SECTION 2.1. HAZARD SUMMARIES

The following eight natural hazards were identified to be significant risks to the county, and specifically hazardous to the populated western areas of Whatcom County:

1. Earthquakes
2. Flooding
3. Coastal Flooding
4. Geologic Hazards
5. Severe Storms
6. Tsunamis
7. Volcanoes
8. Wildland Fires

The updated Hazard Identification and Vulnerability Analysis (HIVA) was received late in the plan update process and will be the basis for the next version of the all-hazards plan.

The following sections describe the seven significant natural hazards and their potential threats to Whatcom County. Much of the information collected in these hazard summaries came from local experts working in hazard assessment or hazard mitigation for a specific hazard. The summaries describe the hazards, convey the areas at potential risk from each hazard, and describe mitigation measures as implemented in the past or to be implemented in the future to manage the effects of natural disasters in Whatcom County.

Each hazard description is organized into the following parts:

Hazard	Related Definitions
Background Information	General description of the hazard relevant to Whatcom County and Washington State
Background Information	General description of the hazard relevant to Whatcom County and Washington State
History	Historical background on the presence of the hazard in Whatcom County; much of this information was obtained from agencies such as FEMA, the Washington Department of Natural Resources (WDNR), and the U.S. Geological Society (USGS)

Vulnerability Assessment	Descriptions of specific areas within the county at risk for each hazard, when this information was available
Mitigation Strategies	Recommended mitigation strategies to lessen the dangers posed by each hazard

Whatcom County's Planning and Development Services provided the hazard GIS datasets, except for the Wildland Fire data, which came from WDNR's North Region. For the current update, new hazard maps were produced by the Western Washington University GIS Department depicting specific hazards posed to municipalities throughout Whatcom County.

See sub section 2.2 for the list of Other Hazards of Concern, including:

1. Avalanches
2. Coastal Flooding/Tidal Overflow
3. Dam Failure
4. Drought

EARTHQUAKES

A. DEFINITIONS

Earthquake Sudden motion or trembling in the earth. This can be caused by the abrupt release of accumulated energy on a fault or by volcanic or magmatic activity.

Crust Outermost major layer of the Earth, ranging from about 10 to 65 km in thickness worldwide. The uppermost 15 to 35 km of crust is brittle enough to produce earthquakes.

Fault Fracture along which the blocks of crust on either side have moved relative to one another, parallel to the fracture.

Liquefaction Phenomenon in which loosely packed, saturated sediments lose intergranular strength in response to strong seismic shaking, causing major damage due to excessive ground settlement.

Lithosphere The outer solid part of the earth, including the crust and uppermost mantle. The lithosphere is about 100 km thick, although its thickness is dependent on age. The lithosphere below the crust is brittle enough at some locations to produce earthquakes by faulting, such as within a subducted oceanic plate.

Subduction zone A place where two lithospheric plates come together, one riding over the other. The process of subduction is where the oceanic lithosphere collides with and descends beneath the continental lithosphere.

B. BACKGROUND INFORMATION

For hundreds of millions of years, the forces of plate tectonics have shaped the Earth as the plates that form the Earth's surface slowly move over, under, and past one another. The speed of these plates is variable: sometimes they move gradually and at other times the plates are locked together, unable to release the accumulating energy. This energy can also be generated by a sudden dislocation of segments of the Earth’s crust, by a volcanic eruption, or even by anthropogenic-caused explosions. When the accumulated energy grows strong enough, the plates break free, resulting in an earthquake. If the earthquake occurs in a populated area, it may result in injury or death, and extensive property damage. The most destructive earthquakes are caused by natural dislocations of the crust. The crust first bends, and when the stress exceeds the strength of the rocks, breaks and "snaps" into a new position.

Geologists have discovered that earthquakes tend to occur along faults, which reflect zones of weakness in the Earth's crust. Even if a fault zone has recently experienced an earthquake, however, there is no guarantee all stress has been relieved, and another earthquake could still occur. Relieving stress along one part of a fault may also increase stress in another part, increasing the probability that an earthquake could occur nearby.

The Juan de Fuca Plate is an ocean tectonic plate that is colliding with the North American Continental Plate near the western coast of Washington State in a subduction zone called the Cascadia Subduction Zone (CSZ). The CSZ is shown in Figure 1. The CSZ extends from southern B.C. to northern California. One of the results of the colliding forces at the CSZ is the uplift that is occurring and is forming the Olympic and Cascade Mountain Range. The convergence of these two plates also creates a more immediate concern: earthquakes. Subduction zone earthquakes can be powerful and sustained for greater lengths of time than other types of earthquakes.

Geologic work along the Oregon and Washington coasts, and Puget Sound and tsunami (commonly called a tidal wave) data from Japan, indicate very large magnitude quakes occur, on average, every 550 years along the CSZ. The last major subduction quake to occur along the Washington Coast occurred in 1700 (Atwater, et al., 2015).

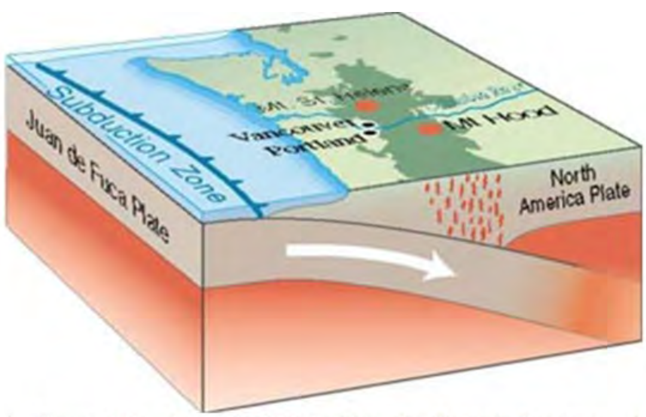
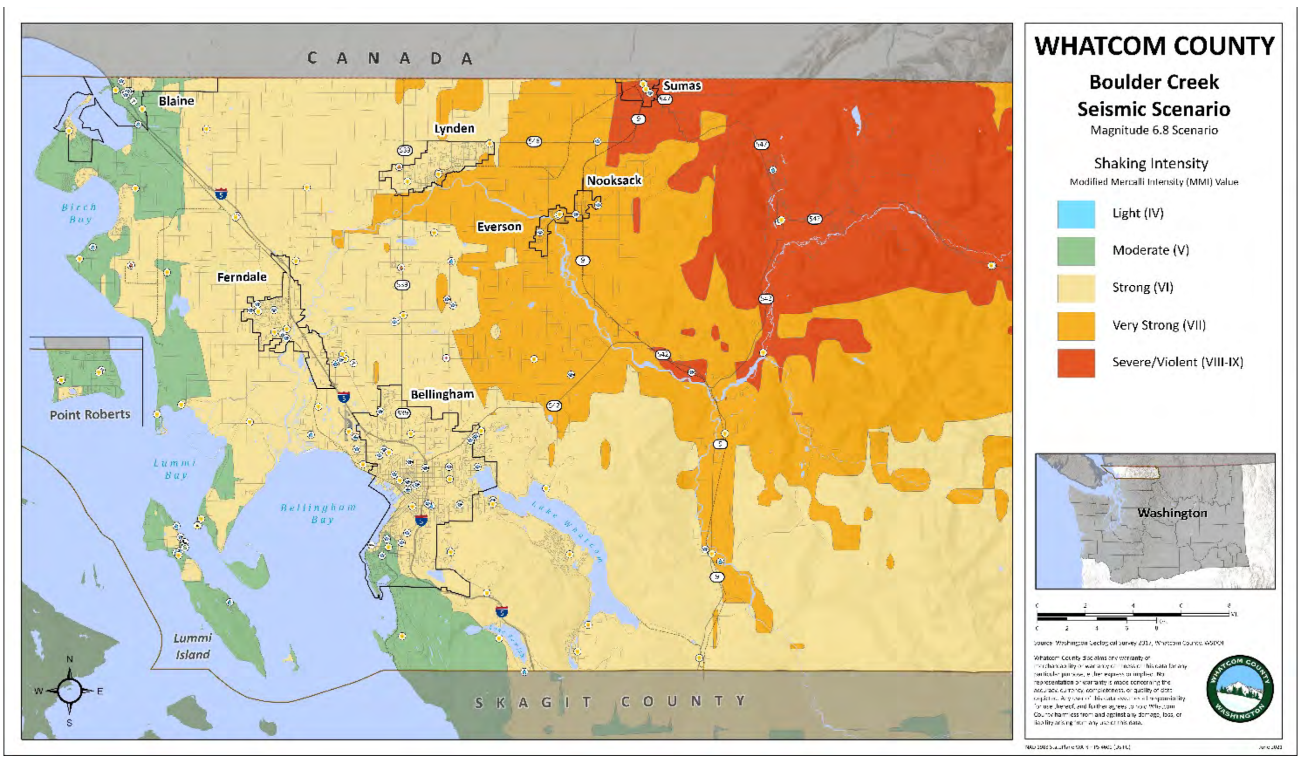


Figure 1 Courtesy of USGS Earthquake Hazards Program.

Earthquakes can also be produced by movement along faults within the North American plate (known as “intraslab” earthquakes). Recent geologic investigations have revealed a number of fault zones in the Puget Sound region of Western Washington, including several recently active faults in Whatcom County. These faults record a number of Holocene (a geologic epoch beginning 10,000 years ago) earthquakes that not only produced substantial ground movement, but also resulted in the rupturing of ground surface. The close proximity of population centers to these fault zones and the potential for surface rupture should be considered when seismic hazard assessments and engineering designs are prepared. Local faults that have been mapped include the McCauley Creek Thrust Fault near Deming and the Boulder Creek Fault and associated Kendall Fault Scarp in the North Fork Nooksack River Valley. The Kendall Fault moved as recently as 900 years ago with an earthquake magnitude potentially larger than the magnitude 6.8 Nisqually earthquake of 2001 (Sherrod, et al, 2013). The Nisqually earthquake, an intraslab earthquake that occurred under Anderson Island, 11 miles northeast of Olympia, was felt in Bellingham, which lies 120 miles to the north. Recent published research identifies a set of northwest-trending Holocene faults capable of producing 6.0-6.5 Magnitude earthquakes beneath the communities of Sandy Point, Birch Bay and (Kelsey, et al., 2012). A Boulder Creek Fault earthquake would be extremely damaging to Whatcom County, as shown in the map below, because it is within County borders.



Washington Department of Natural Resources (WA DNR) 2017 Boulder Creek Fault Zone seismic scenario of magnitude 6.8 data. Displays extent and severity of the modeled earthquake in the Modified Mercalli Intensity (MMI) scale. According to the MMI Scale:

- *Light shaking (IV) generally corresponds to the earthquake Felt indoors by many, outdoors by few during the day: At night, some are awakened. Dishes, windows, and* *doors are disturbed; walls make cracking sounds. Sensations are like a heavy truck striking a building. Standing motor cars are rocked noticeably.*

- *Moderate Shaking (V) Felt by nearly everyone; many awakened: Some dishes and windows are broken. Unstable objects are overturned.*
- *Strong Shaking (VI) Felt by all, and many are frightened. Some heavy furniture is moved; a few instances of fallen plaster occur. Damage is slight.*
- *Very Strong (VII) Damage is negligible in buildings of good design and construction; but slight to moderate in well-built ordinary structures; damage is considerable in poorly built or badly designed structures; some chimneys are broken.*
- *Severe-Violent (VIII-IX) From considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. In some places, damage is considerable in specially designed structures; well-designed frame structures are thrown out of plumb. Damage is great in substantial buildings, with partial collapse. Buildings are shifted off foundations. Liquefaction occurs.*

According to the USGS, Washington ranks fifth in the United States of those states at risk of earthquakes with a magnitude 3.5 or greater. As of 2016, 424 earthquakes occurring in Washington since 1974 accounted for 2.0% of all earthquakes in the United States. Additionally, according to a FEMA study, Washington ranks second in the nation (after California) of states that are susceptible to earthquake losses.

C. RECENT HISTORY IN WHATCOM COUNTY

Each year, more than 1,000 earthquakes are recorded in Washington. Of these, 15 to 20 cause ground movements strong enough to be felt. According to the USGS, recent geologic findings indicate that earthquakes generated within the CSZ pose a significant hazard to urban areas of the Pacific Northwest. Evidence gleaned from syntheses of global subduction zone attributes, as well as from local tsunami deposits, suggests that major earthquakes occurred in the Pacific Northwest perhaps as recently as 300 years ago (Atwater, et al., 2015).

The most recent earthquake to cause widespread damage in Washington occurred in 1965. Since that time, the state's population has more than doubled from roughly 3 million in 1965 to 7.7 million in 2020. Washington residents have largely forgotten the 1965 earthquake, and this has contributed to a general lack of public awareness of the state's earthquake hazards. Some scientists suggest that even larger earthquakes have occurred every several hundred or thousand years in the Pacific Northwest. The Nisqually earthquake, although less severe than the one in 1965, occurred in 2001. This quake was centered 120 miles to the south of Whatcom County, yet was still felt in and caused damage in the area. The April 1990 Deming earthquake swarm included a magnitude 5.0 event that is one of the largest earthquakes recorded in northern Puget Sound between 1920 and 1990 (Amadi, 1992). Table 1 lists the Pacific Northwest's largest earthquakes over the last 150 years.

Table 1. Recent Pacific Northwest Earthquakes 4.5 Magnitude or Greater

Date	Depth	Magnitude	Approximate Location
December 1872	Shallow	7.3	North Cascades
October 1877	Shallow	5.3	Portland, Oregon
December 1880		?	Puget Sound
November 1891		?	Puget Sound
March 1893	Shallow	4.7	SE Washington
January 1896		5.7	Puget Sound
March 1904		5.3	Olympic Peninsula, Eastside
January 1909	Deep	6.0	Puget Sound
August 1915		5.6	North Cascades
December 1918		7.0	Vancouver Island
January 1920		5.5	Puget Sound
July 1932	Shallow	5.2	Central Cascades
July 1936	Shallow	6.4	SE Washington
November 1939	Deep	6.2	Puget Sound
April 1945		5.9	Central Cascades
February 1946		6.4	Puget Sound
June 1946	Deep	7.4	Vancouver Island
April 1949	54 km	7.1	Puget Sound
August 1949		8.1	Queen Charlotte, B.C.
August 1959	35 km	5.5	North Cascades, Eastside
November 1962	18 km	5.3	Portland, Oregon
April 1965	63 km	6.5	Puget Sound
February 1981	7 km	5.8	South Cascades
April 1990	12.6 km	5.0	Deming
March 1993		5.6	Scotts Mills, Oregon
September 1993	Varies	6.0	Klamath Falls, Oregon
January 1995	16 km	5.0	Robinson Point
May 1996	7 km	5.3	Duvall
February 2001	52 km	6.8	Nisqually – Anderson Island
June 2001	40.7 km	5.0	Satsop
April 2003	50 km	4.8	Olympic Peninsula, Eastside
July 2004	29 km	4.9	Newport, Oregon
August 18, 2004	28 km	4.7	Newport, Oregon

Date	Depth	Magnitude	Approximate Location
January 2009	58 km	4.5	Poulsbo

Note: *Information obtained from the Pacific Northwest Seismograph Network (http://www.pnsn.org)*

Most of Washington's earthquakes occur within the Puget Sound region, between Olympia and the Canadian border, along the western side of the Cascade Mountains, and along the Washington-Oregon border. Distant earthquakes also affect Washington, such as the two Vancouver Island, B.C., quakes listed in Table 1 that were felt in Washington.

Damage caused by earthquakes is not limited to the obvious, such as architectural failure in buildings due to the heavy swaying created from an earthquake. Many deaths worldwide are the result of materials falling from buildings to sidewalks and streets below. Ground rupture along an active fault can also cause serious structural damage and disrupt transportation routes. Landslides can also be triggered by earthquakes, as can lateral spreading, which is similar to a landslide but occurs on relatively flat ground adjacent to a slope or waterbody resulting from the loss of lateral support due to seismic shaking. A potential hazard that is unique to Bellingham Bay is the potential for an earthquake-induced landslide on the face of the Nooksack River Delta. Such a landslide could generate a tsunami in Bellingham Bay and impact the Lummi Peninsula and Bellingham.

Liquefaction is another significant hazard that sometimes results from an earthquake, resulting in ground failure due to the loss of intergranular strength (bearing capacity) or liquefaction-induced settlement. Liquefaction and related phenomena have been responsible for tremendous amounts of damage in earthquakes around the world. Liquefaction occurs in saturated soils, when the pore spaces between individual soil particles are sufficiently filled with water. The shaking from an earthquake causes the pore water pressure within the soil to increase to the point where the soil particles readily move with respect to each other and the soil loses its ability to support structures. Once liquefaction has begun in an area, such as under a building, structural support to the foundation would be lost and the building would likely fail. Liquefaction is described in more detail in the "Geologic Hazards" section of this Plan.

Population-dense areas in Whatcom County could be significantly impacted by future earthquakes and their related hazards. The nature and extent of earthquake risk in Washington is determined by a variety of factors, such as estimating the level of predicted ground movement and identifying sites susceptible to ground rupture, enhanced seismic shaking, differential ground settlement from liquefaction, and tsunamis. Combining such hazard information with information concerning the distribution of population, types of building construction, and technological hazards in the County allows for assessing earthquake damage.

For this Plan, all the identified critical facilities are classified as affected by earthquakes since all of Whatcom County is at risk. Future revisions to the Plan will include each critical facility's building structure and more accurate assessments of vulnerability to earthquake danger. Seismic acceleration and response maps are periodically updated by the USGS as new research is published better defining local and regional seismic hazards, and is adopted by local building codes and incorporated in building design by structural engineers.

D. VULNERABILITY ASSESSMENT

The entire population of Whatcom County is vulnerable to the effects and impacts of an earthquake. An earthquake event in urban areas would involve especially elevated risk levels. Tall structures built on seismically-sensitive soils and fill are particularly at risk, due to the potential for liquefaction and lateral spreading. The earthquake risk in Bellingham and other coastal communities in Whatcom County is enhanced where saturated artificial fill was placed along the shoreline during the early to mid-1900's, or -where municipal garbage or wood waste was used as fill over tide flats.

Possible types of damage from an earthquake may include, but will likely not be limited to:

a. Cracking and/or structural failure of foundations, chimneys, decorative cornices, parapet walls, and cantilevered porches or roofs
b. Wall failure in older buildings of non-reinforced masonry construction
c. Damage to waterfront buildings and piers built on piles and artificial fill
d. Structural damage or failure of bridges
e. Damage to streets and roads
f. Damage to railways and airport facilities
g. Broken water lines and natural gas lines
h. Power and communication failures due to damage of electrical and telephone distribution systems
i. Failure of 'dry-stacked' retaining walls on steep slopes in areas of residential development

Examples of potential earthquake impacts to Whatcom County are provided in the five sections below.

1. Landslide Impacts

Landslides can be triggered by earthquakes or by a combination of geologic and climatic factors. The latter are discussed in more detail under Geologic Hazards. Landslides can directly damage a structure built on the landslide or in an area where landslide debris runs out and is deposited (including the base of a hill or an alluvial fan).

Earthquake-induced landslides could impact various locations throughout the County. A lahar (a mud flow originating from a volcano) from Mount Baker could also be triggered during an earthquake. Depending on the specific area of initial failure, the lahar could flow into Baker Lake and cause damage in the Skagit River system or could flow down either the North or Middle Forks of the Nooksack River reaching as far as Sumas and Bellingham Bay. For details regarding lahars, see the "Volcanic Hazards" section of this Plan.

Examples of other locations that may experience earthquake-related landslide include: the Chuckanut Mountains and Chuckanut Drive residential areas built on steep slopes in Bellingham and Sudden Valley; development and roads on or below steep slopes, or within the run-out zone (including alluvial fans) for landslides (such as Nelson Road on the west side of the Van Zandt Dike and Slide Mountain near Kendall); the Mount Baker Highway east of Deming; State Route 9 south of Acme; unstable coastal bluffs on Lummi Island, the Lummi Peninsula, Point Roberts, Cherry Point, Point Whitehorn, Semiahmoo, and Drayton Harbor; Sehome Hill and the Western Washington University campus; and Sumas Mountain. Landslides could also occur on the steep face of the Nooksack River delta in Bellingham Bay, displacing water and sending waves across the bay. This list is intended to illustrate the range of locations where landslides could happen and is not an inclusive list of all possible locations.

The recently published *Landslide Inventory of Western Whatcom County*, produced by the Washington State Department of Natural Resource Geology and Earth Resources, provides a highly improved methodology for the identification of deep-seated landslides discernable by LIDAR image analysis. The inventory identifies both active and dormant (or relict) landslides, and enhanced shaking associated with a large magnitude seismic event has the potential to reactivate dormant deep-seated landslides as well as accelerate or further destabilize currently active deep-seated landslides. Not included in the inventory is the likely location of shallow translational landslides (generally defined as not deeper than the vegetation rooting zone). This type of slope failure does not typically produce geomorphic features discernible in LIDAR and is commonly identified through GIS-based slope stability modeling that determines slope conditions susceptible to shallow failure, and subsequent modeling to determine run-out potential. Neither products are currently available in Whatcom County. The inventory does, however, delineate the location of alluvial fans, which can serve as a proxy for the likely run-out potential for shallow translational landslides, and these areas should be considered susceptible to earthquake-induced landslides, especially if seismic activity coincides with an extended period of wet weather resulting in saturated soil conditions. Additional information on hazards common to alluvial fans is included under 'Landslides' in the section on Geological Hazards, below.

2. Transportation Impacts

Bridges are the most vulnerable component of highway systems, such as the I-5 overpasses. Bridge foundations in liquefiable soils can move, allowing the spans they support to fail. Areas at significant risk are Roeder Avenue bridges near Georgia Pacific and over Whatcom Creek Waterway; I-5 over Whatcom Creek; the Mount Baker Highway at Cedarville and Everson; Highway 9; and Guide Meridian and Hannegan Road bridges over the Nooksack River. An additional impact is that supporting columns can buckle.

