacier Peak, due to its location in Snohomish County, could impact the tribal planning area if the winds were from the south pushing towards the northwest in order to impact the Samish Indian Nation. Mt. Baker, due to its location in Whatcom County, would require winds pushing south towards the west in order to impact the Samish Indian Nation.

Even a relatively small amount of ash could have a significant impact with respect to individuals with health or breathing issues, mechanical or motorized devices, fish and other natural wildlife, and the forest and plant life, particularly within agricultural areas. Figure 12-5 illustrates the probability of ash or tephra collection in any given year. Figure 12-6 shows areas of the U.S. that have been covered by volcanic ash.

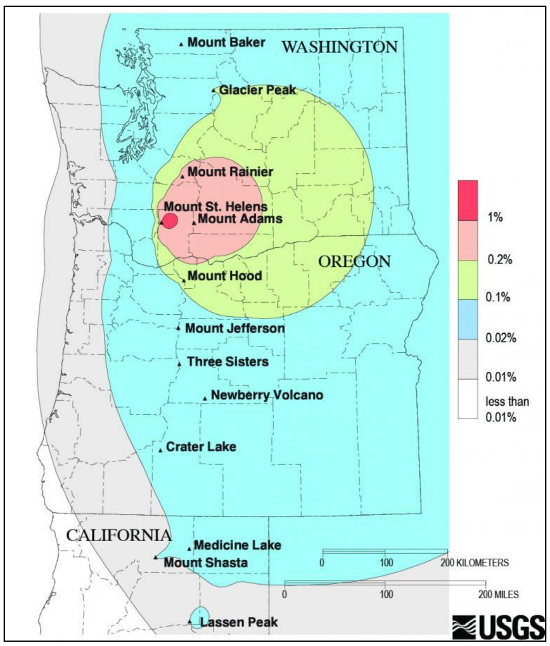


Figure 12-5 Probability of Tephra Accumulation in Pacific Northwest

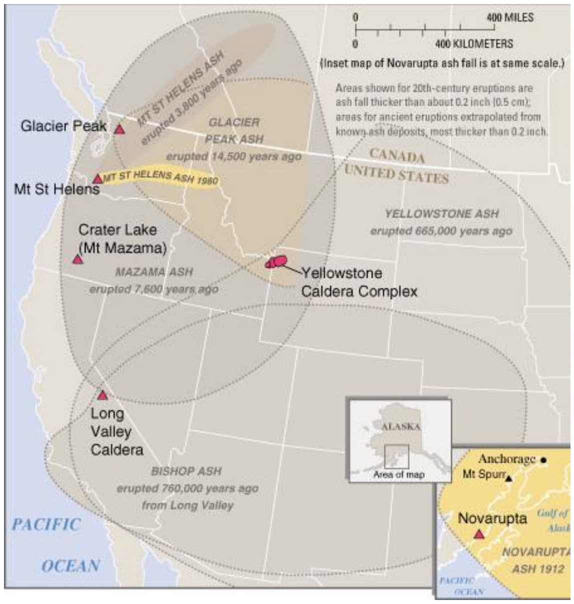


Figure 12-6 Defined Tephra Layers Associated with Historical Eruptions
Source: USGS. http://volcanoes.usgs.gov/vsc/multimedia/cvo_hazards_maps_gallery.html

The degree of volcanic hazard from the volcanoes of the Cascade Range depends on the type, size, and origin of the eruption. While the possibility of a large volcanic eruption exists, these types of events are typically separated by several hundred to a few thousand years and it is unlikely that we will see such an event in our lifetimes. Clearly, persons, property, and infrastructure closest to the volcano at the time of the eruption are most vulnerable.

While ash is of some concern, a lahar is also a possibility within the planning area. Geologic evidence indicates that both Mount Baker and Glacier Peak have erupted in the past and will no doubt erupt again in the foreseeable future. Due to the topography of the region, potential variations in wind directions, and the location of drainage basins and river systems, eruption events on either Mount Baker or Glacier Peak resulting in lahar's, pyroclastic flows, tephra or ash fall, and lava and debris flows could impact the area.

Figure 12-7 and Figure 12-8 illustrate the volcano hazard zones as identified by the USGS. Figure 12-9 and Figure 12-10 illustrate potential impact from the Glacier Peak Lahar Inundation Zone to the City of Burlington, and three of the Samish Indian Nation's structures on Thomas Creek.