1. Railways. Railway bridges have performed well in earthquakes, but may be subject to liquefaction, such as those along the Bellingham waterfront. Additionally, landslides may cover the tracks.
2. Airports. The Bellingham Airport runway is at low to moderate susceptibility to liquefaction.
3. Pipelines: Water, Wastewater, Liquid Fuel, Natural Gas. Water pipelines commonly fail in earthquakes, quickly draining the water system, making water unavailable for fire suppression, drinking, toilet flushing, etc. Sewer pipelines are often gravity systems and a change in grade can impact system operation. The sewer lines relying on pumps will not work if there is no electric power. These sewer pipelines are vulnerable to flotation if the ground around them liquefies. Liquid fuel and natural gas pipelines that are constructed of steel with welded joints have performed well in earthquakes, except in extreme conditions. The high-pressure lines are made of welded steel or polyurethane plastic, which are flexible. Pipelines constructed of brittle materials are the most vulnerable. Water and older gas distribution systems contain brittle materials, such as cast iron and asbestos cement. Additionally, pipelines buried in liquefiable soils or landslide areas may fail. For example, landslide movement was a likely factor in the rupture, explosion, and fire in 1997 of a natural gas pipeline on Sumas Mountain.

E. MITIGATION STRATEGIES

Earthquakes have long been feared as one of nature's most damaging hazards. Earthquakes occur without warning and, after only a few seconds, leave casualties and damage. Therefore, it is important that each person and community take appropriate actions to protect lives and property.

Although earthquakes cannot be prevented, current science and engineering provide tools that can be used to mitigate the damage. Scientists can now identify, with considerable accuracy, where earthquakes are likely to occur and what forces they might generate. Modern engineering has resulted in design and construction techniques that allow buildings and other structures to survive the tremendous forces of earthquakes.

In May 2021 ShakeAlert will be deployed in Washington State by the United States Geological Survey. The system allows the identification of hazardous seismic events and automatically triggers warning systems and alerts registered mobile phones. In the event of a Cascadia Subduction Zone Earthquake, centered 200+ miles west of Whatcom County, many tens of seconds warning time can be provided, allowing for individuals to evacuate or shelter in place prior to arrival of initial seismic wave. Additional mitigation can be achieved through the cessation of construction activities, transportation, industrial processes and other critical activities such as medical procedures. It is important to note that earthquakes generated on local crustal faults may produce lesser magnitude seismic events, but may be associated with more intense, although often shorter duration, ground shaking. Furthermore, early detection systems would only be capable of providing a few seconds of early warning for near-source earthquakes, which is commonly considered ineffective to deploy seismic hazard mitigation measures.

FEMA's National Earthquake Hazards Reduction Program (NEHRP) has four basic strategies related to the mitigation of hazards caused by earthquakes:

1. Promote understanding of earthquakes and their effects
2. Work to better identify earthquake risk
3. Improve earthquake-resistant design and construction techniques
4. Encourage the use of earthquake-safe policies and planning practices

Further study of earthquake behavior and better delineation of shallow crustal fault location, extent, potential earthquakes magnitude and recurrency interval will lead to improved preparation and response to earthquakes.

Selected Works Cited:

Atwater, Brian F.; Musumi-Rokkaku, Satoko; Satake, Kenji; Tsuji, Yoshinobu; Ueda, Kazue; Yamaguchi, David K. (2015) [2005]. The orphan tsunami of 1700—Japanese clues to a parent earthquake in North America (in English and Japanese) (Second ed.). USGS. doi:10.3133/pp1707.

Sherrod, B.L., Barnett, E., Schermer, E., Kelsey, H.M., Hughes, J., Foit, F.F., Weaver, C.S., Haugerud, R., and Hyatt, T., 2013, Holocene tectonics and fault reactivation in the foothills of the north Cascade Mountains, Washington: Geosphere, v. 9 , p. 827–852, doi:10.1130/GES00880.1.

Kelsey, H. M., B. L. Sherrod, R. J. Blakely, and R. A. Haugerud (2012), Holocene faulting in the Bellingham forearc basin: Upper-plate deformation at the northern end of the Cascadia subduction zone, J. Geophys. Res., 117, B03409, doi:10.1029/2011JB008816.

Amadi, Eric Ejike, "The 1990 Nooksack Forks, Washington, Earthquake Sequence: Sequence Geometry and Temporal Characteristics" (1992). Boise State University Theses and Dissertations. 470.

FLOODING

A. DEFINITIONS

Avulsion The rapid abandonment and of a river channel and formation of a new channel.

Flood An inundation of dry land with water caused by weather phenomena and events that deliver more precipitation to a drainage basin than can be readily absorbed or stored within the basin. The NFIP defines a flood as a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties.

Floodplain The land area of a river valley that becomes inundated with water during a flood.

National Flood Insurance Program A federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding. The NFIP is designed to provide insurance as an alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their content caused by floods. When a community chooses to participate in the NFIP, they agree to adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction in Special Flood Hazard Areas. In exchange, the federal government agrees to make flood insurance available within the community as a financial protection against flood losses.

B. BACKGROUND INFORMATION

The natural hazard of most concern to Whatcom County, primarily due to its frequency, is flooding. Several types of flood hazards affect Whatcom County including:

a. Overbank flooding and erosion on the Lower Nooksack River downstream of Deming
b. Overbank flooding and erosion on the three main forks of the Nooksack River upstream of Deming (North, Middle, and South Forks)
c. Debris flows and debris floods on alluvial fans throughout the County (see the “Geologic Hazards” section for more information)
d. Coastal flooding (see the “Coastal Flooding” section for more information)

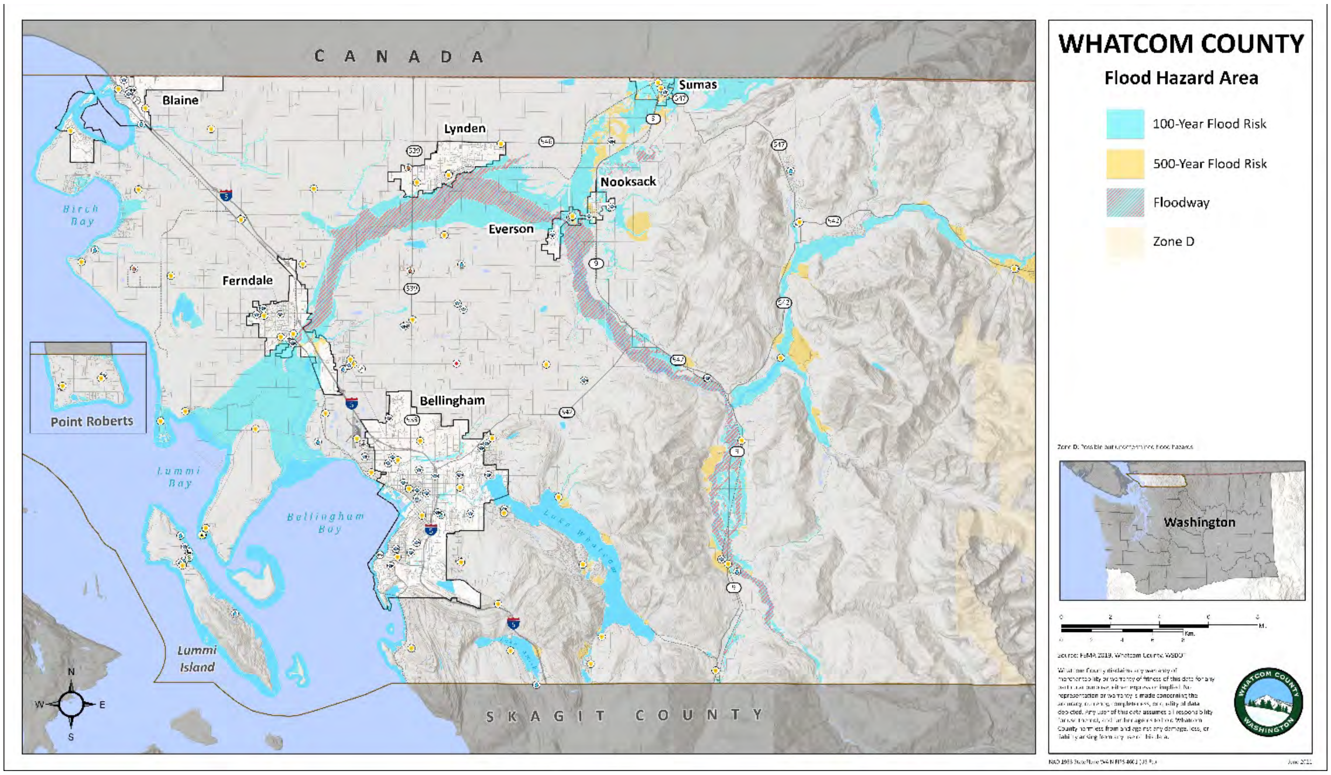
e. Tsunamis or tidal flooding associated with earthquakes (see the “Tsunamis” section for more information)

The communities located within Whatcom County that are currently participating in the NFIP include:

a. City of Bellingham (#530199)
b. City of Blaine (#530273)
c. City of Everson (#530200)
d. City of Ferndale (#530201)
e. City of Lynden (#530202)
f. City of Nooksack (#530203)
g. City of Sumas (#530204)
h. Lummi Indian Reservation (#530331)

Whatcom County (#530198) Whatcom County contains 63.6 square miles of floodplain area, which equals 3 percent of the entire land area. Whatcom County currently holds 994 flood insurance policies and has filed 307 claims through January 31, 2020. Due to privacy concerns, annual information regarding this number is no longer provided by FEMA. FEMA maintains information on repetitive flood loss properties (RFLs) within each community participating in the NFIP. RFLs are properties for which two or more NFIP losses of at least $1,000 each have been paid within any 10-year period since 1978. As of 2020, there were 17 RLP properties within Whatcom County and seven RPL properties that have been mitigated.

Whatcom County also participates in the NFIP Community Rating System (CRS), implemented in 1990 as a voluntary program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP standards. The CRS entry date for Whatcom County was October 1, 1996; since that time, Whatcom County has received enough points to be qualified as a credit class 6 (out of 10), meaning property owners in the floodplain receive a 20 percent discount on flood insurance premiums. Flood hazard areas in Whatcom County can be seen in the map below.



FEMA 2019 flood hazard data showing 100-year flooding, 500-year flooding, floodways, and flood zones. FEMA flood data includes both riverine and coastal flooding.

1. Lower Nooksack River

The primary flooding source affecting Whatcom County residents is the Lower Nooksack River, from Deming to Bellingham Bay. In 1999, the Whatcom County FCZD adopted the *Lower Nooksack River Comprehensive Flood Hazard Management Plan* (CFHMP), which serves as the primary source of information for this flooding summary. This plan is currently being updated through a multi-year collaborative process integrating flood needs with the needs of salmon and floodplain land uses. The results of this new planning process will be incorporated into this plan during a subsequent update.

The Nooksack River watershed is primarily located within the Cascade foothills at the base of the Cascade Mountain Range. The Lower Nooksack River begins at the confluence of the North, South, and Middle Forks and extends down to Bellingham Bay. The watershed encompasses approximately 825 square miles over an elevation range of 10,781 feet to sea level. The Cascade foothills receive more rainfall than the flatter, western lowlands of the County. This precipitation, combined with the steep slopes of the watershed in the foothills and size of the upper watershed, contribute to the conditions that allow floodwater to quickly reach the flat lower river reaches. The devastating and frequent flooding in 1989 and 1990 prompted Whatcom County residents and government to find solutions to perennial flood problems. Because of severe damages occurring along the Lower Nooksack River floodplain, this area was the focus of initial planning efforts and development of the CFHMP.

The Lower Nooksack River is divided by river reach in the CFHMP as described and as shown in Table 2. The five reaches begin with Reach 1 at the mouth of the Nooksack and move upstream to Reach 5.

Table 2
River Reach Descriptions

	River Mile	River Channel		100-Year Floodplain	
		Length (miles)	Gradient (ft/mile)	Area (mi2)	Width (avg. miles)
Reach 1	0 to 6.0	6.0	1.8	13.8	2.8
Reach 2	6.0 to 15.3	9.3	2.3	8.3	1.1
Reach 3	15.3 to 23.6	8.3	4.9	12.0	1.9
Reach 4	23.6 to 26.6	13.0	21.3	7.5	1.3
Reach 5	---	13.2	4.5	21.5*	22.5**

Notes: ** Drainage Area ** Average Creek Width*

Reach 1 includes the area from the mouth of the Nooksack River to Ferndale west to Haxton Way, including a portion of the Lummi Indian Reservation. Reach 1 is physiographically diverse and includes a complex delta estuary, a broad flat plain, and two large, shallow ponds, Tennant Lake and Clay (Brennan) Pond. Both sides of the river are diked, either directly along the existing river channel or set back a short distance from the bank. The banks are heavily riprapped, especially adjacent to the levee.

Reach 2 extends from the I-5 Bridge at Ferndale to the Guide Meridian Bridge, just southwest of Lynden. The river channel is characterized by looped meanders, and relatively small gravel bars. Natural topography along the river includes discontinuous natural levees formed by sediments deposited during flooding. Constructed levees confine the river to a narrow channel along much of Reach 2. A portion of the river in and upstream of Ferndale is not diked.

Reach 3 includes the portion of the Nooksack River between the Everson Bridge and the Guide Meridian Bridge and marks the transition from the braided, unstable channel upstream to the more stable, meandering river channel and broader floodplain that are typical downstream.

each 4 is the uppermost reach in the CFHMP study area. It extends from the Everson Bridge to the confluence of the Middle, North, and South Forks at Deming. This reach is noticeably different than the lower reaches, primarily because of the steep slope of the active channel. Not only does the channel split into multiple paths at many locations, forming a braided channel, but over time it moves laterally across the floodplain.

Reach 5 is not actually a part of the Nooksack River mainstem, but is a flood overflow corridor originating at the Nooksack River, near Everson, and flowing north to the United States/Canada border. At the City of Everson, a low divide separates the Nooksack River basin from the Sumas River basin, where waters flow northward to the Fraser River in B.C. During large floods in the Nooksack, floodwaters flow along the corridor of Johnson Creek through the City of Sumas and over the international border into Abbottsford, B.C.

Flooding Causes

Many factors combine to cause flooding along the Lower Nooksack. River gradient and weather patterns are some of the more significant factors.

River Gradient that Affects Flooding – One of the most important characteristics of the Lower Nooksack River is the change in river gradient from Deming to Bellingham Bay. As mentioned previously, Reach 4 is steep and constantly migrating within a narrow floodplain. Within Reach 4, many abandoned side channels can accommodate floodwaters. In contrast, the lower reaches are flatter with wider floodplains. Side channels in Reaches 1, 2, and 3 have largely been filled and replaced with agricultural fields. Levees have been constructed along these reaches to protect fields, farmhouses, and roadways.

Weather Patterns that Cause Flooding -Heavy fall and winter rainfall in Whatcom County results from an effect called orographic lift. This heavy rainfall, along with the large area feeding into the Nooksack River and extreme slopes, results in large amounts of runoff that quickly reach the flat floodplains along Reaches 1, 2, and 3. Rainfall varies across the watershed and is significantly greater in the mountains. During the 1990 Veterans Day flood, approximately 14 inches of rain fell in the upper reaches of the watershed over 3 days, with snow melt adding an extra 2 inches. During the same storm, Bellingham only recorded 5 inches of rain.

The worst flooding tends to occur during the “Atmospheric River” weather pattern of the fall and winter. Atmospheric river fronts bring warm, wet air into the watershed, resulting in heavy rainfall. If snow has accumulated in the mountains when the warm rains begin, snowmelt can increase runoff to the river. As the snowpack builds through winter, it can also act as a "sponge" during intense rainfalls, storing water and attenuating flood peaks. Runoff is most severe when preceding steady rains have saturated soils within the watershed. Together, the conditions of heavy rain, early snowpack, and saturated soils create the potential for severe flooding.

2. Upper Forks of Nooksack River

The North, Middle, and South Forks of the Nooksack River comprise the upper watershed for the Lower Nooksack River. The headwaters of the North and Middle Forks originate on the flanks of Mount Baker while the South Fork drains the Twin Sisters range, resulting in steep mountainous terrain in their upper basins. The lower portions of the forks include flatter valleys as the rivers drain off the Cascade Foothills and enter into broader valleys shaped in part by past glacial activity.

The North Fork of the Nooksack River generally experiences higher snowfall amounts, which can act to absorb some runoff associated with heavy rainfall and attenuate flood peaks. The South Fork has much of its upper basin at lower elevations than the North Fork and generally responds more quickly to a storm event. During weather patterns like the atmospheric rivers all three forks can experience significant flooding.

Due to the mountainous terrain in their upper watersheds, all three forks have significant sediment sources. As the sediment is routed through the systems, significant channel migration can occur, putting public infrastructure and private property at risk.

3. Coastal Flooding

High winds off the coast combined with high tides and low atmospheric pressures can result in coastal flooding along the western edge of Whatcom County. The main coastal communities impacted by coastal flooding are Sandy Point, Birch Bay, Point Roberts, and Lummi Peninsula. Damages can include structural damage to residences and seawalls as large debris is carried by waves hitting the shoreline, inundation damage to structures, and debris accumulation and flooding of roadways. In some areas where the shoreline is a bluff, coastal erosion and/or improper drainage can threaten the structural integrity of residential structures and the stability of the bluff itself. See the Coastal Flooding Section below.

C. RECENT HISTORY IN WHATCOM COUNTY

1. Lower Nooksack River

Table 3 lists the largest recorded Lower Nooksack River floods as recorded at the Deming/Cedarville and Ferndale stream gages.

Table 3. Largest Recorded Nooksack River Flood Events

Date	Deming Flow* (cfs)	Ferndale Flow (CFS)	Overflow in Everson causing Flood Damage
1/25/1935	39,600	---	Yes
10/25/1945	38,000	41,600	Yes
11/27/1949	36,500	27,500	Yes
2/10/1951	43,200	55,000	Yes
11/03/1955	38,500	35,000	Yes
1/30/1971	---	38,100	Yes
12/3/1975	40,300	46,700	Yes
12/15/1979	---	36,400	No
1/4/1984	---	41,500	Yes
11/23/1986	---	36,000	No
11/9/1989	36,500	47,800	Yes
11/10/1990	37,900	57,000	Yes
11/24/1990	35,100	56,600	Yes
10/17/2003	50,800	39,900	No
11/24/2004	53,200	42,300	No
11/6/2006	56,300 (Cedarville)	38,100	Yes
1/9/2009	50,700 (Cedarville)**	51,700**	Yes
12/12/2010	44,500 (Cedarville)	38,200	No
1/17/2011	42,600 (Cedarville)	36,300	No
11/17/2015	40,800 (Cedarville)	27,000	No
2/1/2020	37,400*** (Cedarville)	37,000	Yes

* The Deming gage is subject to significant bed instability during flood events. Peak flows reported for Deming are prone to error. In 2005, the Deming gage was replaced with the Cedarville gage, located 5.2 miles downstream.

** Hydraulic modeling and comparison of simulated results to observed conditions suggests that the actual flow passing the Deming gage was likely closer to 63,000 cfs during the 11/10/1990 flood, illustrating the potential error in the Deming gage record.

*** USGS flow data for the 2/1/2020flood event is provisional; hydraulic model calibration is ongoing and suggests that the flows at Cedarville may have been higher than reported.

2. Upper Forks of Nooksack River

Generally, the same weather patterns that cause flooding on the lower Nooksack River also result in flooding conditions on one or more of the three upper forks. These same weather patterns can cause landslides that can form temporary landslide dams when they enter tributaries to the forks. Floods much larger than might be expected for a stream of that size can result when the dams breach. These tributary floods may not be easily detected at a gauging station in the fork itself or downstream due to the relatively larger capacity of the fork floodplain.

D. VULNERABILITY ASSESSMENT

Understanding existing flood patterns, and the relationship between flooding and existing flood management structures, provides a basis for predicting circumstances of future flood events.

1. Lower Nooksack River

The following summary describes historic flooding patterns and problems of the Lower Nooksack River. Please note that right and left bank locations are designated facing downstream.

Reach 1 Flooding Patterns

> Ferndale Area – The residential area on the right bank upstream of the Burlington Northern Railroad bridge experiences flooding during major events, as do commercial properties along Main Street on the left bank and a former golf course. Based on the results of recent modeling analyses, most of the right bank levee in Ferndale extending downstream from the Main Street bridge provides protection from floods as large as the 100-year event, except for a gap located adjacent to the two water treatment facilities operated by City of Ferndale and the PUD. Significant flood fighting efforts near the water treatment plants were necessary in 1990 to and 2009 to prevent floodwaters from overtopping Ferndale Road. The City has filled the gap in the levee with super sacks (large sand bags) as an interim measure until a more permanent solution can be implemented.

> Right Bank Downstream of Ferndale – Flooding at Marine Drive and Ferndale Road is frequent, beginning with events of low magnitude. Levee breaks result in inundation of Haxton Way, cutting off access to the Lummi Peninsula and Lummi Island. Other sites of right bank flooding along the reach depend upon levee protection. Levee breaches downstream of Slater Road generally result in flooding between the Nooksack River and

Lummi (Red) River south of Slater Road.

Left Bank Downstream of Ferndale – Floodwaters overtop the left bank between Slater Road and Marine Drive annually; if overtopping is of a long enough duration, both roadways can be flooded. At slightly higher flows, as the river rises to the approximate 5-year flood level, floodwaters also overtop high ground and levees immediately downstream of Ferndale in Hovander Park. Floodwaters travel through Hovander Park toward Tennant Lake and continue south toward and over Slater Road.

Marietta – Marietta experiences the most frequent flooding of any residential area along the Nooksack River and is susceptible to tidal influences that contribute to flooding. A levee surrounds Marietta, but is low and in poor condition, making it susceptible to overtopping and breaching. In both 1990 and 2009, Marietta residences sustained significant flood damage and residents were evacuated.

Overflow to Lummi Bay – Floodwaters flowing west toward Lummi Bay are stopped by the seawall and accumulate despite the two sets of culverts that drain the seawall. Floodwaters can overwhelm the capacity of the seawall, leading to seawall breaches, and allowing saltwater to flow inland when floodwaters recede. A set of six 48–inch-diameter culverts near the Lummi (Red) River mouth draining the area south of the river were replaced with five 6-foot by 4-foot box culverts in 1998. Tide gates in the culverts prevent saltwater from flowing inland as the tide rises. Three 5-foot by 5-foot box culverts drain the area north of the river.

Reach 2 Flooding Patterns

Overflows from Reach 3 – Floodwaters enter Reach 2 from Reach 3 under the Guide Meridian through the main channel bridge and overflow bridges north and south of the river in the floodplain. Main channel and left bank overflows are constricted by high ground on the left bank and levees along River Road on the right bank. Left bank overflows encounter a short section of levee and the natural high ground close to the river bank very shortly after passing under the south overflow bridge. The levee and high ground push the left bank overflow waters back into the river and toward right bank levees. Numerous historical breaches in the River Road levee are attributed to this constriction.

Right bank overflows enter Reach 2 behind the River Road levees through the north overflow bridge. Overflows reach levees along Fishtrap Creek, which funnel floodwaters south, closer to the main river channel, and on toward Bertrand Creek. These flows can be augmented by overflows through breaches in levees along River Road.

Fishtrap Creek – Flood overflows pass from Reach 3 to Reach 2 through the north overflow bridge under Guide Meridian. Floodwaters encounter levees along Fishtrap Creek, which extend from just below Guide Meridian approximately 1.8 miles downstream. The levees limit bank overflows, but do not contain floodwaters during large flood events. The levees along both Fishtrap and Bertrand Creeks are intended to protect agricultural lands from spring flood events, but are not meant to provide protection during large flood events.

Bertrand Creek – Floodwaters that pass Fishtrap Creek reach Bertrand Creek, which is lined with levees on both sides. The Bertrand Creek levees are approximately perpendicular to flood flows, which causes floodwater to back up onto farmlands upstream of the creek. As a result, high velocity flows cause overtopping and levee breaches during almost every flood event. In 2006, the levees along Bertrand Creek were lowered and set back to reduce the frequency of levee failures and to lower upstream flood levels.

Left Bank Overflow Corridor – Levee overtopping has historically occurred on the Vanderpol property immediately downstream of the high ground on the left bank; floodwaters follow a natural overflow corridor along the reach. Left bank levees offer varying levels of protection, and floodwaters historically have overtopped the levees at various locations. Approximately two miles upstream of the I-5 bridge, near Lattimore Road, higher topography along the left bank guides floodwaters back into the river channel. A short distance upstream, a levee on the Appel property blocks flow returning to the river and has experienced repeated overtopping and failure.

Right Bank Downstream of Bertrand Creek – Floodwaters that pass Bertrand Creek continue along the right bank corridor to approximately the I-5 corridor. Levees offer sporadic protection along the right bank for three miles downstream of Bertrand Creek, but no levees are in place for the last three miles of the reach. Random overtopping of levees and river banks is typical.

Ferndale Area – Residential and commercial urban development is encroaching into the 100-year floodplain, increasing the possibility of flood damage. Several multifamily units and a commercial building have been constructed on the west side of the rivers downstream of the Main Street Bridge. Other developments in this location includes a new Park (Star Park) and several new buildings associated with Ferndale's Water

Treatment Plant. To the west of the Main Street Bridge, several commercial buildings, including 2 fast-food restaurants have been constructed.

Reach 3 Flooding Patterns

Levees along both banks have been built and repaired over the years by a variety of public agencies and private property owners, with no coordination of design and sometimes limited maintenance, resulting in a levee system prone to unpredictable breaches and misdirection of flows from natural overflow corridors and floodwater storage areas. Roadway overtopping is common, and floodwaters often remain trapped in depressional areas long after the flood peak passes. Bank erosion has historically been a problem.

Overflows in the Upper Portion of Reach 3 – Natural overflows exist on both banks north of Nolte Road, immediately downstream of Everson. Right bank overflows travel north toward Mormon Ditch and Kamm Creek. During large floods, this flow continues downstream over Hannegan Road, past the Lynden waste water treatment plant, and through the Guide Meridian north overflow bridge. Left bank overflows travel south to Scott Ditch, then west, and return to the river through Scott Ditch or through the south overflow bridge at Guide Meridian.

Hampton/Timon Road Area – The right bank near Northwood Road is a natural overflow. Floodwaters flow north toward Mormon Ditch and Kamm Creek. Floodwaters from upstream overflow on both banks, inundating and damaging roadways in their path, including Timon Road, Slotemaker Road, and Hampton Road on the right bank; and Noon Road, Polinder Road, and Abbott Road on the left bank. Six residences located near the confluence of Kamm Creek along Hampton Road are impacted by right bank overflows as well as by backflows from the Nooksack River up Kamm Creek.

Polinder Road Area – Two farmable levees have been constructed to overtop on the left bank above Polinder Road:

a. North of the intersection of Polinder and Thiel Road on the Bedlington property
b. The river bend just east of Hannegan Road on the Polinder property

Floodwaters from both overflows travel southwest toward Scott Ditch and the south overflow bridge at Guide Meridian.

Scott Ditch – Scott Ditch serves as a conduit for flows leaving the Nooksack's left bank along most of Reach 3.

Lynden Wastewater Treatment Plant – The floodplain is constricted by natural topography as well as structures built in the area west of Hannegan Road. Floodwaters that overtop Hannegan Road must flow either back into the river upstream of the treatment plant or around the north side of the treatment plant and over the plant access road. As floodwaters recede, water backed up between the treatment plant and Hannegan Road drains back to the river by way of a ditch that begins east of the plant, is conveyed through a box culvert under the plant access road, and in a 48-inch culvert through the right bank river levee. The 48-inch levee culvert is failing and is not equipped with a floodgate and water can back up through the culvert when the river rises. Efforts to replace this culvert with a new side-hinge flood gate and upstream habitat improvements are underway with construction planned for 2021.

BC Avenue Area – On the right bank downstream of the treatment plant, there was an overflow on the Stremler property south of BC Avenue in Lynden. The levee at this overflow was restored, strengthened, and raised by the USACE to prevent future overtopping after the 1990 floods.

Bylsma Road Area – There is an overflow on the left bank between Bylsma Road and the confluence of Scott Ditch and the river. Levees on the right bank opposite this overflow historically overtop.

Guide Meridian Overflow Bridges – The Guide Meridian was supported on piles to let floodwaters pass beneath, through the Nooksack River floodplain, until around 1950. Floodwaters are now conveyed through overflow bridges that convey a significant portion of Reach 3 overflows downstream to Reach 2. As floodwaters pass through these narrow openings, flow velocity increases, potentially threatening the structural integrity of the bridges.

Reach 4 Flooding Patterns

With the relatively narrow floodplain and unstable, rapidly migrating river channel in Reach 4, the primary flood hazards are bank erosion and the threat of avulsion.

The Deming Area – At Deming, the river channel has migrated across the floodplain in the last two decades. Aerial photos show that in 1975, the river flowed on the opposite side of the floodplain from the community. By 1986, the river had moved 600 feet across the floodplain to its present location. Recent Nooksack River flooding has threatened the Mount Baker School District bus maintenance and sewage treatment facilities, along with the Walton properties along Deming Road on the right bank. At-risk properties are protected by riprap armoring. Immediately downstream of the riprap protection, erosion occurs on the left bank from deflected flows from the right bank riprap.

Mariotta Road Area Right Bank – An overflow was created during 1990 floods in the vicinity of Mariotta Road by overtopping and eroding the right bank, resulting in bypassing of the existing river bend. Approximately one-third of the river's flow followed this new channel. Floodwaters returned to the main channel approximately 0.5 mile from Mariotta Road. After the 1990 flood, 2,000 feet of bank was restored and new riprap was placed along the right bank to prevent a similar future overflow. A bottleneck immediately downstream of the overflow creates stress on the left bank at an area known as the "Clay Banks." By preventing right bank overflows, the new riprap increases the force of floodwaters on the left bank downstream. The bottleneck created by accumulated sediment on the Sande property, on the inside of the river bend in this area (right bank), increases the force of flow on the left bank. Floodwaters that overflow the right bank between Deming and Nugent's Corner generally follow low topography and swales toward Smith Creek.

Left Bank – The left bank across from Mariotta Road is a steep hillside of silty clay soil that has been increasingly eroding. Slides from this hill have added silt, clay, and other sediment to the river. As the river undercuts the slope, the land sinks and slides. Groundwater seepage along the face of the hillside may also be destabilizing the slope. As the bluff fails, material accumulates at the base of the slope and this material acts to stabilize the slope for a period of typically 5 to 7 years. During this period, the river erodes through the accumulated material at the base of the bluff and causes the bank to become oversteepened and significant bluff failures resume. In 2006, significant bluff failures occurred, causing owners of two houses at the top of the bluff to abandon them when bank failures encroached too close to the structures. Bluff failures on February 14, 2014 and the night of February 20-21, 2014 were large enough that landslide debris temporarily blocked the Nooksack River each time. The latter event caused the downstream Cedarville stream flow gage to fall from ~2250 cfs to 400 cfs in a matter of minutes. Flows at the gage resumed a few hours later as the river reoccupied old channels along the opposite bank and cut around and through the landslide deposits.

Nugent's Corner – Flood fighting efforts in 1990 directed floodwaters around the commercial area, following a system of natural channels, but floodwaters damaged some sections of the community's residential area.

Mount Baker Highway Bridge – The Mount Baker Highway bridge at Nugent's Corner is the only bridge over the river in Reach 4. A flood in 1989 washed out the left bank approach to this bridge. Riprap was subsequently placed on the upstream side of the left bank bridge abutment to protect it. WSDOT replaced the bridge in approximately 2000.

Nugent's Corner to Everson – The river migrates across the floodplain between Nugent's Corner and Everson more than in any other river reach. Channel migration has resulted in erosion and loss of private property, primarily agricultural lands. Bank erosion is limited on the left bank, but the right bank has been heavily impacted by bank erosion. The channel capacity and natural terrain between Nugent's Corner and just upstream of Everson is high enough that floodwaters do not overtop the right bank along most of the section. During larger flood events, however, flood waters overtop the high ground divide, separating the Nooksack River and Sumas River basins, to flow toward Sumas, and sometimes into Canada.

Riverberry-Davis-Vandellen Properties – The Riverberry property includes a farm located approximately halfway between Everson and Nugent's Corner on the right bank. The river eroded between 30 and 40 acres of this site between 1985 and 1993, and an estimated additional 300 feet since that time. The river has meandered eastward approximately 250 linear feet (LF), eroding raspberry and pasture farmland. The continued erosion was diminishing the natural overbank high ground, which was the basin divide between the Nooksack and Sumas basins, increasing the frequency of overland flow and potential for channel avulsion into the Everson–Sumas Overflow Corridor.

In 1997, Whatcom County completed a pilot project to provide fish habitat and bank stabilization on the property. The Riverberry-Davis site, approximately 2,200 LF, incorporates four rock deflectors and four dolo-rock deflectors with woody debris placed between the structures. The Vandellen site, approximately 900 LF, incorporates large organic debris and timber pilings to construct 19 deflector structures.

Everson Overflow Area – The high ground along the right bank south of Everson Road near Massey Road and upstream to the Vandellen property is the area where much of the overflow to Everson originates. The elevation of the riverbank is the first hydraulic control affecting the amount of flow that leaves the Nooksack basin. Emmerson Road serves as a secondary control as some of the flow overtops the road and flows north while the rest of the flow is channeled back to the river by the levee constructed to protect Everson after the 1990 flood. In 2006, the revetment protecting the high ground divide east of Emmerson Road was reconstructed to prevent erosion of the high ground control.

Left Bank Overflow Corridor Opposite Everson – The river has historically overtopped a left bank levee immediately upstream of Everson. Floodwaters follow the low topography through agricultural areas for approximately 1 mile prior to flowing through a large arch culvert under Everson-Goshen Road (SR 544) and returning to the river.

Reach 5 Flooding Patterns

Floodwaters leave the river channel and overflow through Everson at three locations:

1. South (upstream) of Massey Road
2. Along Emerson Road between Massey Road and Everson
3. Approximately 1,500 feet upstream of the Everson Bridge

Floodwaters from the three overflow sites combine after crossing Massey and Emerson Roads and flow northward over Main Street in Everson and into the Johnson Creek basin. A railroad embankment prevents floodwaters from entering the Sumas River until they reach the vicinity of the City of Sumas. During small overflow events, floodwaters pass over fields and enter a drainage ditch that empties into Johnson Creek just north of Lindsay Road. During major events, floodwaters fill Johnson Creek's valley floor and continue to Sumas, typically flooding the downtown area with several feet of water.

Everson – All major Nooksack River floods cause flooding in Everson. Floodwaters generally flow into Everson from the south along Washington Street and from the overflow area to the east. After the 1990 flood, a 1,000-foot levee, referred to locally as Lagerway Dike, was constructed immediately south of Everson. The levee provides some flood protection but is not high enough to prevent Everson from being flooded during a large overflow.

Sumas – During major floods, flows top the divide between the Nooksack and Sumas watersheds and flow north in the floodplain along Johnson Creek, eventually reaching the city of Sumas. Floodwaters often cross the United States/Canada border within hours of an overflow occurring in Sumas.

Sumas Prairie/Abbotsford (B.C.) – After passing through Sumas, floodwaters cross the border into the District of Abbotsford and along the Sumas River, overtopping the Sumas River's left bank. Floodwaters have historically backed up from the Whatcom Road interchange of the TransCanada Highway and ponded in the western portion of Wet Sumas Prairie, with some floodwater ponding in the Lower Sumas River, Saar Creek, and Arnold Slough. A dike prevents flooding of the reclaimed Sumas Lake Bottom, a prime agricultural area.

Avulsion Potential at Everson – It is possible that an avulsion would redirect all or a portion of the Nooksack River from its present path to a northward path along the Johnson Creek corridor. The Johnson Creek corridor drops an average of 6 feet per mile over its 10-mile course, a slope twice as steep as the 3-foot-per-mile drop of the Nooksack River. This steeper slope enhances the tendency toward an avulsion. Geologic evidence indicates the Nooksack River previously flowed north at Everson into the Sumas River and Frasier River Basins.

A study commissioned by the B.C. Ministry of Environment, Lands, and Parks predicts the Nooksack River's right bank would have to erode 820 feet at a critical location for an avulsion to occur, and estimates the likelihood of this is 20 percent during a 100-year flood, a statistical occurrence of once every 500 years.

2. Upper Forks of Nooksack River

North Fork – The Mount Baker Highway (SR 542) runs parallel to the North Fork Nooksack River for much of its length. Channel erosion threatens the highway at several locations; WSDOT has constructed several projects to protect the highway, most recently in 2015, and is considering options to relocate the highway at several other locations with chronic bank erosion or flooding problems. The Mount Baker Highway crosses the North Fork at two locations. Portions of the highway are also subject to inundation during significant flood events, primarily near Maple Falls.

County roads that have the potential to be threatened by the North Fork include Truck Road, Rutsatz Road, and North Fork Road. Emergency projects were implemented to protect Rutsatz Road in 2016 and Truck Road in 2018. The 2020 flood caused additional damage to Truck Road. Bridges cross the river along Mosquito Lake Road and SR 9, just upstream of its confluence with the South Fork. Channel erosion and overbank flooding also affect rural residential and agricultural properties along the river.

Several tributaries to the North Fork also have the potential to flood SR 542 including Glacier, Gallup, Cornell, Canyon, Boulder, and Maple Creeks. Flooding at Boulder Creek in the mid-1980s closed the highway for days, stranding hundreds of residents and skiers east of the road closure.

Middle Fork – While the Middle Fork generally runs parallel to Mosquito Lake Road, it is far enough away along most of its length that it does not pose a threat to the roadway. In 2004, the river eroded close enough to the road at one location upstream of Porter Creek that the roadway was undermined. Whatcom County relocated a section of roadway away from the failing slope so that access could be maintained. The County also took measures to stabilize the bridge at Mosquito Lake Road where it crosses the Middle Fork.

The City of Bellingham's diversion dam for diverting water from the Middle Fork into Lake Whatcom is also located on the Middle Fork approximately 2.5 miles upstream from the Mosquito Lake Road Bridge. Other infrastructure and property impacted by flooding and erosion on the Middle Fork is primarily private developments associated with rural residential and agricultural properties.

Porter and Canyon Lake Creeks, tributaries to the Middle Fork, have also flooded Mosquito Lake Road where it crosses the lower portion of their alluvial fans. The flooding blocked local access and caused damage to the road and to the county bridges.

South Fork – Similar to the other two forks, the South Fork flows through rural residential and agricultural properties for most of its length. The river flows through the town of Acme where overbank flow can damage residential and commercial properties. The water tank for the town's water district is located in the floodplain in Acme. A project to reduce the potential for channel erosion just upstream of Acme was implemented in 2009 to improve fish habitat and limit channel migration.

SR #9 crosses the South Fork in Acme and is inundated by floodwaters both north and south of the bridge, severely limiting access to the South Fork valley during moderate to large flood events. SR #9 also is flooded by the South Fork further downstream south of VanZandt.

Mosquito Lake Road is also flooded by the South Fork at several locations near Acme during relatively frequent flood events. In 2007, the river channel eroded to within 20 feet of the roadway, and Whatcom County in conjunction with the FCZD extended an existing revetment to protect the roadway. Other County roads impacted by the South Fork are Strand Road and Potter Roads; both roadways become impassable during significant flood events. Whatcom County recently replaced the Potter Road Bridge over the South Fork due to structural deficiencies and widened the river opening.

E. MITIGATION STRATEGIES

1. Lower Nooksack River

The Lower Nooksack River CFHMP recognizes that both the short and long term implementation of structural and nonstructural elements and activities must be implemented for the recommended plan to be fully functional. Both operational effectiveness and cost effectiveness must be periodically reviewed and adjusted throughout the life of the plan. A comprehensive and collaborative effort is underway to update the 1999 CFHMP and integrate it with the needs of salmon and floodplain land uses. The results of this effort, known as the Floodplain Integrated Planning (FLIP) process, are not yet available for this plan update.

Over the last twenty years, the FCZD has worked with the diking districts and subzones to get many of the Nooksack River levees eligible for rehabilitation in the USACE's Public Law (PL) 84-99 Program. In late 2013, the FCZD initiated the development of a System-wide Improvement Framework (SWIF) to address the deficiencies identified by the USACE during their biennial inspections of the levees in the program. This process requires establishing an interagency coordination team (ICT) to guide development of the plan, and incorporating environmental considerations to address threatened and endangered species and tribal treaty rights. The ICT developed for the SWIF includes representatives from federal, state and local resource agencies, as well as representatives from the diking districts and agricultural community. The goal of the SWIF process is to reduce flood risk and improve habitat, while keeping the levees eligible in the USACE's rehabilitation program. The plan was completed in 2017; ongoing implementation of the SWIF will keep the levees currently rated as unacceptable by the USACE eligible for repair. While the SWIF process was focused somewhat narrowly on the levee system, many on the ICT wanted to look at the floodplain more broadly. This led to the current FLIP process to update the CFHMP. The current version of the CFHMP recommends the following actions as part of the overall approach for flood hazard management:

a. Hydraulic modeling and alternatives analysis
b. Engineering and design of capital improvement projects
c. Meander limit identification and adoption
d. Sediment management strategy development
e. Floodplain mapping and land use management in the floodplain
f. Land and easement acquisition program development

g. Flood preparedness and emergency response

Since adoption of the CFHMP, significant work has been completed in all of these program areas. These efforts are summarized below; for additional information, contact Whatcom County Public Works, River and Flood Division.

Hydraulic Modeling and Alternatives Analysis - A detailed hydraulic model has been developed and calibrated, and initial alternatives analysis of many of the specific projects identified in the CFHMP has been completed. The model has recently been updated to include 2006 bathymetric and Light Detection and Ranging (LiDAR) data and the updated model has been calibrated to the 2004, 2006, and 2009 floods. The model is currently being used to update the FEMA floodplain maps. A new two-dimensional model based on 2015 bathymetry and 2013 LiDAR is currently being calibrated to more recent events in 2015, 2017, 2018 and 2020. The updated model is being used in the FLIP process and in detailed project design.

Engineering and Design of Capital Improvement Projects - The hydraulic model has been used to perform preliminary hydraulic analysis and design for many of the projects identified in the CFHMP as described below. Some projects, like lowering the Bertrand Creek levees have already been constructed, and others are still in the planning or detailed design phases.

Meander Limit Identification and Adoption - Mapping of historic channel locations, erosion hazard zones, and avulsion hazards has been completed for the entire Lower Nooksack River. Identification of meander limits must be completed in conjunction with design of the flood control system through the hydraulic modeling and alternatives analysis. Some of this work has been initiated for upper Reach 4, between Deming and Nugents Corner as part of the SWIF planning process and for the rest of the lower mainstem as part of the FLIP process.

Sediment Management Strategy Development - A proposed approach for development of a sediment management strategy was developed and distributed to the agencies involved in permitting gravel removal from the river. Feedback from the agencies indicated that existing data was insufficient to support an analysis that would have a small enough error to allow them to support a gravel removal request. In 2006, a detailed bathymetric survey of the river was performed to provide baseline data for future comparisons to estimate the amount of aggradation that may be occurring throughout the river. A preliminary sediment budget using available data suggests aggradation rates that would enable measurement and quantification in a period of 10 to 20 years.

A cooperative study to evaluate the potential impacts of ongoing sedimentation was completed by the US Geological Survey in 2019. The report shows that local channel bed elevations at the USGS streamflow gages vary over time in the range of 1-3 feet. The gage data show long-term trends in bed elevation changes on the order of 1 foot per decade that persist years to decades. These trends in persistent aggradation and incision appear to originate in the North Fork and translate downstream over decades. The pattern of incision and aggradation in the North Fork correlates with the regional climate, where persistent incision follows extended cold and wet periods, and persistent aggradation follows extended warm and dry periods (USGS, 2019).

Floodplain Mapping and Land Use Management in the Floodplain - New floodplain mapping has been developed through FEMA's Cooperating Technical Partners (CTP) program for most of the rivers and streams in the County. The study included detailed mapping for the South Fork Nooksack River, and approximate methods and remapping flood elevations on more recent topography for the North and Middle Forks and many of the smaller streams throughout the. This new mapping was officially adopted by FEMA for use in the NFIP in 2019. Much work was done on the Lower Nooksack River as part of the mapping study, though a change in how FEMA treats levees delayed completion of the mapping for the Lower Nooksack. In 2020 FEMA shared draft work maps for the lower Nooksack River with the affected communities and is working to refine the mapping to try to address community concerns before releasing the preliminary maps to the public.

Land and Easement Acquisition Program Development - A program for land acquisition as a component of flood hazard management was adopted by the FCZD Board of Supervisors in 2000. Numerous acquisitions have been completed under this program as hazard mitigation or other funding becomes available and opportunities with willing land owners arise. Areas targeted for acquisition include Marietta, and the high hazard portions of the alluvial fans associated with Canyon Creek and Jones Creek. Additional lands have been acquired for capital project implementation, wetland mitigation and floodplain preservation.