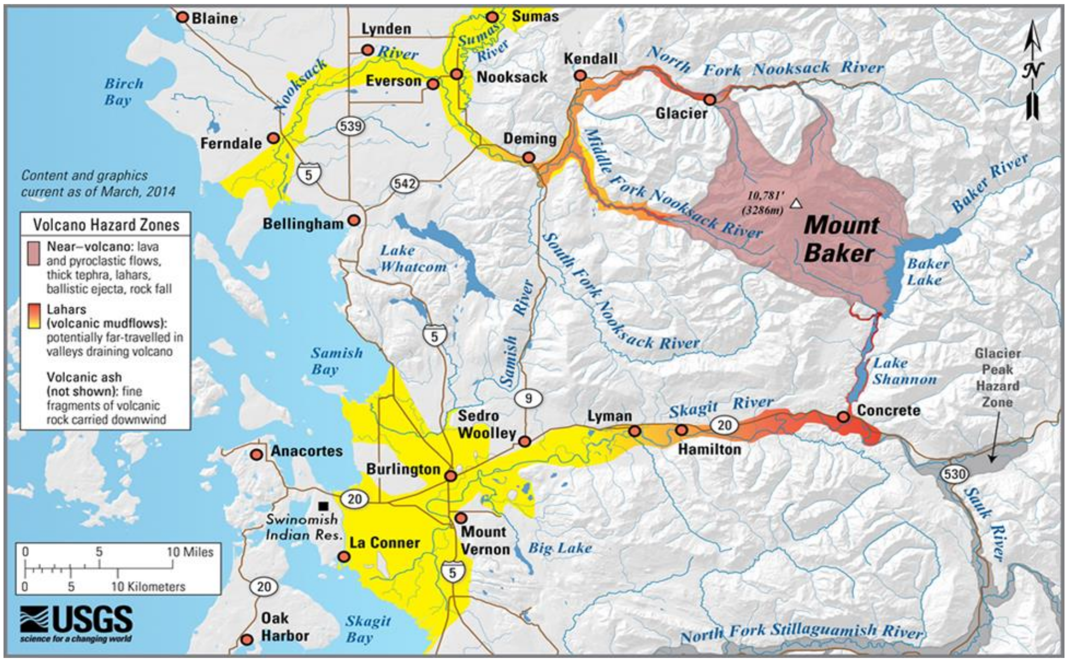


Figure 12-7 Volcano Hazard Zones From Mount Baker
Source: USGS. http://volcanoes.usgs.gov/vsc/multimedia/cvo_hazards_maps_gallery.html