Flood Preparedness and Emergency Response - Annual flood preparedness activities continue to be performed by the various agencies involved in emergency response with overall coordination by Whatcom County DEM. These activities include annual flood meetings, training of sector observers, sandbag training, and sandbag pre-deployment throughout the County.

The CFHMP also outlines recommended projects and programs to implement along the various reaches of the Lower Nooksack River. Below are recommended mitigation strategies for the five reaches of the Lower Nooksack. While many of these recommendations have only been developed to a conceptual level and more detailed hydraulic analysis and design are needed before they can be fully implemented, others have been fully implemented. For more details on these projects, refer to the CFHMP, available from Whatcom County's River and Flood Division, Public Works Department.

Mitigation for Reach 1

Lummi River – The recommended improvement for the Lummi River (Red River) is not to increase flows to the river but to rehabilitate existing culverts at the diversion from the Nooksack River, including a gate or similar flow control structure and modifying downstream structures, if necessary. While this project would do little to reduce flooding, significant habitat benefit could be provided.

The property where the Lummi River diversion is located was recently acquired by the FCZD; restoration alternatives will be evaluated as part of the FLIP process.

Between the Bridges in Ferndale – The recommended improvement is to designate the properties on the right bank for flood proofing and/or property buyouts, and maintain open space at Vander Yacht Park and the golf course on the left bank. Implementation of this recommendation should include defining and stabilizing the overflow path, which could potentially overtop I-5.

The FLIP process will include a cumulative impacts analysis of future planned development within the Nooksack River floodplain in the City of Ferndale.

Left Bank Downstream of Ferndale – The CFHMP recommendation for this area is to maintain the overflows in Hovander Park and maintain the existing natural overflow corridor along the left bank. With this approach, agricultural levees downstream from the overflow area that are not continuous now could be made continuous as maintenance and reconstruction is called for. The rebuilt levees' crest elevations should be the same as those of right bank agricultural levees downstream of Ferndale, and they should be built to withstand overtopping. Computer modeling of this recommendation will be required.

Since the adoption of the CFHMP, the properties in the left overbank floodplain between Slater Road and Marine Drive have been acquired by the Washington Department of Fish and Wildlife (WDFW). The levee on the WDFW property is continuous and its crest is at a lower elevation than the right bank levee, but it does provide some flood protection to Slater Road, Marine Drive, and Marietta during smaller, more frequent flood events. Damage to the crest and backslope of the levee was repaired in 2009 and 2018 to maintain this level of protection as an interim measure until other recommended mitigation measures can be implemented for these areas. Significant flooding during the 2020 flood resulted in more damage to the levee and another repair project is being developed for implementation in 2022.

Slater Road Bridge Approach – The initial CFHMP recommendation for this area is to maintain Slater Road at its current elevation to allow overtopping and temporary road closures during floods. Eliminating overtopping of Slater Road on the left bank during large floods would be of little benefit at times when overtopping on the right bank during large floods inundates the road on the other side of the river. This recommendation should be reconsidered as traffic demands change with time and if special financing were to become available.

Since the adoption of the CFHMP, the Lummi Nation has pursued mitigation grant funding to raise the left approach to the Slater Road bridge to provide access during a 100-year event. Whatcom County and Lummi Nation initiated a project using Pre-Disaster Mitigation grant funding, but the project has been delayed due to increased costs for construction.

Marietta Area – The recommended improvement for the Marietta area is to designate all flood-prone properties in the community for buyout, so that owners would have the option to sell and relocate should federal purchase funds be made available after a future flood. In the interim, property owners are encouraged to flood proof their structures.

Since the CFHMP was adopted, the Whatcom County FCZD has acquired numerous properties within Marietta using a combination of local, state, and federal funds. The 2009 flood event caused extensive damage to residential properties, and a number of these acquisitions were completed after that flood event. Currently, over to half of the properties within Marietta are in public ownership and three additional properties were recently purchased under the Hazard Mitigation Grant Program.

Right Bank Downstream of Ferndale – The recommended improvement is a setback levee to provide 100-year flood protection and manage overflows to Lummi Bay. This improvement will require discussions with affected property owners. Existing agricultural levees along the right bank will remain overtoppable, but a right-bank overflow corridor will be in place, necessitating flood easements, flood proofing, and/or property buyouts in the corridor. Haxton Way will not have to be raised and the Lummi Seawall will not have to be rehabilitated.

Several alternative levee alignments were evaluated during the SWIF planning process and additional work is being performed under the FLIP process to try to determine a preferred alignment.

Treatment Plant and Ferndale, South of the Bridges – This improvement is to provide 100-year flood protection along the right bank downstream of Main Street by raising the existing levee and Ferndale Road, and to connect the Ferndale Road levee to the recommended new levee downstream. This project will resolve several levee deficiencies noted during the USACE inspections and was identified as a high priority for implementation in the SWIF plan.

Funding for detailed design is underway using grant funding through DOE's Floodplains by Design (FbD) Program.

Marine Drive Bridge Approach – The bridge approach will be maintained at its current elevation to allow overtopping and temporary road closure during floods. Lowering the roadway will not be necessary with the recommended setback levee on the right bank to manage overflows to Lummi Bay.

Haxton Way – Implementation of the recommended right bank setback levee would minimize the occurrence of Haxton Way inundation, making the general raising of Haxton Way unnecessary. However, until the right bank cutoff levee recommendation is accepted and fully implemented, levee overtopping and levee breaches will likely continue. Under these circumstances, the raising of the lowest sections of Haxton Way as an interim action is considered appropriate.

Since the CFHMP was adopted, Diking District #1 has widened and added material to the backslope of much of the levee so it is less prone to failure during overtopping events. In addition, the hydraulic model indicates that most of the levee is high enough to prevent overtopping for events as large as the 100-year flood. These factors reduce the need for interim actions at Haxton Way.

Lummi Bay Seawall – The right bank setback levee will minimize inundation of the Lummi Bay seawall, so no significant capital improvements are recommended for the seawall. Continued maintenance of the existing structure and culverts and tidegates is recommended.

Mitigation for Reach 2

Ferndale Urban Area – Flood dynamics in the Ferndale urban area should be analyzed in detail, including an evaluation of the relationship between urbanization, flood storage and conveyance, and the potential for I-5 overtopping. Evaluation of an overflow path in the event of I-5 overtopping should also be included.

This work is being completed as part of the ongoing FLIP process.

River Road Area – A right-bank overflow area should be designated and the remaining levee along River Road should be strengthened.

Fishtrap Creek – The possibility of lowering a segment of the levees to provide a wider flow path for overflows from the Nooksack River should be explored with local property owners. This approach will also require regular sediment removal from the creek in order to maintain channel capacity and/or reduction of sediment inflow from the creek's upper watershed.

Bertrand Creek – New levee profiles should be established along the creek and the levees should be designed to be overtoppable. Since adoption of the CFHMP, the levees along Bertand Creek were lowered and set back from the creek along most of the length within the Nooksack River floodplain. Flood and conservation easements were acquired over the lands between the old and new levee alignments. While these levees typically failed during every significant flood, during the January 2009 flood event, the levees overtopped for a long duration with only minimal damage to the levee system.

Guide Meridian & I-5 – A left bank overflow corridor should be designated between Guide Meridian and I-5.

Mitigation for Reach 3

Detailed Hydraulic Analysis – A program is recommended that includes strategically linking the river channel with the agricultural floodplain. The goal is to limit random bank/levee overtopping, random levee failure, and sudden development of off channel flood flow paths. This would be accomplished by distributing those flows that exceed channel capacity over the floodplain, thereby reducing levee and bank stress. Seven overflow locations would be analyzed under this program, as follows:

1. Right bank south of Slotemaker Road
2. Left bank near the west end of Nolte Road
3. Bend in the right bank south of Northwood Road
4. Left bank near the intersection of Polinder and Thiel Roads
5. Left bank in the bend upstream of the Polinder/Hannegan intersection
6. Right bank downstream of the Lynden treatment plant
7. Left bank northwest of Bylsma Road, upstream of where Scott Ditch enters the river

Since adoption of the CFHMP, initial hydraulic modeling and alternatives analysis has been performed. This work suggests that creating an overflow at the last site near Blysma Road may not be necessary, because it may reduce the effectiveness of the other overflows and redistribute flows between the overflow corridors. Additional analysis will be conducted with the updated hydraulic model during the FLIP process update to optimize the overflow locations, lengths, and elevations.

Strengthening of Roadway Sections – Strengthening of roadway sections should be performed along overflow corridors, as appropriate. Designating overflow locations will maintain the historical pattern of overtopping some roadways in the floodplain. The designated roadway areas are as follows:

- Slotemaker Road
- Timon Road
- Hampton Road
- Noon Road
- Thiel Road
- Polinder Road
- Hannegan Road

Guide Meridian Overflow Bridges – This improvement, in the short term, is to provide protection against erosion and scour through armoring. If the roadway is rebuilt in the future, opportunities for lengthening the bridges and/or creating additional openings should be investigated at that time.

Since the CFHMP was developed, WSDOT completed a widening project for the Guide Meridian that included the segment that crosses the Nooksack River floodplain. Whatcom County staff worked with WSDOT to refine the design of the overflow corridor openings to ensure no rise in flood elevations and provide additional capacity to accommodate overflows identified in the CFHMP. As a result, the newly constructed overflow bridges are of greater capacity and box culverts were added in each overflow corridor.

Mitigation for Reach 4

Limiting of Channel Migration – Reasonable limits for channel migration and the prevention of a right bank avulsion are recommended with three levels of priority:

1. Immediate action to move the channel away from limits mapped as part of the CFHMP
2. Future action when the channel is moving toward the meander limits
3. Long-term, ongoing future action to move the channel toward the middle of the corridor along Reach

This action is called for at the following sites:

- In Deming near the Mount Baker High School
- Southwest of Williams Road, downstream from Deming
- West of Mariotta Road
- The property west of Hopewell Road
- The property just south of Massey Road and west of Cole Road

Deming Right Bank Areas at High Risk of Avulsion -- The adopted CFHMP identifies three projects, for this portion of the reach as discussed below. Through the SWIF planning process, several alternative levee alignments were evaluated; additional work is needed during the FLIP process and the relevance of these projects will be revisited in that work.

1. New protection should be added downstream of Deming and the existing protection at the high school should be shortened
2. Existing bank protection south of Williams Road should be ensured to provide avulsion protection
3. New protection should be added between the protection projects already in place on the Sande property and west of Marietta Road

Mariotta Road – At Mariotta Road, 300 feet should be removed from the downstream end of the existing riprap protection, the remaining riprap should be tied into the right bank, and gravel should be removed from the bar on the right bank of Sande property. The remaining riprap should be retrofitted to reduce vulnerability to scour and increased fish habitat should be considered. Additional work on the left bank downstream of the clay banks may be warranted.

Nugent's Corner – Low levees should be constructed on the upstream and downstream sides of the Mount Baker Highway Bridge. This improvement to Nugent's Corner should be given a lower priority than projects to prevent avulsion elsewhere in Reach 4.

Levees near Nugent's Corner – The existing overtopping levee upstream of Everson (on the left bank) should be maintained and strengthened, if necessary.

Several recent repairs to this levee (known as the Twin View Levee) have been completed in the past five years.

Mitigation for Reach 5

Everson Bridge – The stand of timber at the upstream end of the overflow on the river's right bank, approximately 1 mile upstream from the Everson Bridge, should be maintained. Additionally, an overtopping levee on the left bank in the same area should be retrofitted and maintained.

Nooksack River and Johnson Creek Watersheds – Maintenance of the divide between the Nooksack and Johnson Creek watershed involves structurally maintaining the divide with an aggressive alternative, a rock trench, as well as discussions with property owners to ensure local farming activities do not involve fields along the divide and changing ground elevation. The second measure is to provide continuous hard protection along the entire length of the overflow from the Nooksack River to the Johnson Creek corridor.

Since the CFHMP was adopted, 1,200 feet of the revetment along the riverbank at the Everson overflow near Massey Road was reconstructed. Prior to this project, the high ground divide was being eroded by the river. Emergency projects were constructed in 2003, 2005, and 2006 to curb this erosion until a more extensive project could be constructed in the summer of 2006.

Recent flooding including during the 2020 flood has caused bank instability damage downstream of the Trans Mountain pipeline crossing. Efforts are underway to develop a project to address this new damage.

2. Upper Forks of Nooksack River

Comprehensive flood hazard management plans have not been developed for any of the three upper forks. The FLIP process will include recommendations to address flood issues for the upper forks as part of the final plan. Some studies to support development of comprehensive flood plans have been performed including the following:

a. Mapping of historic channel locations, erosion hazard zones, and avulsion hazards for all three forks
b. Development of a detailed hydraulic model for the South Fork Nooksack River
c. Detailed floodplain studies to develop new floodplain mapping for the South Fork Nooksack River
d. Updated approximate floodplain mapping for the North and Middle Forks using updated topographic data and historic channel migration mapping

While the FLIP process is underway, ongoing mitigation efforts will primarily consist of repair of existing flood control structures to protect existing infrastructure and implementation of the County's emergency preparedness, NFIP, and early flood warning programs.

3. Other Areas

Areas other than Nooksack River floodplains have been vulnerable to floods or isolation by flood waters in the past. This often relates to the presence of alluvial fans or smaller streams that can cause localized flooding, including in urban areas. Examples include the following areas:

- Austin Creek and Sudden Valley
- Smith Creek and North Shore Road
- Hillside Road
- Blue Canyon
- Iowa Heights
- Henderson Road
- Mount Baker Highway Communities, as discussed above
- Whatcom Creek and Iowa Street
- Squalicum Creek and Meridian Street and Roeder Avenue
- Double Ditch Creek and Double Ditch Road at Lynden

Residents of Whatcom County should understand the flood potential of areas in which they elect to live. It is important to remember that dangers associated with flooding do not end when the rain stops. Electrocution, structural collapse, hazardous materials leaks, and fire are secondary hazards associated with flooding and flood cleanup.

COSTAL FLOODING (Including Storm Surge)

A. DEFINITIONS

Coastal Flooding An inundation of dry land with water caused by weather phenomena and events that push coastal waters onto the shore at levels that are above Mean High High Water due to the effects of wind, surge and atmospheric pressure. As coastal flood is generally a temporary condition that recedes when the tide begins to ebb.

Coastal Floodplain The land area of a coastal area that becomes inundated with water during coastal flooding.

National Flood Insurance Program A federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding. The NFIP is designed to provide insurance as an alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their content caused by floods. When a community chooses to participate in the NFIP, they agree to adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction in Special Flood Hazard Areas. In exchange, the federal government agrees to make flood insurance available within the community as a financial protection against flood losses.

B. BACKGROUND INFORMATION

A **coastal flood**, or the inundation of land areas along the coast, is caused by higher than average high tide and worsened by heavy rainfall and onshore winds. **Storm surge** is an abnormal rise in water level in coastal areas, over and above the regular astronomical tide, caused by forces generated from a severe storm's wind, waves, and low atmospheric pressure. Storm surge is dangerous, because it is capable of flooding large coastal areas. Extreme flooding can occur in coastal areas particularly when storm surge coincides with normal high tide.

High winds off the coast combined with high tides and low atmospheric pressures can result in coastal flooding along the western edge of Whatcom County. The main coastal communities impacted by coastal flooding are Sandy Point, Birch Bay, Point Roberts, and Lummi Peninsula. Damages can include structural damage to residences and seawalls as large debris is carried by waves hitting the shoreline, inundation damage to structures, and debris accumulation and flooding of roadways. In some areas where the shoreline is a bluff, coastal erosion and/or improper drainage can threaten the structural integrity of residential structures and the stability of the bluff itself.

In Whatcom County many areas are subject to coastal flooding, principally Sandy Point, Birch Bay, Point Roberts, Lummi Island and the Lummi Peninsula.

C. RECENT HISTORY IN WHATCOM COUNTY

Recent significant coastal flooding events are summarized as follows:

October 12, 1962 (Columbus Day) The inclusion of the infamous "Columbus Day Storm" is primarily due to it being the wind storm for which virtually all other Pacific Northwest wind storms are compared. Although actual tidal information is not available, extreme low pressure and south/southeasterly winds of nearly 100 miles per hour likely created significantly higher than predicted sea levels and waves large enough to result in some coastal flooding. However, reports of the timing of the strongest winds during the storm indicate that they coincided closely with a low tide in the area. Further, any coastal flooding would have been moderated by the fact that the predicted high tides were at least 1 foot lower than high tides generally predicted during mid-winter months. The largely undeveloped state of southerly and southeasterly shores of Sandy Point, Birch Bay Village area, Point Roberts, Lummi Island, Lummi Peninsula, Eliza Island, etc. would have also minimized any property damage due to coastal flooding. Newspaper articles about the storm largely focused on damage and problems on land and water due to the wind with no mention of coastal flooding.

March 30, 1975 (Easter Sunday) Extremely strong northwesterly wind coincided with a predicted 6:21 a.m. high tide of 8.98 feet mean lower low water (MLLW), causing coastal flooding, especially along the west shore of Sandy Point. The northwesterly/westerly facing shoreline of Birch Bay was also likely impacted. Many homes and property along Sucia Drive suffered damage of varying degrees.

December 16, 1982 Strong westerly and southwesterly wind coincided with low pressure to create a record high tide of 12.93 feet MLLW (Cherry Point) that was 2.90

feet above the predicted level of 10.03 feet MLLW. Significant coastal flooding and damage, including low-lying inland areas, occurred in the Birch Bay, Sandy Point, and Gooseberry Point areas. Legoe Bay Road on Lummi Island and roads and property along the south shore of Point Roberts were also flooded.

December 4, 1993 Strong westerly wind of 45 to 50 miles per hour (mph) with gusts to 68 mph reportedly coincided with high tide and low pressure to create coastal flooding along the westerly facing shorelines of Sandy Point and Birch Bay. Newspaper accounts reported minor damage to homes as well as water and debris on Sucia Drive and Birch Bay Drive. Actual tidal levels are not available, but at Cherry Point high tide was predicted at 9:36 a.m. to be 9.97 feet MLLW; the actual height was likely significantly higher.

December 15, 2000 Reported 70 mph northwesterly winds caused coastal flooding along the westerly shores of Sandy Point and Birch Bay as a rising tide approached a predicted 9:21 a.m. high tide (Cherry Point) of 10.64 feet MLLW. Several dozen homes and property along Sucia Drive were especially hard hit, suffering damage of varying degrees. Most of the damage occurred as much as two or more hours prior to the predicted high tide when the winds were strongest out of the northwest and the tide level was rising between the 8 to 10 foot MLLW range. The wind had eased and shifted to northeast (off-shore) by the time of high tide.

December 14, 2001 Almost exactly one year after the December 15, 2000 event, very similar coastal flooding and damage occurred at Sandy Point and Birch Bay. Strong northwesterly winds closely coincided with an observed 6:12 a.m. Cherry Point high tide of 10.58 feet MLLW. The observed tidal levels were 0.5 to 1 foot higher than predicted during the period of strongest winds due to low pressure. Damages were less extensive than the previous year because the County's Division of Emergency Management contacted homeowners prior to the event to warn them of the upcoming potential for coastal flooding. Property owners were able to take protective measures to reduce property damage.

February 4, 2006 Strong southeasterly wind coincided with extreme low pressure to create a 9:06 a.m. high tide of 12.34 feet MLLW that was 2.44 feet higher than the predicted 9.90 feet. Significant coastal flooding occurred in virtually all vulnerable coastal areas, including Sandy Point, Gooseberry Point, along the northerly shore of Birch Bay, the southeasterly shore of the Lummi Peninsula (Lummi Shore Road area), and the southerly shore and the Maple Beach/Bay View Drive areas of Point Roberts.

December 17, 2012 Strong westerly winds coincided with a low pressure system (+/-980 mb), resulting in a 9:00 am high tide of 11.94 feet (MLLW) that was 1.4 feet higher than the predicted 10.53 feet (MLLW) at Cherry Point. Moderate flooding and damage occurred along westerly facing shorelines, primarily at Birch Bay, Neptune Beach/Sandy Point, and Gooseberry Point areas. Water overtopped and deposited woody debris and seaweed along much of Birch Bay Drive resulting in temporary closure of much of the road from the State Park to the Cottonwood Beach area. Flooding occurred around and in many homes in the area with damage largely limited to water issues, although some structural damage likely occurred to buildings along the shoreline that were exposed to waves and large woody debris. Sucia Drive and several homes were also flooded in the vicinity of 4783 Sucia Drive. It is noteworthy that much of the flooding/damage occurred as much as 2 hours prior to high tide when the Cherry Point water level was only at about 10-11 feet (MLLW) due to strong northwest/westerly wind and resulting waves that had subsided significantly by the time of highest tide at 9:00 am.

December 2019 Strong westerly winds coincided with a low-pressure system (+/-980 mb), resulting in a 1300 high tide of 13.4 feet (MLLW) that was 2.5 feet higher than the predicted 10.9 feet (MLLW) at Cherry Point. Significant flooding and damage occurred along westerly facing shorelines, primarily in Birch Bay, Blaine and Point Roberts. Water overtopped and deposited woody debris and seaweed along much of Birch Bay Drive resulting in temporary closure of much of the road from the State Park to the Cottonwood Beach area. This flooding also largely undercut and destroyed the southbound lanes of Birch Bay Drive resulting in a nearly one-year closure of the road to one lane. Flooding occurred around and in many homes in the area with damage largely limited to water issues, although some structural damage likely occurred to buildings along the shoreline that were exposed to waves and large woody debris. It is noteworthy that much of the flooding/damage occurred as much as 2 hours prior to high tide when the Cherry Point water level was only at about 10-11 feet (MLLW) due to strong northwest/westerly wind and resulting waves that had subsided significantly by the time of highest tide at 1500.

D. VULNERABILITY ASSESSMENT

Sandy Point – Virtually the entire Sandy Point area, including the shoreline in the Neptune Beach area, is subject to coastal flooding, primarily due to a combination of high tidal levels and wind-driven waves from east through northwest. Homes and property along the shoreline are especially vulnerable to damage from wind-driven water and large debris. Homes and property on the interior of the peninsula are generally only subject to water damage due to flooding from high tide levels and wash over the shoreline properties. Virtually all roads within the peninsula, including the main access roads of Sucia Drive and Saltspring Drive, are subject to flooding. The Sandy Point Fire Hall on the east side of Sucia Drive south of Thetis Way is also subject to flooding.