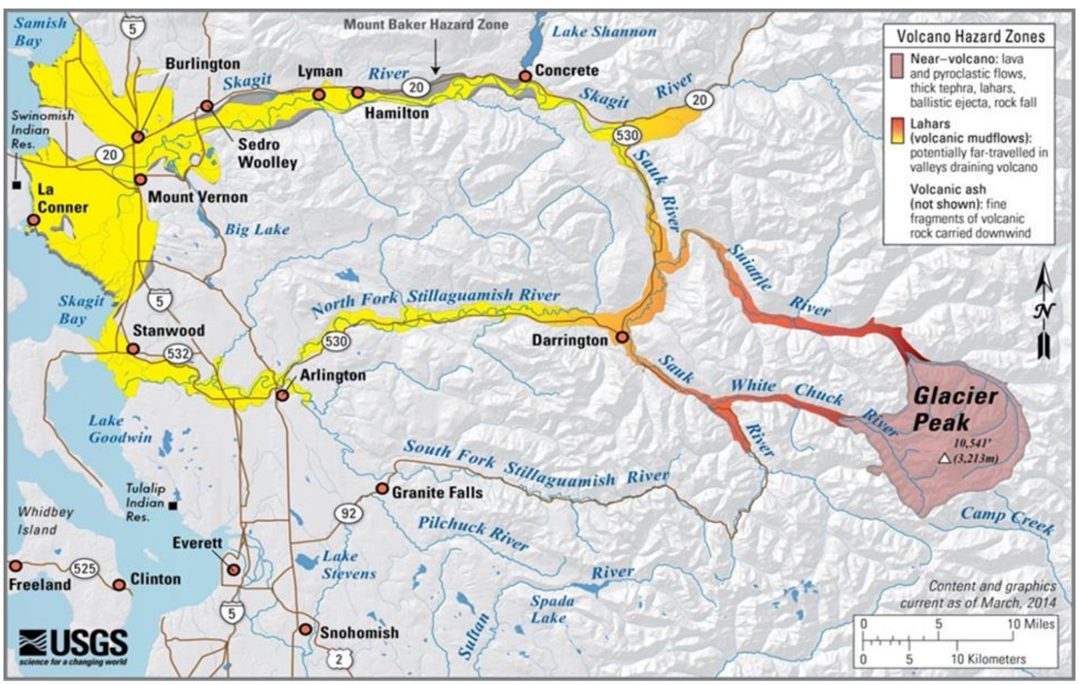


Figure 12-8 Volcano Hazard Zones from Glacier Peak

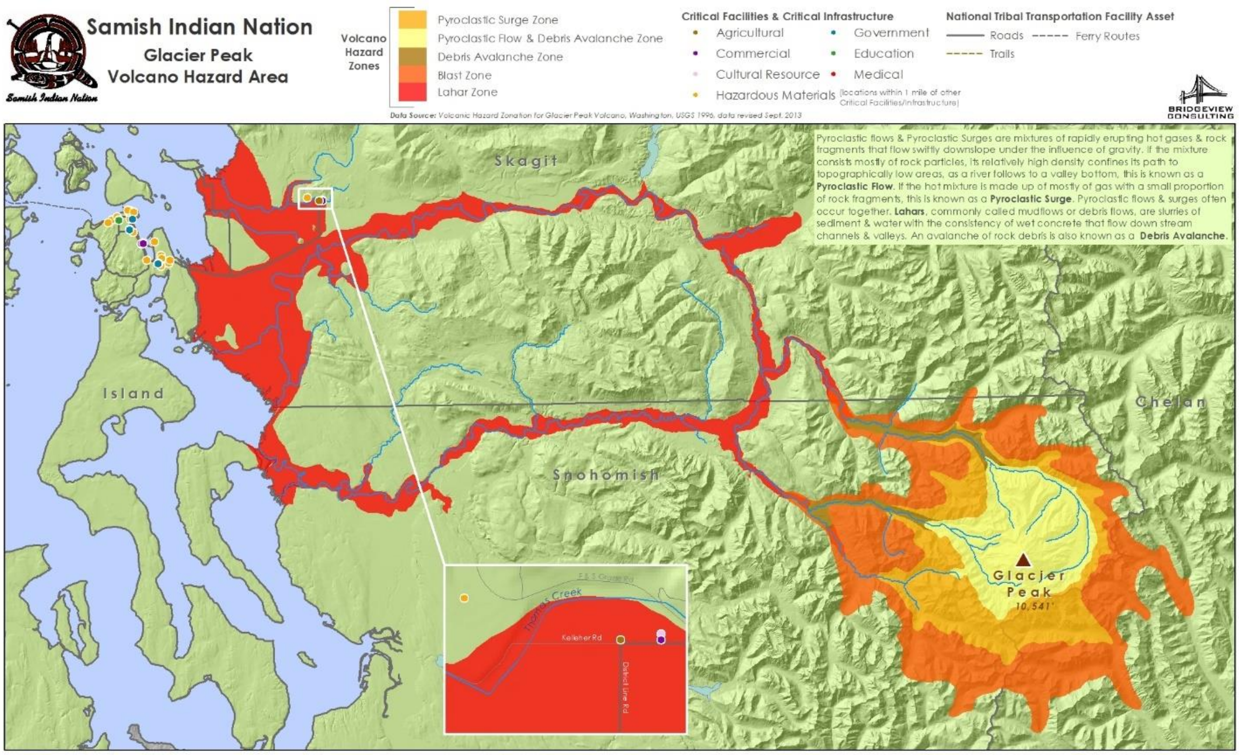


Figure 12-9 Glacier Peak Volcano Hazard Area

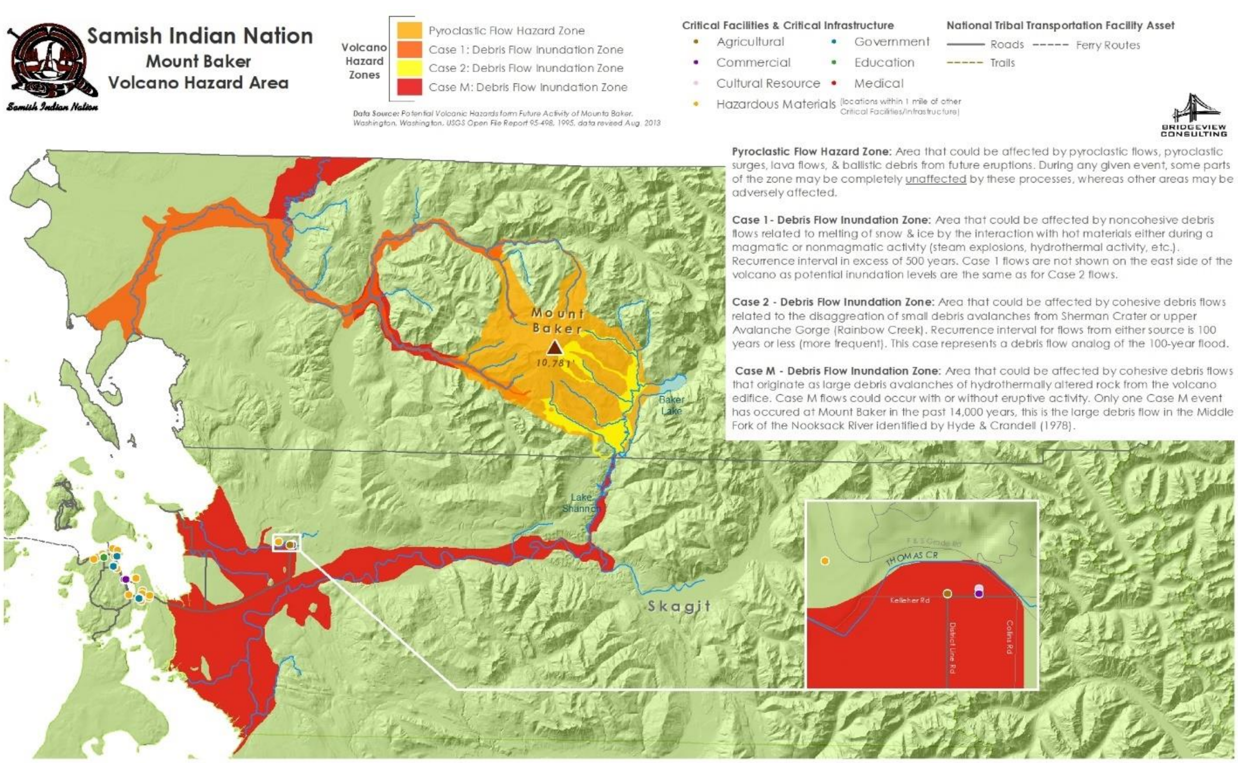


Figure 12-10 Mount Baker Volcano Hazard Area

12.2.4 Frequency

Many Cascade volcanoes have erupted in the recent past and will be active again in the foreseeable future. Given an average rate of one or two eruptions per century during the past 12,000 years, these disasters are not part of everyday experience; however, in the past hundred years, California's Lassen Peak and Washington's Mount St. Helens have erupted with terrifying results. The U.S. Geological Survey classifies Glacier Peak, Mt. Adams, Mt. Baker, Mt. Hood, Mt. St. Helens, and Mt. Rainier as potentially active volcanoes in Washington State. Mt. St. Helens is by far the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years. There is a one (1) in 500 probability that portions of two counties in the state will receive four (4) inches or more of volcanic ash from any Cascade volcano in any given year. The probability increases to one (1) in 1,000 that parts, or all, of three or more counties will receive same quantity. There is a one (1) in 100 annual probability that small lahars or debris flows will impact river valleys below Mount Baker and Mount Rainier, with a less than 1:1,000 annual probability that the largest destructive lahars would flow down Glacier Peak, Mount Adams, Mount Baker or Mount Rainier.

12.3 VULNERABILITY ASSESSMENT

12.3.1 Overview

The closest Cascade volcanoes to the planning area are Mount Baker and Glacier Peak. Because of the location of Mount Baker and Glacier Peak and the flow direction of prevailing winds, the majority of airborne ash would most likely be carried to the northeast or east should an ash eruption occur. According to the USGS analysis, westerly winds dominate in the Pacific Northwest sending volcanic ash east and north–eastward about 80–90 percent of the time, though ash can blow in any direction. However, even 10 percent of ash reaching the planning area could have a negative impact on the natural resources and the agricultural economy. In addition, regardless of wind direction, there would still be considerable amount of ash fall in the immediate vicinity of the volcano during and immediately flowing an explosive tephra and ash eruption. In addition, large amounts of ash would be carried by moving vehicles traveling into the area as well. The potential for fire danger also increases as a result of static charge contained within the ash.