Birch Bay – Virtually the entire non-bluff shoreline area of Birch Bay is subject to extensive coastal flooding, primarily due to a combination of high tidal levels and wind-driven waves from southwest through northwest. Homes and other residential structures, businesses, and properties in low areas along and near the shoreline are especially vulnerable to damage from wind-driven water and large debris. For the most part, residential structures and properties in low areas landward of shoreline properties in the Birch Bay Village development and along and including Birch Bay Drive and Birch Point Road are only subject to water damage due to flooding from high tide levels and wash over the shoreline roads and properties. Flood waters between Alderson Road and the low area of the Sea Links development can extend almost 1 mile inland to Blaine Road. High tidal levels, waves, and storm surge can also restrict the outflow of Terrell Creek, resulting in flooding of residential structures, properties, and roads in low areas adjacent to or in the vicinity of Terrell Creek, such as the Birch Bay Park and Leisure Park development areas. Land and structures along the shoreline and in the low areas of Birch Bay State Park along Terrell Creek are also subject to coastal flooding. Most of the bluff areas along the shoreline are subject to slope instability due to erosion from high tidal levels and wind-driven waves.

Point Roberts – The entire shoreline area of Point Roberts is subject to coastal flooding, especially in the non-bluff areas, primarily due to a combination of high tidal levels and wind-driven waves from the northwest through northeast. Residential and business structures and properties along low-lying shoreline areas along the westerly, southerly, and easterly shore are especially vulnerable to damage from wind-driven water and large debris. Generally, residential structures, properties, and roads in low areas landward of shoreline properties along Marine Drive and Edwards Drive are not prone to significant flooding due to the Point Roberts Dike (Point Roberts Diking District is non-active) and detention of upland drainage in the canal in the vicinity of and around the Point Roberts Marina. However, residential structures, businesses, and properties adjacent to and along Bay View Drive in the Maple Beach area are vulnerable to damage from wind-driven waves, splash, and debris over the seawall. Structures and properties in low areas landward of the properties fronting Bay View Drive are generally only subject to water damage from coastal flooding. A portion of Whatcom County's Lighthouse Marine Park is subject to coastal flooding. Most of the bluff areas along the shoreline are subject to slope instability due to erosion from high tidal levels and wind-driven waves.

Lummi Peninsula – The entire shoreline area of the Lummi Peninsula is subject to coastal flooding, especially in the non-bluff areas, primarily due to a combination of high tidal levels and wind-driven waves from the northwest through southeast. Low-lying residential and business structures and properties along the shoreline in the Gooseberry Point area are especially vulnerable to damage from wind-driven water and large debris. For the most part, residential structures, properties, and roads in low areas landward of shoreline properties in the Gooseberry Point and Hermosa Beach areas, including Haxton Way, Lummi View Drive, and Lummi Shore Road, are only subject to water damage due to flooding from high tide levels and wash over the shoreline roads and properties. Most of the bluff areas along the shoreline are subject to slope instability due to erosion from high tidal levels and wind-driven waves.

Lummi Island – The two low areas on Lummi Island that are particularly vulnerable to damage from coastal flooding are Lummi Point and the Legoe Bay Road area immediately east of Village Point. Virtually the entire low area of Lummi Point has many residential structures and properties that are subject to flooding and damage from a combination of high tidal levels and waves from a southerly or northerly direction. The Legoe Bay Road area has residential and other structures and properties that are subject to flooding due to high tidal levels in combination with wind-driven waves from a southerly direction. The portion of Legoe Bay Road close to the shoreline in the low area is vulnerable to debris deposition and damage from erosion. Most of the non-rocky bluff areas along the westerly and easterly shorelines of Lummi Island shoreline are subject to slope instability due to erosion from high tidal levels and wind-driven waves.

E. MITIGATION STRATEGIES

In recent years, the level of development activity in areas prone to coastal flooding increased significantly. Whatcom County initiated a study to develop new floodplain mapping for several coastal areas in 2000. In 2004 and 2007, new mapping developed by the County with assistance from FEMA's CTP program was finalized for Sandy Point and Birch Bay. FEMA has developed new County-wide coastal floodplain maps. Other mitigation options for coastal areas could include working with homeowners to elevate and/or flood-proof structures or voluntary acquisition if these approaches are cost-effective and funding becomes available.

In 2019 and 2020 the Birch Bay Drive and Pedestrian Facility was installed along a 1 ½ mile stretch of Birch Bay Drive, which effectively created a 14' elevated berm and cost approximately $12 million. This area was heavily impacted in previous storms. These types of structures could be considered for other shoreline areas in Whatcom County.

GEOLOGIC HAZARDS

A. DEFINITIONS

Alluvial Fans Lobate, or fan-shaped, gently sloping deposits of stream-deposited sediment (alluvium) located where a steep-gradient stream or canyon issues onto a broader, low-gradient valley floor, plain, or lake. The term alluvial fan encompasses debris flow fans, composite fans, and fan deltas.

Landslide A term that includes a wide range of ground movement, such as rock falls, deep-seated failure of slopes, and shallow debris avalanches and flows.

Liquefaction The loss of intergranular strength in saturated, loosely-packed sediment due to elevated pore pressures typically generated by seismic shaking during large magnitude earthquakes. Liquefaction can result in a loss of foundation bearing support and significant building damage, as well as lateral spreading, sand boils, and excessive ground settlement with associated disruption of utilities, roadway systems, and infrastructure.

Seismic Hazard Refers to areas subject to severe risk of earthquake damage, such as those areas underlain by sediments susceptible to liquefaction. Almost all of the lower Nooksack River floodplain is categorized as seismically hazardous, as are areas underlain by peat soils (see the "Earthquakes" section for more information regarding seismic hazards).

B. BACKGROUND INFORMATION

Due to their presence in Whatcom County, as well as data availability, three geologic hazards were identified and analyzed as part of this Plan:

1. Alluvial Fans – All alluvial fan areas were classified as hazardous.
2. Coal Mines – Any areas on top of a historical coal mine were determined to be hazardous.
3. Landslides – Risk areas were determined based on slope gradient (specifically slope gradients greater than 15 degrees), underlying geology and soil saturation potential. Although slope gradients not a complete predictor of stability, it was a primary for determination, recognizing shallow rapid landslides tend to be triggered in the 33-35% plus range.

1. Alluvial Fans

Alluvial fans form where there is a sharp decrease in stream gradient and a loss of channel confinement, which results in decreased stream velocity and rapid sediment deposition; generally, where a stream or canyon issues onto a valley floor, plain, or lake. Active mass wasting processes in upland areas, including landslides and erosion, function as the primary catalyst for the natural introduction of fine to coarse grained sediment, soil material, and woody debris to stream channels in the Pacific Northwest. Sediment and debris generated by mass wasting are introduced to stream channels, which may then be routed, either en masse by channelized landslide processes such as debris flows or floods, or incrementally via fluvial sediment transport processes. Stream bed aggradation on the alluvial fan surface due to fluvial, as well as episodic debris flow/flood deposition on low-gradient fan surfaces results in a continued potential for avulsion, or channel-switching, which, over long periods of time, creates the lobate, or fan-shaped morphology commonly observed in plan view for alluvial fans. These processes function continually on the small-scale, but extreme events occur episodically and contribute significantly to alluvial fan formation, as well as pose significant hazards to proximal development.

The majority of alluvial fans have been mapped in Whatcom County by the Washington Geological Survey. Alluvial fans can be expected to be present wherever a stream exits a steeper hillside or mountain and enters a broader valley floor such as the Nooksack River valley or a body of water such as Lake Whatcom, Lake Samish, Silver Lake, or Reed and Cain Lakes. The alluvial fans in Whatcom County are formed both by ongoing transport of fine- to coarse-grained sediment and woody debris by normal stream flow as well as periodic sediment-laden floods and debris flows. These latter two are generally triggered by landslides that enter the channel from the adjoining hillside. The landslide deposits then either continue moving down the channel, bulking with water to create a debris flow, or form a temporary landslide dam. A landslide dam can block stream flow and then fail catastrophically, releasing compounded sediment and water. Both sediment-laden floods and debris flows consist of a mixture of water, sediment, and debris that is routed through the steep stream channel during an event. The location and extent of alluvial fans in Whatcom County was greatly improved by the publication of the Whatcom County Landslide Inventory by the Washington State DNR Geological Survey in 2019. In addition to mapping deep-seated landslides, the inventory identified nearly 2,500 alluvial fans in Whatcom County using bare-earth imagery derived from high-resolution lidar data obtained in 2017.

Debris flows contain a higher proportion of sediment relative to water and can be particularly damaging due to the ability to scour and grow in sized as sediment and woody debris stored in the channel is incorporated. This can produce a sediment volume at the fan that is many orders of magnitude larger than the initial landslide that triggered the event. When a debris flow reaches an alluvial fan, the debris may be quickly deposited within the existing stream channel leading to a channel avulsion, the sudden changing of stream course to a new channel. Both sediment-laden flood and debris flow material may run-out some distance from the head of the alluvial fan before fully depositing and may not follow a defined channel when doing so. In some instances, run-out has exceeded the previously mapped alluvial fan extent, which may, in part, be due to land clearing practices prevalent in river valleys. Examples of this are the debris flows that initiated on the west face of the Van Zandt Dike during the January 2009 flood event that ran out more than 600 feet from the base of the hillside, crossing private land and a county road before entering the South Fork floodplain. Potential run-out is not included on county geological hazard maps, which are primarily based on a coarse-scale geologic mapping efforts that did not specifically address alluvial fan hazards, and could be greatly improved by detailed assessment conducted by a qualified professional. In early 2021 the Washington State Legislature passed and funded Washington State Bill “SB5088-Landslide Hazard Mapping and Inventory”, that will improve understanding of landslide and other geological hazards in Whatcom County. As noted above, the Washington Geological Survey published an updated deep-seated landslide and alluvial fan mapping product in 2020 (WGS Report of Investigations 42, February 2020).

2. Coal Mines

According to the *NW Source*, William H. Prattle, one of Bellingham's earliest settlers, responded to Native American tales of local coal outcroppings by opening a marginally successful coal mine in the settlement called Unionville in 1853. The same year, San Francisco investors opened the Sehome Mine, adjacent to the Whatcom settlement, and it became one of the two largest employers in the area until the mine was flooded in 1878. Coal mining ceased until the Bellingham Bay Company opened the largest mine in the state in the city's north end in 1918; it operated until 1951, when decreased demand led to its closure. Refer to Figure 2 for locations of the Bellingham area’s primary historical mines.

Figure 2 shows the Bellingham area's historic mine locations.

In a January 2003 report titled "Preliminary Assessment of Bellingham Mines," the U.S. Environmental Protection Agency (EPA) assessed possible environmental problems related to 11 mines in and around Bellingham. Two other mines were inventoried, but not assessed, because their exact location was unknown. This report showed that hazardous substances were potentially present and could pose a threat to public health or the environment.

Along with the potential for toxic contamination from these historical mines, these sites pose a risk for ground failure and subsidence in downtown Bellingham and in the Birchwood neighborhood.

3. Landslides

Landslides occur along the hillsides and shorelines of Washington due to the area's steep mountainous terrain, miles of coastal bluffs, complex geology, high precipitation rate, both as rain and snow, abundance of unconsolidated glacial sediments, and tectonically active setting astride the Cascadia Subduction Zone. Unstable landforms and landslide failure mechanisms have been recognized for decades, but that information has not always been widely known or used outside the geologic community. As the population of Washington grows, increasing pressures to develop in landslide-prone areas, or in landslide run-out zones, make basic knowledge about landslide hazards on the part of the general public more important.

A number of factors control landslide type and initiation. These include topography, underlying geology, soils, weather patterns and individual storms, surface- and groundwater, wave action, and human actions including rerouting of drainage by development, de-vegetation, and modification of existing topography. Typically, a landslide occurs when several factors converge and the forces allowing the hill to stay put are overcome by those influencing a move downhill driven by gravity. The following map shows the existing landslide hazards in Whatcom County.

A simplistic view of landslides divides them into two categories: shallow landslides where the depth of failure corresponds roughly to the rooting depth of mature forest vegetation; and deep-seated landslides where the failure plane may be 10's to 100's of feet deep. For shallow landslides, the presence of a healthy root network can effectively increase the forces holding the slope in place, while root strength is not an important factor for deep-seated landslides. Many slides on Puget Sound occur in a geologic setting that places permeable sand and gravel above less permeable layers of silt and clay, or bedrock. Water seeps downward through the upper materials and accumulates on the top of the underlying units, forming a zone of elevated pore pressure, which effectively acts to counter the normal force resisting slope failure. Gravity works more effectively on steeper slopes, such as the bluffs that surround Puget Sound, but more gradual slopes may also be vulnerable. Most slides in northwest Washington occur during or immediately after heavy rains. Shallow landslides often result from individual storms that provide significant precipitation over a matter of days. Deep-seated slides often respond to prolonged wet periods from January through March, and in some cases to multi-year climatic trends. This may correspond to an elevation of the water table. As water tables rise, slopes become less stable. In addition, wave action can erode the beach or the toe of a bluff, cutting into the slope, triggering or setting the stage for future slides. Human actions, most notably those that affect drainage patterns or groundwater, can trigger landslides. Clearing vegetation, poor drainage practices, and onsite septic systems can all add to the potential for landslides.

C. RECENT HISTORY IN WHATCOM COUNTY

1. Alluvial Fans

The last several decades have seen meteorological conditions and land use activities combine to produce increasingly frequent and severe consequences from debris and flooding events associated with streams in Whatcom County, due to increased platting and building on alluvial fans**.** This has also resulted in an increased awareness of the risks associated with alluvial fans, and several measures have been taken by the County to address the problem. Several studies have been prepared that examine the risks associated with a number of alluvial fans. These studies focus on fans with recent damage or with significant development and document the history of the alluvial fan assessed and the associated risks to human life and property and public infrastructure located on that fan. However, they do not provide an inclusive examination of all fans that are present on the landscape. Such an inventory is challenging because the fans can range from hundreds of acres in size to less than one acre. Many of those small fans have a single home on them so while the relative risk may be less, it is no less consequential to the current or future owners.

A study was conducted in 1983 in response to a storm in January of that year, where a number of debris flow events generated from failed forest roads and concave hillsides on the slopes of Stewart and Lookout Mountains caused major damage to property, roads, and bridges on alluvial fans in Lake Whatcom, the South Fork Nooksack River Valley[1] and the Austin Creek alluvial fan at Sudden Valley. The resulting report summarized the causes of these events, recommended mitigation measures, and designated hazards zones surrounding the streams that were examined.

Another report, *Alluvial Fan Hazard Areas*, issued by Whatcom County's Planning and Development Services Department in August 1992, presents an inventory and compilation of the major alluvial areas recognized at that time. Although this was an extensive study, many smaller alluvial fans were not assessed. The Washington Geological Survey completed a comprehensive inventory of Whatcom County alluvial fans using lidar imagery in 2020. The GIS shapefiles with alluvial fan locations were downloaded to the County GIS system and are available to county departments for their use and are available to the public through WDNR/WGS.

6 Weden and Associates, 1983. Alluvial Fans and Deltas Flood Hazard Areas. Report prepared for Whatcom County, 98 pages.

In January 2009, significant rainfall amounts combined with frozen ground conditions and snowmelt resulted in debris flows and landslides in several alluvial fan areas including Stewart Mountain into Lake Whatcom and South Fork Valley, the Van Zandt Dike, Sumas Mountain, Slide Mountain, Red Mountain, and Lake Samish Mountains. The debris flows generate by this storm impacted homes, farms, and public roadways. No injuries were reported, but some homes were rendered uninhabitable. Early reports indicated that more than 100 landslides were triggered by this landslide event in Whatcom County alone, with many more landslides slides likely to be found pending further investigation and coordinated reporting. The slides generated by this storm event were documented by Washington Department of Natural Resources geologists in a series of 9 site reports and a summary report (Powell et al. January 2010, Reconnaissance Study of Landslides Related to the January 2009 Storm in the Acme Watershed).

Smith and McCauley Creeks, located near Deming within Reach 4 of the Nooksack River floodplain (refer to the “Flooding” section Background Information or Mitigation Strategies), are other examples of relatively small alluvial fan areas. The Smith and McCauley Creek alluvial fans are shaped by both fluvial (stream flow driven) and debris flow events; this is typical of alluvial fans in Whatcom County. Stream avulsions, a sudden shift in channel location as one channel is abandoned and the stream shifts to a new path, have occurred during past events and are a fundamental mechanism responsible for creating the alluvial fan landform. Any residences and farm buildings on the alluvial fan are at risk. The McCauley Creek Flood Control District has constructed sediment traps on both these systems to try to reduce the risk to downstream properties.

The Whatcom County Flood Control District has performed detailed studies on four additional fans; a brief history of flooding on these fans follows.

Canyon Creek – A large debris flood event occurred on Canyon Creek in November 1989, destroying one residence. Two smaller debris flood events in November 1990 destroyed three additional residences and several hundred feet of Canyon View Drive, a County road within the Glacier Springs development. The deposits from each event indicate that sediment transport likely ranged from clearwater flood, to sediment laden flood, to true debris flow during the course of each storm event; these are referred to here as debris flood events for simplicity. Bank armor was installed along the west bank adjacent to the Glacier Springs development in summer 1990; this was destroyed or buried by the November 1990 events. A levee and flow deflection structures were constructed using FEMA funding in 1994; in November 1995, a predominantly clearwater flood damaged the recently-constructed project. Since 2000, acquisition of most of the highest risk properties on the fan has proceeded to reduce the risk to life and property (see the "Mitigation" section). The acquisitions have allowed the County to remove the old levee and replace it with an 1850 feet long setback revetment that reconnects the creek to its floodplain where 23 engineered log jams have been installed to slow bank erosion and restore critical habitats for salmon, steelhead, and bulltrout.

Jones Creek – Significant debris flows occurred on the Jones Creek fan during January 1983 and January 2009. The 1983 debris flow destroyed a private log bridge at Galbraith Road and flattened approximately 4 acres of mature trees. The Turkington Road Bridge is a constriction that gets blocked by debris and sediment on top of the bridge deck and in the channel upstream. Debris depositing in the channel between Galbraith and Turkington Roads reduces channel capacity and results in water and sediment overflowing the right bank (looking downstream) and flowing down slope towards the town of Acme. This occurred during the 1983, 1990, and 2009 events. A small debris flow also occurred in 2004, but the event was not big enough to fill in the channel and cause overland flow. An active deep-seated landslide, the "Darrington Slide", located approximately 4000' upstream from Turkington Road constricts the Jones Creek channel and creates a partial dam and small impoundment of water upstream of the slide. The USGS installed a stream stage gage at Turkington Road to detect sudden drops in streamflow if the Darrington Slide were to move rapidly, form a larger landslide dam, and cut off streamflow temporarily while the dammed area fills with water and increases the potential for a landslide dam failure. The gage sends a warning to the Acme Fire District who then sends responders to check the creek at Turkington Road and to the landslide area to verify if landslide dam conditions are present so that an appropriate response can be instituted to protect the community members living in Acme if necessary. The County is working on a debris flow mitigation project to reduce risk through a combination of acquisition of high risk properties and construction of a berm designed to redirect debris flows and other events to an unpopulated portion of the alluvial fan.

Swift Creek – A significant debris flow event occurred in 1971 on Swift Creek. A large volume (estimated at 100,000 to 150,000 cubic yards) of sediment was delivered to the fan causing significant aggradation of the channel. Swift Creek flowed out of its bank to the north across South Pass Road towards Breckinridge Creek. Since then, Swift Creek has experienced extensive ongoing sedimentation of the stream channel originating from a very large, deep-seated landslide upstream on Sumas Mountain. This has resulted in the streambed becoming perched above adjacent properties in some locations. The County is currently working with state and federal agencies on a plan to manage on-going and future sedimentation on the Swift Creek alluvial fan and downstream reaches. This work is complicated by the presence of naturally occurring asbestos in the sediment originating from the landslide which necessitates additional precautions.

Glacier-Gallop Creeks- The Glacier Creek and Gallop Creek alluvial fans merge into a combined alluvial fan at the community of Glacier. A number of reports have been prepared over the years that document flood or debris flood impacts dating back as far as the 1930's. Several large floods of note have occurred including large ones in 1962 and 1963 and in 1989 and 1990 which threatened or caused damage to the highway bridge and other structures. A west bank levee on Glacier Creek was installed following the 1962 event to protect the west SR 542 abutment and the community of Glacier. This same levee was breached/overtopped during the November 1989 event sending Glacier Creek flow into the community where it combined with Gallop Creek floodwaters. State highway crews dug sediment from under both the Gallup and Glacier Creek bridges during the 1989 even to maintain flow under the bridge even as water raised high enough to splash onto the Glacier Bridge deck. Roads and homes in the Mt. Baker Rim development during were damaged during the 1989 and 1990 floods. The Glacier left (west) bank levee which was damaged again by several high water events over the past decade.

This brief history only provides examples of recent alluvial fan activity and is not meant to be exhaustive.

2. Coal Mines

The City of Bellingham abandoned underground mines that stretch from State Street to Sehome Hill and from Connecticut Street northwest to McLeod Road present significant hazards, mostly related to mine subsidence and collapse. Subsidence refers to a relatively slow settling of the overlying ground. Collapse of a mine roof can cause a sinkhole to form, creating a hazard. The Sehome mine workings under downtown Bellingham are relatively shallow and are thought to pose a greater sinkhole hazard than the Birchwood mine farther to the northwest, although a small sinkhole formed in the Birchwood neighborhood in the late 1980's or early 1990's.

3. Landslides

The susceptibility of Whatcom County to landslides is apparent from the examples provided by the numerous landslides listed in Table 4.