The 1980 eruption of Mount St. Helens produced enough ash fall to reduce the maximum flow capacity of the Cowlitz River from 76,000 cubic feet per second to less than 15,000 cubic feet per second and also reduced the channel depth of portions of the Columbia River from 40 feet to 14 feet. Should a St. Helens-type event occur from either Mount Baker or Glacier Peak, large portions of the numerous Skagit County rivers would be severely impacted.

Ash and chemical products in any of the rivers in the area could contaminate water supply to the area. Transportation for ships, boats, and vehicles traveling into the area could carry additional ash into the region, washing off during rains and contaminating the ground and water bodies, or potentially being impacted by ash with respect to visibility, and mechanically if large amounts of ash accumulate in engines' air intake systems. In addition, transportation interruptions as a consequence of eruption and impact on surrounding communities could cause moderate to high impact in the region as a whole, as commodity flows would decrease, as well as interruptions to power transmission, telecommunications outages, and potentially medical services. Residents with health issues, especially those with breathing difficulties, would also be impacted, even by small amounts of ash.

Warning Time

Constant monitoring by the USGS and the Pacific Northwest Seismograph Network (PNSN) at the University of Washington of all active volcanoes means that there will be more than adequate warning time before an event. Newly standardized Alert Levels issued by USGS volcano observatories are based on a volcano's level of activity. These levels are intended to inform people on the ground and are issued in conjunction with the Aviation Color Code. The highest two alert levels (Watch and Warning) are National Weather Service terms for notification of hazardous meteorological events, terms already familiar to emergency managers that are becoming increasingly more familiar to the public.