Table 4. Major Whatcom County Landslides Beginning With the Great Depression

Dates	Description
Great Depression Era	Cutting trees caused a very large Sehome Hill landslide toward Western Washington University.
October 1975	Following a heavy downpour, the State Street Boulevard hillside turned into wet mud and swept two cars over the 25-foot bank. 100 yards of mud slid onto the boulevard.
January 1983	A debris flood accompanied by landslides into Lake Whatcom took homes, cars, people, and pets into the lake and caused major flooding.
January 1983	A huge boulder rolled onto railroad tracks near Larrabee State Park, derailed 12 cars of a 66-car northbound Burlington Northern freight train, and tumbled the lead engine into the Bay.
1996	Landslides at Point Roberts destroyed several beachside vacation homes.
February 1997	Ground movement on Sumas Mountain resulted in the rupture of a 26-inch natural gas pipeline that subsequently exploded.
January 2009	In the storm-related Racehorse Creek Slide, a large rock avalanche in Chuckanut Formation moved approximately 650,000 cubic yards down Slide Mountain into Racehorse Creek.
January 2009	More than 100 storm-related landslides, primarily shallow, were triggered by a rain-on-snow event on top of potentially frozen ground.
May 31,2013	A landslide off the north valley wall near the terminus of the Easton Glacier on Mount Baker initiated a debris flow that traveled ~3.5 miles down the Middle Fork Nooksack River. Fine grained sediment from this and 2 smaller events in June 2013 raised turbidity in the river to levels that required downstream municipal water intakes be shut down to avoid damage to the water treatment systems.
Ongoing; exacerbated	Continued landslide activity in glacial deposits at the “Clay Bank” on the south side of the Nooksack River 1.75 miles upstream from the SR

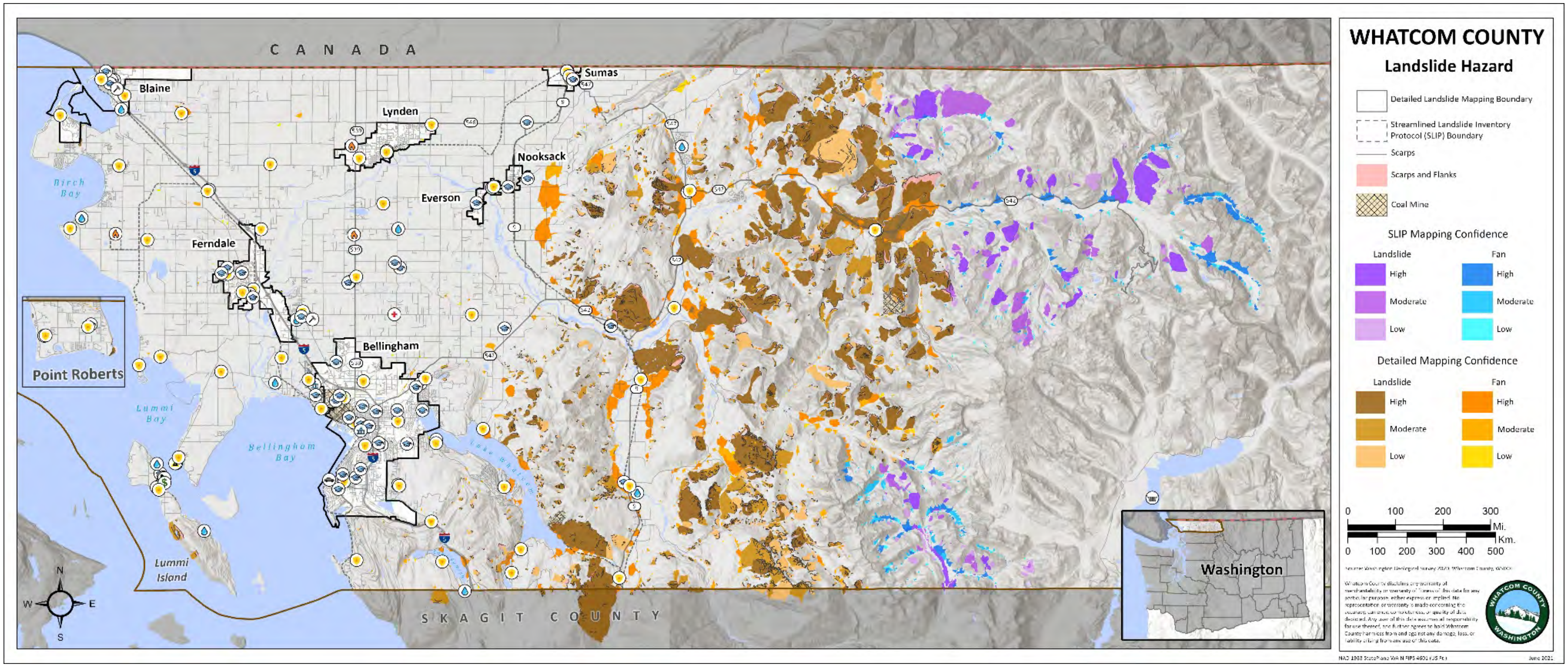
Dates	Description
activity January & February 2014, reactivation of 2006 slide area	542 Bridge at Cedarville temporarily dammed the river. Erosion of the slide deposits increased downstream turbidity. The 2014 landslides shifted the main flow towards the opposite bank where the main flow is now entrained along the levee. This has contributed to a reactivation and retreat of the 2006 slide area.
Ongoing	Rock slides occur onto I-5, south of Bellingham.
Ongoing	123,000 cubic yards of dirt and rock is carried from Sumas Mountain each year and deposited into Swift Creek. This debris and dirt are threatening several hundred acres of farmland near Everson and impacts multiple county roads.

Hundreds of landslides have also been mapped in the forested upper watershed during watershed analysis and watershed restoration planning. Most of these landslides originated in forest land, but many routed to and deposited on lands where development, infrastructure, or agriculture occur. The location of deep-seated landslides in Whatcom County was greatly improved by the publication of the Whatcom County Landslide Inventory by the Washington State DNR Geological Survey in 2019. The Washington Geological Survey has recently completed mapping of large, deep-seated landslides throughout Whatcom County (WGS 2020) which expands on the existing mapping and is available through GIS.

4. Seismic Hazards

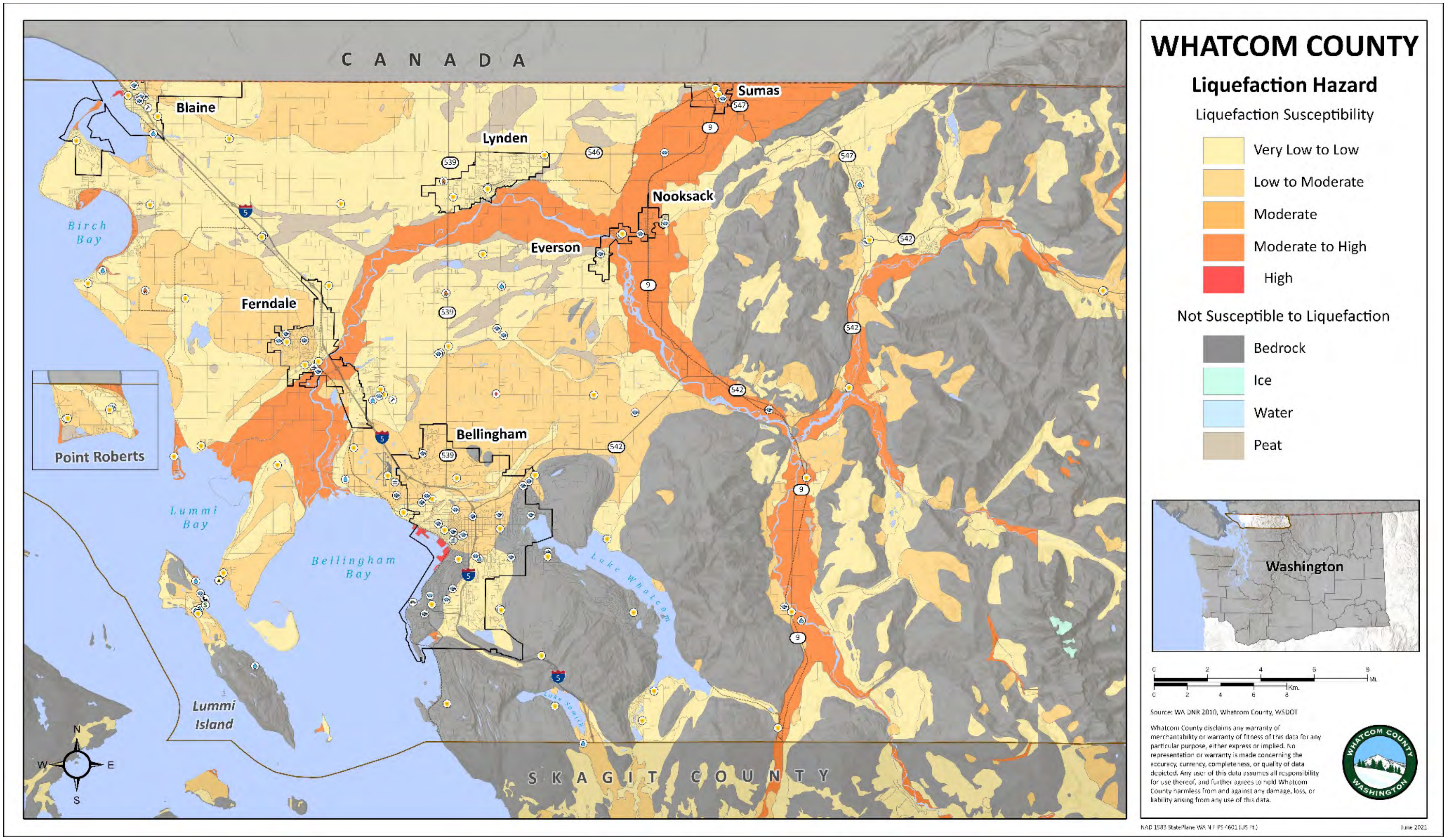
A history of seismic hazards is described in further detail in the "Earthquakes" section of this Plan.

Exhibit A



Washington Geological Survey (WGS) 2020 Washington landslide inventory data compiled following streamline landslide mapping protocol (SLIP). SLIP was developed by the WGS's Landslide Hazards Program to help geologists rapidly map landslide landforms from lidar. This data shows both detailed mapping and SLIP landslide data. Landslides and alluvial fans are most prevalent in the Cascade foothills of eastern Whatcom County, on Lummi Island, and the southern end of Lake Whatcom. Coal mine areas, also shown on the map, are present in northwest Bellingham and south of Glacier.

Exhibit A



Washington Department of Natural Resources (WA DNR) 2010 liquefaction susceptibility data. This feature class is part of a geodatabase that contains statewide ground response data for Washington State.

D. VULNERABILITY ASSESSMENT

1. Alluvial Fans

Detailed studies have examined specific alluvial fans in Whatcom County. The 1992 report, *Alluvial Fan Hazard Areas,* inventoried many of the alluvial fans that pose a risk to human life or property. It should be noted, characteristics of alluvial fan hazards identified in the report apply to all alluvial fans in Whatcom County whether or not the fan is mapped. More extensive alluvial fan mapping was done by Washington Geological Survey (2020) which captures the fans reported on in 1992 plus many smaller or less developed fans. The degree of risk depends on the specifics of an individual fan including the potential for upstream landslides to trigger and route through the stream channel to the fan and the nature and extent of development on the alluvial fan. An individual risk assessment should be performed by a qualified professional in the absence of specific information that has been prepared, to current risk assessment standards. Table 5 lists alluvial fans identified in the 1992 report (table also updated in 2010), as well as developments at risk.

Table 5. Alluvial Fan Inventory in Whatcom County

Alluvial Fan	Size	Developments/Structures at Risk
Lake Whatcom Watershed		
Austin Creek Fan	150 acres	Sudden Valley golf course, homes, private and County roads
Lake Louise 2 Fan	approximately 5 acres	Approximately 20 houses, driveways, three development roads, a path around the lake, and Lake Whatcom Boulevard
Albrecht's Fan	2.5 acres	County Rd., Lake Whatcom Blvd., the private bridge to the Albrecht residence, and the older buildings on the property
Wildwood Fan	16 acres	Wildwood has a very high population density during the summer months and provides trailer and boat storage during the rest of the year; at least 40 trailers, a general store, cabins, and Lake Whatcom Boulevard are at risk
South Blue Canyon Creek Fan	Data not available	The Blue Canyon Complex and approximately 11 homes; future development is planned, which will eliminate existing trees and further increase the risk in this area
Middle Blue Canyon Creek Fan	Data not available	Limited residences and a picnic area
North Blue Canyon Creek Fan	Data not available	Limited residences

Alluvial Fan	Size	Developments/Structures at Risk
Smith Creek Fan	107 acres	Residences and a bridge, which is located at the apex of the fan
Olsen Creek Fan	137 acres	30 homes
Carpenter Creek Fan	16.5 acres	15 buildings, including the local fire hall, and two County roads
Samish River and Lake Samish Watershed		
Barnes Creek Fan	Data not available	Residences and four roads: Interstate 5, East Lake Samish Rd., Old State Route 99, and Manley Rd.
Kinney Creek Fan	74 acres	Multiple residences on north shore of Lake Samish; fan impacted by January 2009 storm event, which damaged and closed North Lake Samish Drive
Reed Lake 2 Reed Lake 3 Reed Lake 4	620 acres	Approximately 30 homes, a clubhouse, and numerous roads in the Reed Lake development
North Fork, Nooksack River		
Glacier Creek Fan	Data not available	Town of Glacier, the Mount Baker Rim Development, a U.S. Forest Service Ranger Station, multiple restaurants, lodgings, approximately 45 houses and outbuildings, and Mount Baker Highway (SR 542)
Gallop Creek Fan	Data not available	Town of Glacier, 25 houses, restaurants, lodgings, the Glacier post office, county road/logging access road and bridge, and Mount Baker Highway; note that WSDOT has removed a lodge and cabins as part of a risk reduction project at Gallop Creek bridge
Cornell Creek Fan	90 acres	Approximately five houses, Mount Baker Highway, Cornell Creek Road, and a large wetland that may be salmon habitat
Canyon Creek Fan	210 acres	Glacier Springs Development and Mount Baker Highway. Note that acquisitions have removed development potential on ~30 lots and the former Logs Resort all in high alluvial fan risk zones. The 1994 levee that was at risk has been removed and replaced by a setback structure.
Boulder Creek Fan	126 acres	25 buildings of the Baptist camp, three roads, and Mount Baker Highway
Coal Creek Fan	Data not available	Small community located at the mouth of Coal Creek and Mount Baker Highway
Racehorse Creek Fan	246 acres	Five residences, several barns, a county road, a private access road, and a county bridge, all near Welcome, Washington
Bell Creek Fan	Data not available	Agricultural lands, Mount Baker Highway, eight residences, and two secondary roads
Middle Fork, Nooksack River		
Canyon Lake Creek	312 acres	Multiple residences, Mosquito Lake Road, Canyon Lake

Alluvial Fan	Size	Developments/Structures at Risk
Fan		Road, and three private roads; note that Kenney Creek fan is largely in the North Fork Nooksack River but there is overflow from Canyon Lake to Kenney during floods
Kenney Creek Fan	188 acres	
Filbert Creek Fan	49 acres	
Porter Creek	95 acres	Residences, Mosquito Lake Road, the bridge at Porter Creek, and a private road
South Fork Nooksack River		
Falls/Todd Creek	Data not available	Multiple residences, Hillside Drive, and agricultural lands
Terhorst Creek	94 acres	Residences, Hillside Drive, a county road, outbuildings
Sygitowicz Creek Fan	163 acres	Residences, a county bridge, and a county road
Radonski Creek Fan	Data not available	Two farms, residences, and Hillside Drive
Hardscrabble Creek Fan	45 acres	Residences, several barns and outbuildings, a County road, and a County bridge (New bridge placed fall 2009 and repaired in winter 2009/2010)
McCarty Creek Fan	162 acres	Turkington Road county bridge and agricultural land
Jones Creek Fan	376 acres	Town of Acme, Turkington Road, State Highway 9, elementary school, fire hall, and church
Middle Nooksack River (Flood Reach 4)		
Smith Creek Fan	Data not available	Residences, True Log Homes, Smith Creek Hydro projects, Mount Baker Vineyards, Mount Baker Highway, and Burlington Northern Railway
McCauley Creek Fan	Data not available	Residences, farm buildings, and Mount Baker Highway
Sumas River		
Swift Creek	Data not available	Residences, Great Western Lumber & Mill, and Mount Baker Mushroom Farm

Note: Information obtained from "Alluvial Fan Hazard Areas", Whatcom County PDS

2. Coal Mines

Infrastructure constructed over abandoned shallow underground coal mines is highly susceptible to collapse. Risk of collapse decreases with depth of mine workings below ground surface, particularly during seismic events. These mines stretch from State Street to Sehome Hill and from Connecticut Street northwest to McLeod Road. Ground failure and subsidence in downtown Bellingham could result in damage to infrastructure and possibly injury and death.

3. Landslides

As population density increases and houses and roads are built below or on steeper slopes and mountainsides to obtain marketable views, landslide hazards become an increasingly serious threat to life and property. Residential development along slopes such as Chuckanut Mountain, Stewart Mountain, Lookout Mountain, and other hillsides throughout the County are subject to slides. These slides take lives, destroy homes and businesses, undermine bridges, derail railroad cars, cover fish habitat and oyster beds, interrupt transportation infrastructure, and damage utilities. Forest fires, clear-cutting of trees, land clearing for housing developments, rearrangement of drainage patterns by roadside ditches and cross drains, lack of proper cross drain spacing, sizing, construction, maintenance, and non-road related stormwater runoff can all contribute to or trigger landslides.

Due to the many factors that contribute to landslide potential widespread identification of all hazard areas is not possible. However, slope stability assessment methodologies are well established and can accurately assess landslide potential for an individual building site or development. This type of assessment should be used to inform land-use decisions, direct project siting, and establish criteria for structural designs to mitigate landslide risk, all of which is mandated by the Whatcom County Critical Areas Ordinance.

Examples of possible landslide areas and possible damages in Whatcom County include the following:

- Chuckanut Mountain and Chuckanut Drive; residential areas on steep slopes such as Sudden Valley; and along the foot of Steward, Sumas, and Red Mountains and the Van Zandt Dike; near Lake Samish and Cain and Reed Lakes; eastern Mount Baker Highway; and parts of Highway 9
- Unstable bluffs on Lummi Island, Lummi Peninsula, Point Roberts, Cherry Point, Point Whitehorn, and Birch Bay
- Western Washington University below Sehome Hill; The Sehome Hill Arboretum has had slides in the past – the growth of some tree trunks shows evidence of slow movement downhill above the university
- Slopes overlooking Hale Passage, Bellingham Bay, Boundary Bay, and Strait of Georgia
- Eldridge Avenue and Edgemoor homes overlooking Bellingham Bay
- Mount Baker – Landslides may be caused by melting snow, or steam resulting in a lahar (mudflow off a volcano); a lahar could possibly cause floods of the Nooksack River and massive mudslides into Baker Lake which could over-top, or break, Baker Lake Dam (see previous discussion in the “Earthquake” Section); glacier retreat removes support for unconsolidated sediment which can landslide and route as debris flows, similar to, but smaller than, lahars.

- Sumas Mountain and the Swift Creek landslide the deposits, which imperil County roads and private property and which increase flooding and distribution of asbestos-containing sediment

E. MITIGATION STRATEGIES

For alluvial fans and landslides, mitigation measures recommended by various studies are listed below. In general, the following steps should be implemented to reduce risk of the four geologic hazards—alluvial fans, coal mines, landslides, and seismic hazards—affecting Whatcom County:

1. Limit, and if possible, eliminate new development in high-risk areas. If possible, direct new development to portions of the subject parcel beyond the area of potential affect.
2. If new development is to be permitted, a qualified professional should assess the risks and recommend how to mitigate new construction to address the specific geological hazard.
3. Educate existing property owners at risk to help minimize the risk of the local hazards.
4. If cost effective, buyout high risk properties.
5. As a last-case resort, consider engineering solutions to manage the specific geologic hazard, if proven effective.

1. Alluvial Fans

To help reduce the impact of debris events, the *Alluvial Fan Hazard Areas* report mentioned above, outlines preliminary mitigation actions to be considered when developing on or near an active fan. Mitigation alternatives are also identified in both the *Canyon Creek and Jones Creek Alluvial Fan Risk Assessments*. Those recommendations are based on detailed analysis specific to those fans, but offer risk mitigation alternatives that can be applicable to most alluvial fans. Specific mitigations should be developed by a qualified professional and presented in a manner that is structured, reproducible, and defensible and should utilize all available alluvial fan mapping when considering a specific site.

1. Limit, and if possible, eliminate new development in high-risk areas.
2. If new development is to be permitted, a qualified professional should assess the risks and recommend how to mitigate new construction to address the specific geological hazard.

3. Educate existing property owners at risk to help minimize the risk of the local hazards.
4. If cost effective, buyout high risk properties.
5. As a last resort, consider engineering solutions to manage the specific geologic hazard, if proven effective.
6. Avoid road crossings that obstruct debris passages in debris flow source areas, in the stream network that routes material to an alluvial fan, or on an alluvial fan itself.
7. Locate and orient roads carefully- Road beds can act as levees or potential avulsion channels depending on their locations and orientation, especially those roads oriented parallel to flow.

The report also details primary and secondary measures to consider in alluvial fan mitigation strategies:

Primary Measures

Mapping and avoidance – The impact zone of debris flows and sediment laden floods must first be delineated by careful hazard mapping. In general, areas of historic or prehistoric flows, scoured channels and headwaters, and initiation points of landslides or debris flows constitute debris flow hazard zones. Appropriate zoning regulations or building restrictions can limit development in these areas. Low intensity development land use, such as agriculture or park lands, may be appropriate.

Precipitation thresholds – Precipitation thresholds are often suggested as a method to predict debris flow occurrence. Antecedent rainfall and snow melt must be factored in to increase the accuracy of event prediction. Church and Miles (1987) state that simple precipitation thresholds cannot be used to predict debris flow events. However, by analyzing approaching storm events and tying this to the characteristics (geology, soil type and thickness, vegetative cover, hydrologic maturity, slope and landform) for areas of known debris flow activity, warnings for potential debris flows may be issued. This would assist those monitoring hazardous areas during storm events. The Washington Geological Survey has a coarse scale shallow landslide warning tool that incorporates a precipitation threshold model in use and available through their website at: https://www.dnr.wa.gov/slhfm.Ideally this model would be further refined as more detailed input data are made available specific to Whatcom County. The USGS maintains a monitoring network in the Seattle area to evaluate landslide potential at: https://www.usgs.gov/natural-hazards/landslide-hazards/science/seattle-area-washington?qt-science_center_objects=0#qt-science_center_objects. This information can be used as a general guide to potential Whatcom County conditions.

Warning systems – Warning systems should include advance warning measures, warnings of an event in progress or of an event that has just passed. Existing warning systems that have proven valuable are those used on highways and railways to warn of coming debris flow such as a trip wire and transmitter located in a debris flow path upstream of the infrastructure. The problem with these systems is false alarms could be frequent because these systems are easily damaged. Whatcom County collaborates with USGS in using a landslide dam warning system on Jones Creek which uses rapid drops in stream stage at Turkington Road to issue a warning to the fire district. Once warned, district personnel are dispatched to check on the status of an existing landslide dam upstream or for other channel obstructions.