The U.S. Geological Survey (USGS) volcanic alert-level system provides the framework for the preparedness activities of local jurisdictions, tribal governments and state and federal agencies. The USGS ranks the level of activity at a U.S. volcano using the terms "Normal", for typical volcanic activity in a non-eruptive phase; "Advisory", for elevated unrest; "Watch", for escalating unrest or a minor eruption underway that poses limited hazards; and, "Warning", if a highly hazardous eruption is underway or imminent. These levels reflect conditions at a volcano and the expected or ongoing hazardous volcanic phenomena. When an alert level is assigned by an observatory, accompanying text will give a fuller explanation of the observed phenomena and clarify hazard implications to affected groups. The USGS Cascade Volcano Observatory works in conjunction with PNSN to provide constant monitoring and notification when activities increase. Figure 12-11 depicts one of the sensors used by USGS and PNSN for monitoring purposes. Figure 12-12 identifies the various types of remote sensing devises available.

Based on past events and especially the 1980 eruption of Mount St. Helens, future eruptions from either Mount Baker or Glacier Peak will almost certainly be preceded by an increase in seismic (earthquake) activity, and possibly by measured swelling of the volcano and emission of volcanic gases. The University of Washington Geophysics Program, in cooperation with the USGS, monitors seismic activity at Mount Baker and other Cascade Range volcanoes that could signal a possible future eruption. In addition, the USGS monitors gas emissions from Sherman Crater on Mount Baker to detect possible changes in the volcano that may be a warning of impending magma activity or an increase in hydro-volcanic activity in an effort to predict the likelihood of an eruption event. This ability to monitor seismic and other types of activity at Mount Baker and Glacier Peak provides a warning system of sorts for volcanic eruptions that could impact the planning area.

Furthermore, the 1980 Mount St. Helens eruption made it clear that preparing for and responding to a large-scale volcanic eruption must involve a wide variety of agencies and jurisdictions. For this reason, emergency managers from Skagit, Snohomish, and Whatcom Counties, the State of Washington, and the Province of British Columbia, as well as personnel from the United States Forest Service developed the Mount Baker-Glacier Peak Coordination Plan. The plan was adopted in April 2001, and updated in 2011 and the plan provides a tool to coordinate the actions that various agencies must take to minimize loss of life and damage to property before, during, and after a hazardous geologic event occurring at either volcano.

Figure 12-11 Monitoring Equipment

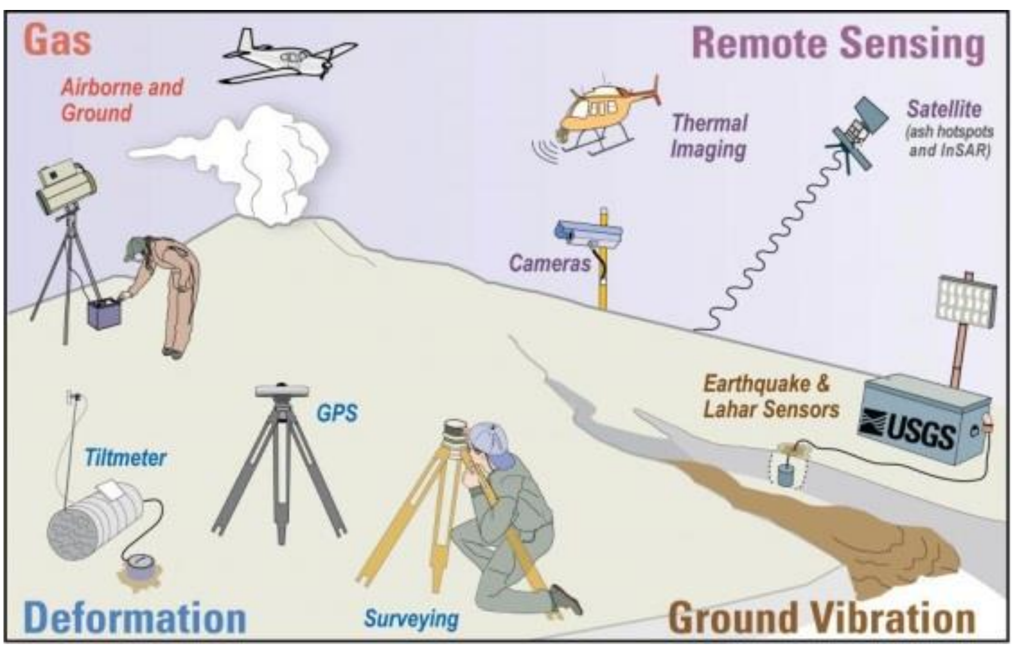


Figure 12-12 Remote Sensing Devices

12.3.2 Impact on Life, Health, and Safety

The entire population of the planning area, as well as any tourists traveling through the area could be exposed to ash and its side effects. As a result of the river drainage basins and the topography of the planning area, an ensuing lahar could also be of impact from a Glacier Peak event.

A Case M Debris Flow could also occur as a result of a Mount Baker event. A Case M Debris Flow is an area that could be affected by interconnected debris flows that originate as large debris avalanches of hydrothermally altered rock from the volcano. Case M flows could occur with or without eruptive activity. Only one Case M event has occurred at Mount Baker in the past 14,000 years, which was a large debris flow in the Middle Fork of the Nooksack River identified by Hyde and Crandell (1978).