Secondary Measures

Forest practices –Poor forest practices can initiate landslides by destabilizing soils on slopes from the loss of root strength after the trees are cut, by road placement that destabilize a slope, and by increasing the average pore water pressure in soils through changes in slope hydrology caused by roads, cross drains, landings, and skid trails. State of Washington Forest Practice Rules have been dramatically revised since the mid-1980's to address these issues and reduce the potential for forest practices to increase landslide potential on forest lands. In addition, road maintenance and abandonment plans are required for forest landowners and guide how roads are maintained while active and how they are abandoned once they are no longer needed.

Slope modifications – Slopes in potential sediment source areas can be stabilized to reduce their failure potential. Slope height can be limited, the slope angle decreased, drainage installed, and fill compacted. Drainage systems for the slopes must have culverts sized large enough to carry debris and water.

Do not develop on areas subject to sediment laden flooding, debris flow routing, or run out such as on an alluvial fan.

Specific mitigation measures were identified for the three fans studied in detail, as described below.

Mitigation Strategy for Canyon Creek

The following measures were recommended to reduce the risk associated with the Canyon Creek fan:

1. Advise property owners and residents on the fan of the hazard and the study results
2. Distribute the alluvial fan risk assessment study to other agencies involved in natural resources management

3. Proceed with acquisition of highest risk properties on the fan
4. Implement site-specific land use regulations using the detailed risk mapping included in the report
5. Consider removing the lower two-thirds of the levee constructed in 1994 (which would route any overflow behind the levee away from the creek) and using the riprap to reinforce the right bank adjacent to Canyon View Drive
6. Consider other mitigation options identified in the report with referral to appropriate agencies; these options include regulation of future logging, event warning system, regional advance warning system, and monitoring of the landslides in the upper basin and the Canyon Creek channel

Since completion of the study, the following progress has been made in implementing some of these recommendations:

1. Several community meetings have been held to increase public awareness of the hazard and to involve the community in the development of mitigation measures. In addition, the report was provided to the Glacier Springs Community Association, who has it available for download on their website.
2. The report was distributed to the other agencies involved in resource management. Extensive coordination has occurred with WSDOT as it relates to protection of Mt. Baker Highway.
3. Three residences and 26 undeveloped lots along the active fan margin, and The Logs Resort were acquired through an integrated hazard mitigation and salmon recovery project by the FCZD and the Whatcom Land Trust.
4. The detailed mapping in the report is now being used for administering the County's critical areas ordinance related to new development on the fan.
5. A portion of the lower levee was removed and the ground surface in the fan was re–graded in 2009 to direct any overflow that might get behind the levee back towards Canyon Creek rather than towards Mount Baker Highway. The riprap removed from the levee face was stockpiled in an area near the highway to enable future use.
6. 1850' of the 2000' of levee remaining after the 2009 project was removed in 2013 and an 1800' armored setback structure was constructed 200' to the west along Canyon View Drive and paralleling the historic floodplain area to the south. The historic floodplain was recreated and a total of 23 engineered log jams were installed in 2013 and 2014 to reduce bank erosion and to provide instream and riparian habitat

restoration. Since 2014 vegetation planted post-construction has become increasingly well-established along the right bank and flood plain and will provide increased protection to the downstream residences in the future.

7. Coordination with the National Weather Service and WDNR continues to occur regarding development of a regional hydroclimatic threshold for an advance warning system for the Puget Sound Region.

Mitigation Strategy for Jones Creek

The following measures were recommended to reduce the risk associated with the Jones Creek fan:

1. Advise property owners and residents on the fan of the hazard and the study results
2. Distribute the debris flow study to other agencies involved in natural resources management
3. Consider acquisition of all properties within Zone 1, the highest risk area, and possibly within Zone 2, the next at-risk area
4. Consider constructing a deflection berm extending from the fan apex to below Turkington Road
5. In conjunction with the deflection berm, consider a channel realignment that diverts the creek to the north
6. Consider implementation of other measures identified in the report with referral to appropriate agencies; these measures include:
   – Improved regulation of land use and logging activities
   – Landslide monitoring
   – Creek channel inspections
   – Removal of the berm along the creek downstream of Turkington Road
   – Abandonment of the Turkington Road bridge and upgrade of the Hudson Road and railway; an alternative to road relocation is to increase the capacity of the Turkington Road bridge at its current location

Since completion of the study, the following progress has been made in implementing some of these recommendations:

1. Significant public outreach has occurred in the Acme community. The small debris flow

in 2004 prompted the County to host several community meetings to inform residents on the fan of the hazard and they types of conditions that could trigger an event. Additional meetings have been hosted by the Acme/Van Zandt Fire District (#16) since fall 2008.

2. The report was distributed to natural resource agencies as well as to the Acme Fire District. The Fire District initiated development of a detailed emergency response plan to address debris flows on Jones Creek late in 2008. They were able to implement portions of the draft plan in January 2009. Since then they have conducted additional planning and drills to improve their response.
3. Two residential properties in hazard Zone 1 near Turkington Road have been acquired by the FCZD.
4. Preliminary design work to evaluate alternative alignments and a planning-level cost estimate for a deflection berm has been completed.
5. Evaluation of alternative access routes for Turkington Road were evaluated .
6. Detailed design of deflection is currently underway
7. Acquisition of additional properties needed to construct a deflection berm is currently underway
8. The detailed mapping in the report is now being used for administering the County’s critical areas ordinance related to new development on the fan.
9. The local community members and Fire District representatives have been informally monitoring the landslide and the creek since the January 2009 event.
10. In 2014 Fire District #16 and the Mt. Baker School District have conducted Landslide evacuation/ shelter in place drills.
11. Annual Winter Storm/ Disaster Readiness Town Hall meetings were started in 2014 with County Public Works, Whatcom County Sheriff’s Office Division of Emergency Management and Fire District #16.
12. In 2012 four members of Fire District #16, were trained by Whatcom County Sheriff’s Office Division of Emergency Management to use the reverse 911 messaging system for the Acme area.

Mitigation Strategy for Swift Creek

In addition to the types of hazards most often associated with alluvial fans, the sediment within Swift Creek contains elevated levels of naturally occurring asbestos and heavy metals. This has added additional health and safety issues and added to the complexity of dealing with sedimentation problems along Swift Creek. The following measures are completed to reduce the risk associated with the Swift Creek fan:

a. February 15, 2013 Whatcom County published the Draft Environmental Impact Statement for the Swift Creek Sediment Management Action Plan (SCSMAP).
b. June 12, 2013 Whatcom County published the Final Environmental Impact Statement for the SCSMAP.
c. July 23, 2013 the Whatcom County Council adopted the SCSMAP by resolution #2013-026. The following chapters are included in the SCSMAP:
    1. Chapter 1 includes a description of the Swift Creek setting and background, as well as a description of Whatcom County's approach and response to Swift Creek management to date. This chapter also includes goals and objectives that informed development of active (project) and passive (program) strategies recommended in the Plan.
    2. Chapter 2 outlines relevant laws, regulations, rules, plans, and policies that provide the framework for Swift Creek management. The regulatory outline provides general applicability; specifics as to regulatory approach would be developed in conjunction with implementation of recommended strategies. The approach included in the SCSMAP is intended to encourage cooperative and consistent Swift Creek sediment management among agencies and jurisdictions involved in the Swift Creek problem.
    3. Chapter 3 describes the watershed in detail and includes conditions assessments for each identified watershed issue. An overall list of problems that result from watershed conditions is provided. This problem list, which identifies areas of high risk for overbank flooding, avulsion, and sediment accumulation, provides the basis for future direction and management strategies.
    4. Chapter 4 includes active and passive management strategies identified as feasible in development of the SCSMAP. Strategies were developed to target high risk areas and protect public health and welfare, public infrastructure, and the environment. Some identified strategies meet the goals of the plan through direct application of public works projects (active management strategies), while others include development of programs (passive management strategies) to address the major Swift Creek issues.
    5. Chapter 5 provides the final recommendations identified and discussed in the

SCSMAP.

6. Chapter 6 addresses the costs of implementing the strategies identified in Chapter 4. Costs are provided as planning level estimates only. Active strategy planning level cost estimates include the estimated cost for on-site development. Passive strategy estimates are based on the project number of full time equivalents in terms of Whatcom County staff to develop and implement an identified program.
7. Chapter 7 provides a set of guidelines for project-level plan implementation, along with a prioritization protocol. The prioritization protocol developed for this plan will be utilized for all projects developed under the umbrella strategies included in Chapter 4.

d. December 6, 2019 the Washington State Department of Ecology and Whatcom County (together with the Whatcom County Flood Control District) entered into a Consent Decree. The mutual objective of the Consent Decree is to implement a cooperative program of actions to limit potential future impacts on human health and the environment from naturally occurring asbestos (NOA)-bearing material generated from the Sumas Mountain landslide, both as that material exists today in the Swift Creek/Sumas River floodplain and as it will continue to be generated and transported as sediment from the landslide toward the floodplain in the future.

e. Since 2019 Whatcom County has completed several elements of the plan, including:

   i. Purchasing properties for the construction of the debris flow levee, sediment traps, sediment basins, first repository and wetland mitigation site.
   ii. Completed designs for the debris flow levee, sediment traps, and repository (including the wetland mitigation site).
   iii. Completed the design and construction of the Oat Coles setback levee and access road improvements and setback levee mitigation in the form of wetland mitigation.
   iv. Continued monitoring, dredging, and armoring the lower reach section of the stream to prevent the sediment material from entering and destroying adjacent valuable habitat.
   v. Completed scoping the Supplemental EIS for the repository site.

f. Future projects include:

   i. Completion of the Draft and Final Supplemental EIS for the repository site.

ii. Development of the repository site.

iii. Construction of the debris flow levee.

iv. Construction of the sediment traps.

v. Williams Pipeline crossing control structures.

vi. Development and construction of the sediment basins.

vii. Development and construction of the wetland mitigation site.

viii. Continued monitoring, dredging, and armoring the lower reach.

Mitigation Strategy for Glacier-Gallup Creeks

The SWIF process included recommendations to address the deficiencies on the Glacier Levee on the left bank of Glacier Creek. The SWIF plan recommends working in collaboration with WSDOT to implement their preferred alternative to address the chronic environmental deficiencies associated with sedimentation at their bridges over SR 542. WSDOT's preferred alternative includes constructing a bridge with openings that span across both creeks and the channel migration zone in between them. They acquired the Glacier Creek Motel that was between the creeks downstream of the highway and constructed a new Gallup Creek bridge in 2010.

While WSDOT still has plans to construct the additional spans east of Gallup Creek, the timing of funding for project implementation is uncertain. Once the bridge project is complete, the Glacier Creek Levee will be in the middle of the channel migration zone and no longer needed to protect the roadway. The FCZD recently initiated a project to better assess the hazards associated with the creeks and evaluate options to relocate the Glacier Creek Levee to enable restoration of alluvial fan processes while mitigating hazards in the town of Glacier.

2. Coal Mines

Coal mines in Whatcom County are not considered a major concern.

3. Landslides

Washington is one of seven states listed by FEMA as being especially vulnerable to severe land stability problems. An increasing population and demand for "view" property, with the concomitant removal of trees to attain the view, increases the risk of landslides in residential areas. Buildings on steep slopes and bluffs are at risk in seasons of heavy rains or prolonged wet spells.

Landslide, mudflow and debris flow problems are often complicated by land management decisions. By studying the effects of landslides in slide-prone regions, plans for the future can be made and the public may be educated to prevent development in vulnerable areas. Applying established ordinances where geological hazards have been identified will prevent some landslide losses. However, Whatcom County already has many areas above or below unstable slopes with established houses and businesses. Prevention of landslide damage is best achieved through careful identification and avoidance of unstable landforms and landslide run-out zones. For areas where development may occur near unstable slopes an appropriate mitigation plan prepared by a qualified professional and that is tailored to the site conditions and the type or types of mass wasting that may occur is necessary to manage landslide risks.

The primary mitigation strategy to employ in areas at danger of landslides or landslide run-out is to limit or eliminate development in any high risk areas. Employing public buyouts of especially high risk areas should be considered. If new development is to occur, the Washington State Department of Ecology has outlined the following recommendations and information to improve public preparedness. This information was developed for coastal bluffs, but provides good guidance for many situations where the stability of a slope may be an issue.

1. Do research – Learn about the geology and the history of your property. Talk to local officials, your neighbors, or visit the local library. Review geologic or slope stability maps of your area.
2. Get advice – Talk with a licensed geologist or geological engineer before buying a potentially unstable site or building your home. Although waterfront lots can be attractive sites, they often have severe natural limitations. They may also be subject to strict environmental and safety regulations.
3. Leave a safe setback **–** Build a prudent distance from the top or bottom of steep slopes. Avoid sites that are too small to allow a safe setback from the slope. Allow adequate room for drainfields and driveways. Local setback requirements should be viewed as absolute minimums. Consider how far landslide material may run out once it reaches the bottom of the hill or the alluvial fan. Resist the urge to trade safety for a view.
4. Keep plants – Maintain existing mature vegetation, above, on, and below steep slopes. Trees, especially native conifers, shrubs, and groundcovers help anchor soils and absorb excess water. Get expert advice identifying and removing weeds.
5. Maintain drainage – Collect runoff from roofs and improved areas and convey water away from the steep slope or to the beach in a carefully designed pipe system. Regularly inspect and maintain drainage systems.

SEVERE STORMS

A. DEFINITIONS

Blizzard A blizzard means that the following conditions are expected to prevail for a period of 3 hours or longer:

- Sustained wind or frequent gusts to 35 miles an hour or greater; and
- Considerable falling and/or blowing snow (i.e., reducing visibility frequently to less than ¼ mile)

Freezing Rain Rain that falls as a liquid but freezes into glaze upon contact with the ground.

Funnel Cloud A condensation funnel extending from the base of a towering cumulus or cumulonimbus, associated with a rotating column of air that is not in contact with the ground (and hence different from a tornado). A condensation funnel is a tornado, not a funnel cloud, if either a) it is in contact with the ground or b) a debris cloud of dust whirl is visible beneath it.

Gale An extratropical low or an area of sustained surface winds of 34 (39 mph) to 47 knots (54 mph).

High Wind Sustained wind speeds of 40 mph or greater lasting for 1 hour or longer, or winds of 58 mph or greater for any duration.

Severe Local Storm A convective storm that usually covers a relatively small geographic area, or moves in a narrow path, and is sufficiently intense to threaten life and/or property. Examples include severe thunderstorms with large hail, damaging wind, or tornadoes. Although cloud-to-ground lightning is not a criteria for severe local storms, it is acknowledged to be highly dangerous and a leading cause of deaths, injuries, and damage from thunderstorms. A thunderstorm need not be severe to generate frequent cloud-to-ground lightning. Additionally, excessive localized convective rains are not classified as severe storms but often are the product of severe local storms. Such rainfall may result in related phenomena (flash floods) that threaten life and property.

Storm Surge An abnormal rise in sea level accompanying a hurricane or other intense storm, whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge is usually estimated by subtracting the normal or astronomic tide from the observed storm tide.

Flooding Any high flow, overflow, or inundation by water which causes or threatens damage

Thunderstorm A local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder.

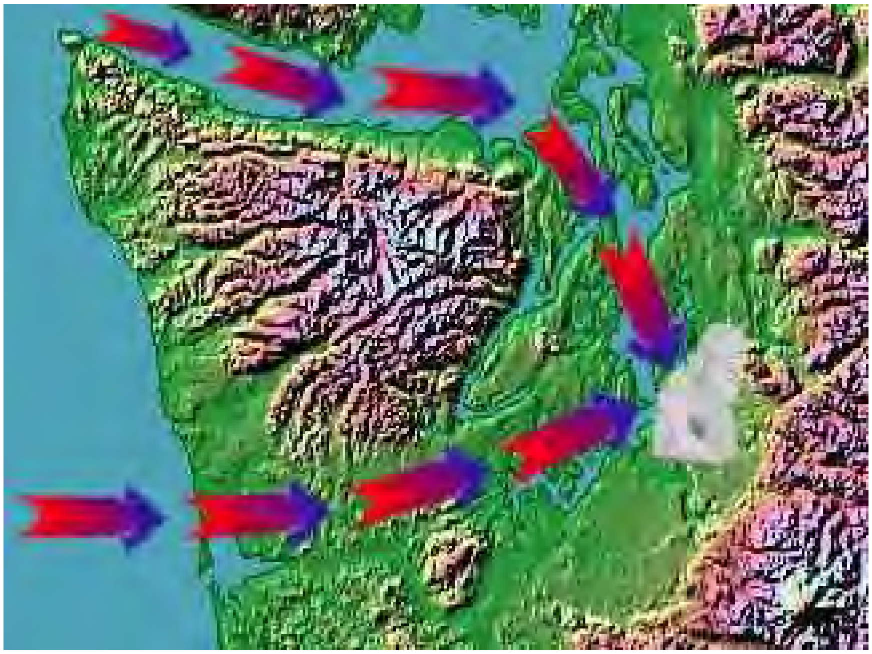
Tornado A violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. It nearly always starts as a funnel cloud and may be accompanied by a loud roaring noise. On a local scale, it is the most destructive of all atmospheric phenomena.

Waterspout In general, a tornado occurring over water. Specifically, it normally refers to a small, relatively weak rotating column of air over water beneath a Cumulonimbus or towering cumulus cloud. Waterspouts are most common over tropical or subtropical waters.

NOTE: All definitions taken from National Weather Service Glossary accessed by internet @ https://w1.weather.gov/glossary/

B. BACKGROUND INFORMATION

Severe storm weather comes in many forms, the most common for Whatcom County being heavy rain and wind during the winter months. Several wind storms have occurred in late summer with trees still retaining their full complement of leaves resulting in toppled trees and broken branches interrupting power to tens of thousands. Whatcom County experiences blizzards periodically, though not as commonly as unfrozen or partially frozen precipitation. Two types of winds primarily affect Western Washington: westerlies and easterlies. Westerly wind storms originate from the Pacific Ocean and are caused by pressure differences between deep oceanic storms and adjacent upland areas. This wind pattern is typical for fall and winter.



Westerly winds in Washington figure courtesy of http://www.islandnet.com

Easterly winds are caused by high pressure systems in eastern Washington, causing strong winds to form west of the Cascade mountain range that occur in late summer and early fall.

Easterly winds in Washington figure courtesy of http://www.pep-c.org

C. RECENT HISTORY IN WHATCOM COUNTY

Recent severe storm events in Whatcom County include the following:

February 2020	Significant rain led to Nooksack River overtopping bank in numerous locations. Beginning with overtopping the bank in Everson, water flowed north through Everson and Nooksack continuing north along the Sumas River and Johnson Creek damaging numerous homes and businesses in Sumas. Farther downstream, Marietta residents were evacuated due to rising water.
December 2018	Strong wind storm brought significant waves to Birch Bay and Point Robert resulting in downed trees and powerlines and significant erosion to Birch Bay Drive. Additionally, several businesses were impacted by high water level and surge.
December 2017	Ice storm knocked out power in Sumas and surrounding area for days after accumulated ice snapped numerous power poles blocking roads and preventing power crews from completing rapid repairs.
December 2008	Heavy rainfall over most of Western Washington, causing record levels and flooding for five major rivers including the Nooksack.
December 2000	The Sandy Point storm that caused severe damage to Sandy Point beachfront homes ($750,000) was a combination of gale force northwest winds, extreme high tides, and low pressure.
Winter 1998-1999	Record snowfall, up to 1,140 inches of snow fell on Mount Baker Ski Area, the most ever recorded in the United States.
Winter 1996-1997	Up to 3 feet of snow dropped by a holiday storm. Wind, snow, flooding, and freezing resulted in landslides, avalanches, road closures, and power outages throughout Whatcom County.
Winter 1990-1991	Six major storms (two floods, two Arctic windstorms, and two heavy snowstorms, along with bouts of freezing rain and silver thaw) across Whatcom County resulted in power losses to nearly 100,000 residents. The Lummi Island ferry service was cut off. Damages to Whatcom County were up to $30 million, not including private property damage and economic losses.
November 1989	Severe storm resulting in a wind-chill factor estimated at between 50 and 70 degrees below zero with wind gusts up to 104 miles per hour.

	Up to 16,000 residents lost power, resulting in school closure, damaged crops, and frozen milk in pumping equipment at local dairies.
January 1969	Severe storm froze stretches of the Nooksack River. Snow blocked portions of the Guide Meridian with a snowdrift on Pangborn Road measuring up to 25 feet high and 300 feet wide.
October 12, 1962	The famous Columbus Day storm brought winds up to 98 miles per hour.
March 1951	Severe storm dumped 23 inches of snow over 4 days. Temperatures plunged down to 10 degrees.
January 1950	Repeated snow storms hit Whatcom County for more than 1 month beginning on New Year's Day. Temperatures hit zero with winds of up to 75 miles per hour. Winds destroyed five planes and damaged 29 others at Bellingham International Airport.
February 1916	Seventeen inches of snow fell in Bellingham for the first week, followed by 42 inches of rain over a 2-week stretch. Snowdrifts up to 30 feet in height were found throughout the County.
February 1893	A blizzard consisting of snow and hail hit Whatcom County with up to 80 mile per hour winds and temperatures hitting 13 degrees below zero.

D. VULNERABILITY ASSESSMENT

Whatcom County is highly vulnerable to severe storms. According to the Washington State Emergency Management Division, Whatcom County lies in an area of Washington vulnerable to high winds.[2] The Washington State Hazard Mitigation Plan identifies Western Washington to be most susceptible to inclement weather during the following time periods[3]:

- Primary flood season – November through February

---

[2] Accessed on July 9, 2014 on the Emergency Management Department website at: http://www.emd.wa.gov/plans/documents/SevereStormNov2007Tab5.7.pdf

[3] Washington Military Department Emergency Management Division, 2014. *Washington State Hazard Mitigation Plan*. Approved by the Federal Emergency Management Agency Region 10 Office 2014.

- Windstorm season – October through March
- Snow season – November through mid-March

Severe storms can result in costly hazards, due primarily to their frequent occurrence and ability to disrupt lifelines such as arteries of transportation and above-ground electric lines. Because the worst storms typically occur during winter, loss of power/heating can be dangerous, especially for homes with children or elderly residents. Severe weather also poses additional risks resulting from tree fall to both structures and humans.