When an ash cloud combines with rain, sulfur dioxide in the cloud combines with the rainwater to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat. Given the high amount of annual rainfall and the mist occurring from waves, this increases the potential impact on the population. The elderly, very young and those who experience ear, nose and throat problems are especially vulnerable to the tephra hazard, as well as the ash itself causing respiratory issues. In addition, the high number of tourists who annually visit the area would potentially increase the number of people to which the region would have to provide emergency services, housing, and associated support.

12.3.3 Impact on Property

All of the property in the planning area to some degree would be exposed to ash fall and tephra accumulation in the event of a volcanic eruption. Three structures owned by the Samish Nation (on Thomas Creek) are within the lahar zone based on current USGS projections of the lahar zone. A Case M Debris Flow from Mount Baker could also impact the same three structures, although the properties are not within the actual Mount Baker lahar zone.

Current building codes and regulations in place do have increased snow- and wind-load capacities, which increase the ability to withstand the weight of ash for more recently constructed buildings. The ash itself is harsh, acidic, and gritty, and may carry a high static charge for up to two days after being ejected from a volcano. This static charge has the potential for igniting forest fires in the densely forested areas.

The 1980 eruption of Mount St. Helens produced enough ash fall to reduce the maximum flow capacity of the Cowlitz River from 76,000 cubic feet per second to less than 15,000 cubic feet per second and also reduced the channel depth of portions of the Columbia River from 40 feet to 14 feet. Should a St. Helens-type event occur from either Mount Baker or Glacier Peak, large portions of the various rivers in the area and the floodplains themselves could be severely impacted by flooding and associated debris in addition to the direct effects of the ash eruption.

The river valleys and associated floodplains within Skagit County are all especially vulnerable to the effects of large-scale lahars and associated flooding that will no doubt result from a large lahar. As demonstrated during the 1980 Mount St. Helens eruption, the hydraulic power of fast-moving lahars and debris flows is astonishing. Sandbags and other “normal” flood fight measures will not be effective to provide any type of protection for such an event.

Furthermore, problems related to lahar debris could last for years and even decades because of the tremendous volume of loose rock and ash that has could potentially have been added to the ground surface near the volcano. This debris could provide a source of material that would no doubt flow downstream during flood events for many years following the eruption event.

12.3.4 Impact on Critical Facilities and Infrastructure

While exposure analysis was conducted on the critical facilities with respect to the Lahar Zone, the ability of the structure to withstand impacts cannot be determined as specific building data was not available, and exceeds the scope of this project. It is estimated that three of the critical facilities owned by the Samish assessed during this HMP process would be impacted by a Glacier Peak lahar, and also fall within a debris flow from Mount Baker. Total building and content value of those structures exceed $498,000.

In addition to the lahar and debris inundation, all critical facilities and infrastructure would also be exposed to the weight of ash. Due to the age of some of the building stock, some structures may fail to withstand the weight of the ash. Outside building equipment, such as HVAC systems, could also be impacted by the ash clogging systems. All transportation routes in the area would be exposed to ash fall and tephra accumulation, which could create hazardous driving conditions on roads and highways and hinder evacuations and response. Utilities, including water treatment plants and wastewater treatment plants are vulnerable to contamination from ash fall, as well as impact from the ash itself that could damage motors.

12.3.5 Impact on Economy

A severe lahar event could impact most of the region, resulting in a catastrophic disaster and long-term economic impacts throughout the area. In addition to the economic losses associated with the critical facilities and infrastructure, economic impact could also result from the potential losses to natural resources, the loss of tourism due to suspended travel and visitors to the area, structural losses, including businesses and governmental offices/buildings. Structures containing hazardous materials within the lahar inundation zone would also cause significant economic loss, including the potential clean-up costs if a point source location cannot be identified. Lost revenues from businesses disrupted by structural damage or as a result of fewer patrons would also impact the tribe's economy.

12.3.6 Impact on Environment

The environment is highly exposed to the effects of a volcanic eruption. Even if the related ash fall from a volcanic eruption were to fall elsewhere, the watersheds, lakes, rivers, and tributaries are vulnerable to damage due to ash fall since ash fall can be carried throughout the area by its rivers. A volcanic blast would expose the local environment to other effects, such as lower air quality, and many elements that could harm local vegetation and water quality, adversely impact wildlife and fish habitat. The sulfuric acid contained in volcanic ash could be very damaging to area vegetation, increasing the risk of wildfire danger, as well as wildlife. The potential release from any of the hazardous materials sites countywide would be a significant environmental impact. The lahar itself would also cause significant impact to the river drainage basins, and influence the topography of the area as the lahar continues out to sea. Glaciers could melt resulting in mudflows and flooding throughout the area.

12.3.7 Impact from Climate Change

Climate change is not likely to affect the risk associated with volcanoes; however, volcanic activity can affect climate change. Volcanic clouds absorb terrestrial radiation and scatter a significant amount of incoming solar radiation. By reducing the amount of solar radiation reaching the Earth's surface, large-scale volcanic eruptions can lower temperatures in the lower atmosphere and change atmospheric circulation patterns. Such effects can last from two to three years following a volcanic eruption. The massive outpouring of gases and ash can influence climate patterns for years following a volcanic eruption as sulfuric gases convert to sub-micron droplets containing about 75 percent sulfuric acid. These particles can linger three to four years in the stratosphere.

12.4 FUTURE DEVELOPMENT TRENDS

Building codes utilized by the Tribe during development currently include stringent regulations with respect to support and payload structuring of facilities. Building codes with respect to load capacity does influence the ability to withstand impact. The Tribe does adhere to current building codes in place. Skagit County and the City of Anacortes do have building codes in place for load-capacity. The Samish Indian Nation adheres to all building code requirements in place for all construction and remodel practices.

12.5 ISSUES

In the event of a volcanic eruption, there would be enough advanced warning that there hopefully would be no direct loss of life in the planning area as a direct result of the eruption. However, there could be significant health issues related to ash fall and health concern (especially for the young, elderly and those with breathing issues). In addition, there is also the potential for the increased potential for motor vehicle accidents; and potential structural damage if large amounts of ash accumulate as a result of the weight of the ash on structures. The potential exists for impact on the agricultural community, which would have an economic impact on the planning region. There would also be the possibility of severe environmental impacts due to ash within area lakes and streams, with the water supply potentially impacted by ash. One of the most significant impacts would be on the area's environment and the water supply. Both of these elements would have a significant impact on the Tribe.

12.6 IMPACT AND RESULTS

Although the probability of a volcanic eruption is low, if an eruption were to occur, the greatest threat to life, property, infrastructure, and the environment would be from lahars or debris avalanches. Based on past events and especially the 1980 eruption of Mount St. Helens, future eruptions from either Mount Baker or Glacier Peak will almost certainly be preceded by an increase in seismic (earthquake) activity, and possibly by measured swelling of the volcano and emission of volcanic gases.

The river valleys and associated floodplains are particularly vulnerable to the effects of large-scale lahars and associated flooding that will no doubt result from a large lahar. Problems related to lahar debris could last for years and even decades because of the tremendous volume of loose rock and ash that has could potentially have been added to the ground surface near the volcano. This debris could provide a source of material that would no doubt flow downstream during flood events for many years following the eruption event.

Based on review and analysis of the data, the Planning Team has determined that the probability for a future event is low; however, the impact at some level could be significant based on the lahar inundation zone, the topography of the area, the impact to the river drainage basins, ashfall, and the very high potential for impact to the I-5 corridor and the ensuing impact on commodity flow. The Samish have three structures that fall within the lahar zone for Glacier Peak, and the debris zone for Mount Baker (the Thomas Creek properties).

Implementation of mitigation strategies which help increase load capacities on roofs would help reduce the number of structures at risk due to ashfall accumulations, but the environmental and economic impact cannot be so easily mitigated. Based on the potential impact, the Planning Team determined the CPRI score to be 1.35, with overall vulnerability determined to be a low level.

CHAPTER 13.
HAZARD RANKING

The risk ranking process conducted by Planning Team members assessed the probability of each hazard's occurrence, as well as its likely impact on the people, property, and economy of the planning area. Also of significant concern to the Samish Indian Nation is the impact of these hazards on the environment, which factor was also taken into consideration during this plan update.

For some hazards, estimates of risk were generated with data from Hazus, using methodologies promoted by FEMA. For other hazards, citizens, and Planning Team members (who have an extensive historic perspective and knowledge base concerning the impact of hazards on the Tribe) provided invaluable information during this process. That information had a significant impact on the risk ranking process.

In ranking the hazards, the Planning Team completed a Calculated Priority Risk Index worksheet for each hazard (Figure 13-1). The Index examines the various criteria for each hazard (probability, magnitude/severity, geographic extent and location, warning time, and duration) as discussed in Chapter 5, defines a risk index for each criterion according at four levels (1-4), and then applies a weighting factor.

The result is a score that has been used to rank the hazards for the Tribe. Table 13-1 presents the results of the Calculated Priority Risk Index (CPRI) scoring for the hazards of concern. Once the hazard ranking was completed, the Planning Team also assigned an ordinal scale to identify the level of significance based on the CPRI score and rank, assigning a low-to-high rating of concern or significance. Those ratings are categorized into the following levels, with Table 14-2 presenting the overall results:

- Extremely Low—The occurrence and potential cost of damage to life and property is very minimal to nonexistent.
- Low—Minimal potential impact. The occurrence and potential cost of damage to life and property is minimal.
- Medium—Moderate potential impact. This ranking carries a moderate threat level to the general population and/or built environment. Here the potential damage is more isolated and less costly than a more widespread disaster.
- High—Widespread potential impact. This ranking carries a high threat to the general population and/or built environment. The potential for damage is widespread. Hazards in this category may have occurred in the past.
- Extremely High—Very widespread with catastrophic impact.

CPRI Category	Degree of Risk			Assigned Weighting Factor
	Impact/ Level ID	Description	Impact Factor	
Probability	Unlikely	• Rare with no documented history of occurrences or events. • Annual probability of less than 1% (~100 years or more).	1	40%
	Possible	• Infrequent occurrences; at least one documented or anecdotal historic event. • Annual probability that is between 1% and 10% (~10 years or more).	2	
	Likely	• Frequent occurrences with at least two or more documented historic events. • Annual probability that is between 10% and 90% (~10 years or less).	3	
	Highly Likely	• Common events with a well-documented history of occurrence. • Annual probability of occurring. (1% chance or 100% Annually).	4	
Magnitude/ Severity	Negligible	• People – Injuries and illnesses are treatable with first aid; minimal hospital impact; no deaths. Negligible impact to quality of life. • Property – Less than 5% of critical facilities and infrastructure impacted and only for a short duration (less than 24-36 hours such as for a snow event); no loss of facilities, with only very minor damage/clean-up. • Economy – Negligible economic impact. • Continuity of government operating at 90% of normal operations with only slight modifications due to diversion of normal work for short-term response activity. Disruption lasts no more than 24-36 hours. • Special Purpose Districts: No Functional Downtime.	1	25%
	Limited	• People – Injuries or illness predominantly minor in nature and do not result in permanent disability; some increased calls for service at hospitals; no deaths; 14% or less of the population impacted. Moderate impact to quality of life. • Property – Slight property damage -greater than 5% and less than 25% of critical and non-critical facilities and infrastructure. • Economy – Impact associated with loss property tax base limited; impact results primarily from lost revenue/tax base from businesses shut down during duration of event and short-term cleanup; increased calls for emergency services result in increased wages. • Continuity of government impacted slightly; 80% of normal operations; most essential services being provided. Disruption lasts >36 hours, but <1 week. • Special Purpose Districts: Functional downtime 179 days or less.	2	
	Critical	• People – Injuries or illness results in some permanent disability or significant injury; hospital calls for service increased significantly; no deaths. 25% to 49% of the population impacted. • Property – Moderate property damages (greater than 25% and less than 50% of critical and non-critical facilities and infrastructure). • Economy - Moderate impact as a result of critical and non-critical facilities and infrastructure impact, loss of revenue associated with tax base, lost income. • Continuity of government ~50% operational capacity; limited delivery of essential services. Services interrupted for more than 1 week, but <1 month. • Special Purpose Districts: Functional downtime 180-364 days.	3	
	Catastrophic	• People - Injuries or illnesses result in permanent disability and death to a significant amount of the population exposed to a hazard. >50% of the population impacted. • Property – Severe property damage >50% of critical facilities and non-critical facilities and infrastructure impacted. • Economy – Significant impact - loss of buildings /content, inventory, lost revenue, lost income. • Continuity of government significantly impacted; limited services provided (life safety and mandated measures only). Services disrupted for > than 1 month. • Special Purpose Districts: Functional Downtime 365 days or more.	4	
Geographic Extent and Location	Limited	Less than 10% of area impacted.	1	20%
	Moderate	10%-24% of area impacted.	2	
	Significant	25%-49% of area impacted.	3	
	Extensive	50% or more of area impacted.	4	
Warning Time / Speed of Onset	<6 hours	Self-explanatory.	4	10%
	6 to 12 hours	Self-explanatory.	3	
	12 to 24 hours	Self-explanatory.	2	
	> 24 hours	Self-explanatory.	1	
Duration	< 6 hours	Self-explanatory.	1	5%
	< 24 hours	Self-explanatory.	2	
	<1 week	Self-explanatory.	3	
	>1 week	Self-explanatory.	4	

Figure 13-1 Calculated Priority Risk Index

TABLE 13-1
CALCULATED PRIORITY RANKING SCORES

Hazard	Probability	Magnitude and/or Severity	Geographic Extent and Location	Warning Time	Duration	Calculated Priority Risk Index Score
Drought	3	2	2	1	4	2.35
Earthquake	4	3	4	4	1	3.65
Flood	4	2	2	1	2	2.65
Landslide	2	2	2	4	3	2.35
Severe Weather	4	2	3	1	2	2.85
Tsunami	1	2	3	4	2	2.10
Volcano	1	1	2	1	4	1.35
Wildfire	2	2	2	4	1	2.25

The Calculated Priority Risk Index scoring method has a range from 0 to 4. “0” being the least hazardous and “4” being the most hazardous situation.

TABLE 13-2
HAZARD RANKING

Hazard in Ranked Order	CPRI Score	Level of Concern and Significance
Earthquake	3.65	High
Severe Weather	2.85	High
Flood	2.65	Medium
Landslide	2.35	Medium
Drought	2.35	Medium
Wildfire	2.25	Medium
Tsunami	2.10	Medium
Volcano	1.35	Low

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