Whatcom County's location and geography leave it susceptible to heavy storm activity. Coastal systems move in relatively easily and release most of their moisture, being blocked by the Cascade Mountain Range. Multiple marinas along the shoreline of Whatcom County are vulnerable to storm action and represent a high loss potential for the area. The County's limited routes of transportation mean that inclement or severe weather can slow both intrastate and interstate commerce. Additionally, Fraser outflows from north of the border bring very cold temperatures and strong northeast winds. This cold air frequently clashes with the warmer moist flowing north leading to freezing rain, significant snowfall and in some cases, blizzard conditions.

Additionally, Fraser outflows from north of the border bring very cold temperatures and strong northeast winds. This cold air frequently clashes with the warmer moist flowing north leading to freezing rain, significant snowfall and in some cases, blizzard conditions.

E. MITIGATION STRATEGIES

The National Weather Service continues to refine weather forecasting. In addition, when significant weather systems are forecast for Washington and Whatcom County, weather forecasters conduct daily virtual briefings to ensure the most current conditions are promulgated to response agencies. The Whatcom County Sheriff's Office Division of Emergency Management website contains real-time data for severe storm events and other hazards and can be accessed at https://www.whatcomcounty.us/201/Emergency-Management . The website also contains educational tools to inform residents of potential hazards, such as severe storms, and how to prepare for them.

Whatcom County has been awarded the "Storm Ready Certification" by the by the National Oceanic and Atmospheric Administration National Weather Service for its, monitoring, communication, and warning efforts.

TSUNAMIS

A. DEFINITIONS

Tsunami A series of traveling waves of extremely long length generated by earthquakes occurring below or near the ocean floor. Underwater volcanic eruptions and landslides can also generate tsunamis.

B. BACKGROUND INFORMATION

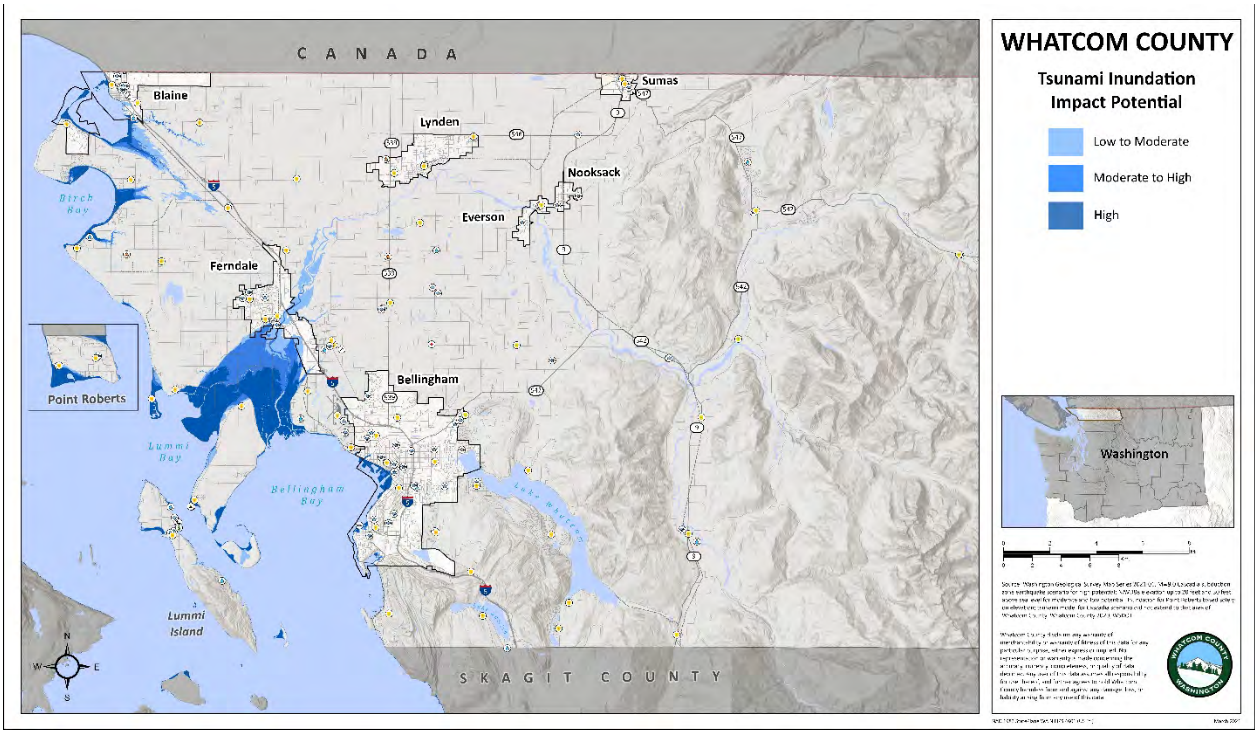
Sudden movement of the Earth's crust during an earthquake may displace water and generate an energy wave called a tsunami. In the deep ocean, a tsunami's length from wave crest to wave crest may be 100 miles or more but with a visible wave height of only a few feet or less. They may not be felt aboard ships nor can they be seen from the air in the open ocean. Large Pacific Ocean tsunamis typically have wave crest-to-crest distances of 60 miles and can travel about 600 miles per hour in the open ocean. A tsunami can traverse the entire 12,000 to 14,000 miles of the Pacific Ocean in 10 to 25 hours, striking any land in its way with great force. Tsunamis can cause great destruction and loss of life within minutes of origination. For example, the first tsunami waves from the 2004 Indian Ocean Earthquake reached Sumatra's shores within 15 minutes of the earthquake and those of Somalia seven hours later.

On the Pacific Coast, from southern British Columbia to northern California, people and property are at varied risks both from distantly and locally generated tsunamis. Recent studies indicate about a dozen very large earthquakes (with magnitudes of 8 or more) have occurred in the CSZ west of Washington. Computer models indicate that tsunami waves generated by these local events might range from 5 to 55 feet in height and could affect the entire coastal region.

In April 2021, the Washington State Department of Natural Resources (DNR) completed new tsunami inundation maps for the state, including a new tsunami inundation map for North Puget Sound and parts of the Strait of Georgia. The new tsunami inundation map for the North Puget Sound shows postulated inundation areas and modeled inundation depth from a Mw 9.0 Cascadia subduction zone megathrust earthquake scenario. Inundation depths vary, based not only on the tsunami wave height but how these waves may "stack up" or "funnel" into bays, rivers, and stream estuaries. The bay on the north side of Portage Island is expected to experience about 14.5 feet of inundation, with higher levels of inundation at the mouth of the Nooksack River. If this tsunami inundation occurs during high tide, it could create inundation of over 20 feet above mean sea level (NAVD88) in some locations of the Whatcom county.

Notably, the DNR tsunami inundation map is for a single scenario event and does not fully model all coastline inundation. DNR only infers, but does not fully model, inundation along much of Whatcom County's coastline and does not model any inundation for the Point Roberts area. Furthermore, other scenarios may pose a tsunami or seiche risk to Whatcom county. These include earthquake-triggered collapses of the Fraser River mouth or tidal flats at the mouth of the Nooksack River. Earthquakes or other events could cause large-scale landslides along the marine headlands of Lummi Island, displacing water in Bellingham Bay and potentially causing a local seiche with little warning time before it inundates shorelines in Bellingham Bay. Smaller earthquakes may also occur on crustal faults in Whatcom County and these faults may extend out into coastal waters. Little or no research has been completed on these scenarios and whether they may produce tsunami inundation larger than the Cascadia subduction zone scenario.

Given the incomplete nature of tsunami modeling in Whatcom County, this Natural Hazards Plan takes a conservative approach, as shown in the Tsunami Inundation Hazard map below. In additional to planning for the Cascadia subduction scenario, shown as high tsunami inundation impact potential in the map, the map also shows areas outside of this scenario inundation but under 30 feet above mean sea level (NAVD88). Areas up to 20 feet above mean sea level (NAVD88) are shown in medium blue and labeled as moderate to high tsunami inundation impact potential. Areas up to 30 feet above sea level are shown in light blue and labeled as low to moderate tsunami inundation impact potential. (Areas above 40 feet of elevation should be considered as completely above tsunami inundation impact.) These areas outside of the DNR model, but labeled as having some potential for tsunami inundation impact are meant to help address the lack of complete tsunami modeling in the county. They are also meant to help address secondary impacts, such as debris pushed ahead of tsunami inundation, ground subsidence, or even debris fires that can ignite in and near tsunami inundation areas. Future changes to coastal morphology and continued sea level rise may also lead to tsunami inundation impacts in areas outside of the DNR modeling of the Cascadia subduction zone earthquake inundation in the future.



Map of Whatcom County tsunami inundation impact potential. The high impact potential zone is based upon Washington Geological Survey Map Series 2021-01, Mw9.0 Cascadia subduction zone earthquake scenario occurring at mean high tide. The moderate to high and the low to moderate impact potential areas are based upon elevation of up to 20 feet and 30 feet, respectively, above mean sea level (NAVD88). Inundation for Point Roberts is based solely on elevation; tsunami model for the Cascadia subduction zone scenario did not extend to Point Roberts.

C. RECENT HISTORY IN WHATCOM COUNTY

Recent research on subduction zone earthquakes off the Washington, Oregon, and northern California coastlines and resulting tsunamis (Atwater 1992; Atwater et al. 1995) has led to concern that locally generated tsunamis will leave little time for response. Numerous workers have found geologic evidence of tsunami deposits attributed to the CSZ in at least 59 localities from northern California to southern Vancouver Island (Peters et al. 2003). While most of these are on the outer coast, inferred tsunami deposits have been identified as far east as Discovery Bay, just west of Port Townsend (Williams et al. 2002) on the west shore of Whidbey Island (Williams and Hutchison 2000). Heaton and Snavely (1985) report Makah stories may reflect a tsunami washing through Waatch Prairie near Cape Flattery, Washington, and Ludwin (2002) has found additional stories from native peoples up and down the coast that appear to corroborate this and also include apparent references to associated strong ground shaking. Additionally, correlation of the timing of the last CSZ earthquake by high-resolution dendrochronology (Jacoby et al. 1997; Yamaguchi et al. 1997) to Japanese historical records of a distant-sourced tsunami (Satake et al. 1996) demonstrate that it almost certainly came from the CSZ. This tsunami may have lasted as much as 20 hours in Japan and caused a shipwreck about 100 km north Tokyo in A.D. 1700 (Atwater and Satake 2003). The frequency of occurrence of CSZ earthquakes ranges from a few centuries to a millennium, averaging about 600 years (Atwater and Hemphill-Haley 1997). It is believed the last earthquake on the CSZ was about magnitude (M) 9 (Satake et al. 1996, 2003). It is not known, however, if that is a characteristic magnitude for this fault. Evidence gleaned from syntheses of global subduction zone attributes and local tsunami deposits suggests that great earthquakes have occurred in the Pacific Northwest perhaps as recently as 300 years ago.

Tsunamis may also be generated by movement on faults located within Puget Sound. This is discussed in further detail under the Vulnerability Assessment portion of this section.

Tsunamis are a threat to life and property and to anyone living near the ocean. In 1995, in response to tsunami threat, Congress directed NOAA to develop a plan to protect the West Coast from locally generated tsunamis. A panel of representatives from NOAA, FEMA, the USGS, and the five Pacific coast states wrote the plan and submitted it to Congress, which created the National Tsunami Hazard Mitigation Program (NTHMP) in October 1996. The NTHMP was designed to reduce the impact of tsunamis through warning guidance, hazard assessment, and mitigation. A key component of the hazard assessment for tsunamis is delineation of areas subject to tsunami inundation. Since local tsunami waves may reach nearby coastal communities within minutes of the earthquake, there will be little or no time to issue formal warnings; evacuation areas and routes will need to be planned well in advance.

Spatial data used to assess tsunami hazards in Whatcom County was developed by the Center for the Tsunami Inundation Mapping Efforts (TIME) at NOAA's Pacific Marine Environmental Laboratory in Seattle. The data and maps were produced using computer models of earthquake-generated tsunamis from nearby seismic sources, and analyzed to determine the risks of a CSZ earthquake.

TIME’s tsunami inundation maps are based on a computer model of waves generated by a scenario earthquake. The earthquake scenario adopted for that study was developed by Priest et al. (1997) and designated Scenario 1A (also see Myers et al. 1999). It was one of a number of scenarios they compared to paleoseismic data and found to be the best fit for the A.D. 1700 event. This scenario has been the basis for tsunami inundation modeling for the other maps produced by the NTHMP in both Oregon and Washington based on a CSZ event. The land surface along the coast is modeled to subside during ground shaking by about 1.0 to 2.0 meters (Fig. 1), which is consistent with some paleoseismologic investigations and also matches thermal constraints of Hyndman and Wang (1993). This earthquake is a magnitude 9.1 event, with a rupture length of 1,050 km and a rupture width of 70 km. Satake et al. (2003) have recently calculated a very similar magnitude and rupture dimension from an inversion of tsunami wave data from the 1700 event. The model used is the finite difference model of Titov and Synolakis (1998), also known as the Method of Splitting Tsunami (MOST) model (Titov and González 1997). It uses a grid of topographic and bathymetric elevations and calculates a wave elevation and velocity at each grid point at specified time intervals to simulate the generation, propagation, and inundation of tsunamis down the Strait of Juan de Fuca and into the Bellingham Bay area.

Based on new seismic research demonstrating the potential for increased seafloor displacement during a subduction zone earthquake with a recurrence interval of ~2500 years, the Washington Geological Survey published updated tsunami hazard modeling in June 2018 (Eungard, 2018). The model demonstrates the potential for increased inundation depth and current velocities to impact the shoreline and other low-lying areas of Whatcom County. Increased inundation depths of 5 to 18 feet above mean high water are possible, as are current velocities exceeding 20 knots. Due to the low recurrence interval of the defined seismic event the results of the model are intended to inform the design of critical infrastructure and are not currently being used in the regulation of residential or commercial development.

D. VULNERABILITY ASSESSMENT

TIME Results – The computed tsunami inundation model emphasized three depth ranges: 0 to 0.5 m, 0.5 to 2 m, and greater than 2 m. These depth ranges were chosen because they are approximately knee-high or less, knee-high to head-high, and more than head-high and so approximately represent the degree of hazard for life safety. The greatest amount of tsunami flooding is expected to occur in the floodplain of the Lummi (Red) and Nooksack Rivers up to their confluence near Ferndale and then be confined to the relatively narrow floodplain of the Nooksack. Sandy Point Shores is expected to be flooded to a depth of a few feet. Elsewhere, tsunami flooding is expected only in the immediate vicinity of the shoreline where evacuation to higher ground would be an easy matter if sufficient warning is given.

The inundation data also emphasized current velocities:

1. Less than 1.5 m/s (approximately 3 mph), which is the current speed at which it would be difficult to stand
2. Between 1.5 and 5 m/s

3. Greater than 5 m/s which is a modest running pace; within zones with this designation, computed velocities locally exceed 20 m/s (approximately 40 mph) in confined channels

Tide gauge records at five locations in the bay show fluctuations of water surface elevation and also the time history of the waves. The initial water disturbance is a trough of about 1 meter at 2 hours after the earthquake followed by a crest at between 2.5 and 3 hours after the earthquake. At around 4 hours after the earthquake, a deeper trough occurs and reaches about 3 meters near the Port of Bellingham. A trough this large, if it occurred at low tide, could cause a significant grounding hazard for ships in the harbor. This is visually displayed in Figure 3, which shows an animation of the tsunami troughs and crests in and around Bellingham Bay.

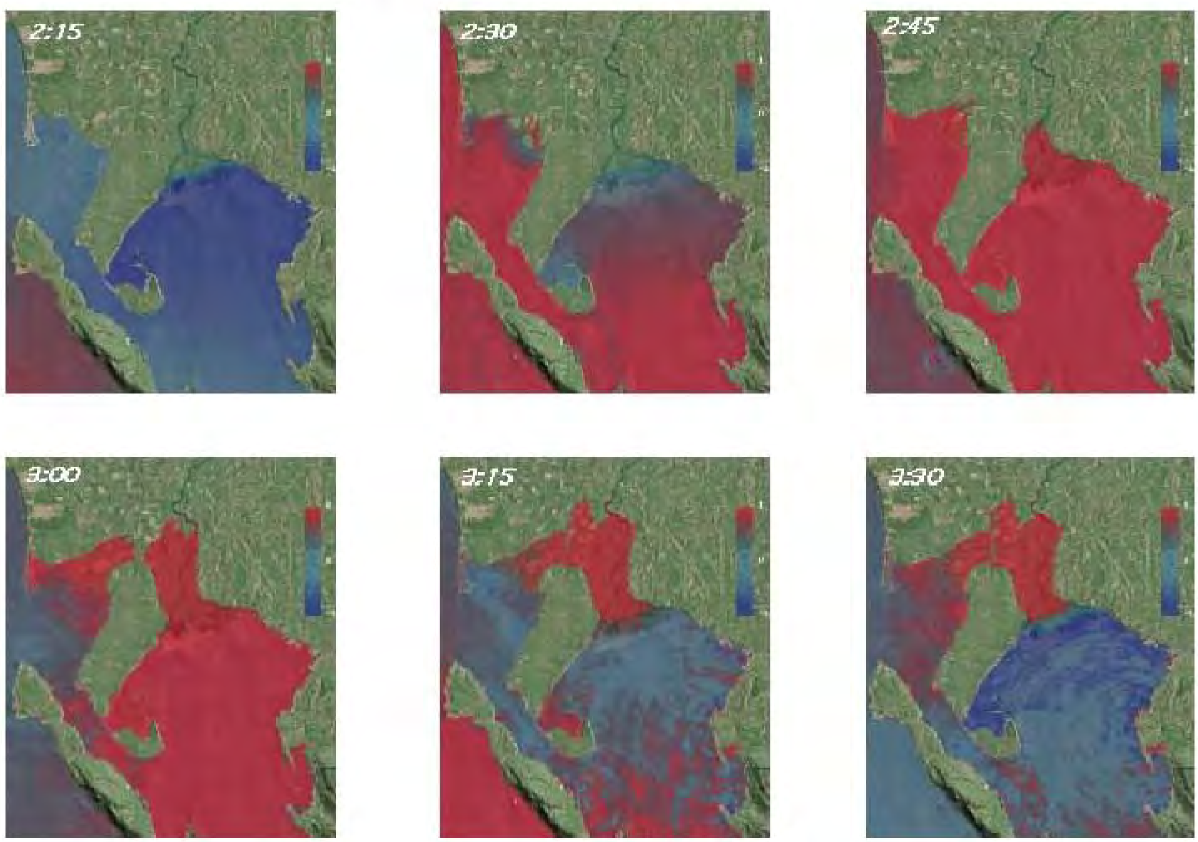


Figure 3 – Screen shots of animation of a tsunami arriving in Bellingham area, lasting about 3:30 hours. Red areas are crests, blue are troughs. (Picture obtained from the NOAA T.I.M.E. Center)

These models do not include potential tsunamis from landslides, including failure of the Nooksack River delta front, or nearby crustal faults, which are generally not well enough understood to be modeled. Apparently locally generated tsunami deposits have been found on Whidbey Island (Williams and Hutchinson 2000; Atwater and Moore 1992); in Discovery Bay, southwest of Port Townsend (Williams et al. 2002); in the Snohomish delta near Everett

(Bourgeois and Johnson 2001): and at West Point near Seattle (Atwater and Moore 1992). Gonzalez (2003) summarizes the evidence for tsunamis generated within the Puget Lowland by local earthquakes and landslides and estimates their probabilities.

When an earthquake that might generate a Pacific Coast tsunami is detected, the Alaska Tsunami Warning Center calculates the danger to the northeast Pacific Coast and notifies the communities at risk. Those warnings may give people a few hours to prepare and evacuate (depending on the distance to the earthquake).

If the earthquake occurs off our coast, however, there may be no time to send out hazard warnings. The first waves could arrive within minutes of the earthquake. The only tsunami warning might be the earthquake itself.

E. MITIGATION STRATEGIES

In order to plan for hazards, citizens need to know what to expect. In the last few years, there have been significant advances in understanding the earthquakes that have occurred on the CSZ and the tsunamis that struck the Pacific Coast. This information is the foundation for planning efforts. Because tsunami events provide little warning, one of the keys to mitigating tsunamis to effectively educate the population at risk about the hazards they face:

1. Hold public meetings to educate the public about the hazard they face. Provide handouts, evacuation maps, and a description of the warning system (typically the Emergency Alert System) that will be used to warn residents. Distribute hazard and evacuation maps to all interested parties, such as public safety agencies, citizen groups, etc.
2. Establish evacuation plans for all affected communities to effectively remove all people from the hazard area in the event of a tsunami warning. This includes identifying all facilities that may need extra assistance in evacuating (nursing homes, day cares, etc.). The evacuation plan should also address the timeline for a full evacuation, as well as a division of labor to identify which agencies will do which actions.
3. Establish requirements that existing critical facilities must be reviewed for susceptibility to tsunamis. These facilities should be reviewed to determine what kind of mitigation action should be taken for each facility.
4. Post Tsunami signs that show the existence of the hazard area, and the way to the

nearest evacuation route.

5. New critical facilities constructed in the tsunami hazard zone must be elevated above the hazard area, armored in place, or built outside the hazard area if at all possible. The 2018 model, demonstrating increased inundation potential, published by the Washington Geologic Survey, should be used to inform the siting and mitigation measures employed during permitting of critical facilities.
6. Early warning systems should be evaluated to see if an automated system can be put into place to provide automated early warning in the event a tsunami occurs.
7. Develop Tsunami Resistant Communities, according to NOAA's Strategic Implementation Plan for Tsunami Mitigation Projects. These communities would be outfitted with the knowledge and tools outlined above to deal with a tsunami event.

Five All Hazard Alert Broadcast (AHAB) Warning Systems have been added to the five already placed along the shoreline to provide warning of tsunami waves. New locations include:

- Birch Bay Park
- Blaine (Water Treatment Plant)
- Port of Bellingham (South Harbor Loop)
- Birch Bay Village Marina
- Fairhaven (Port of Bellingham)

Three additional AHAB systems are planned for 2021

- Lummi Nation
- Birch Bay State Park
- Semiahmoo Marina

These sirens are being added due to population growth in these areas and increased tsunami risk. Also in 2020, Whatcom County started the TsunamiReady certification process with NOAA and also started the process of evaluating the risk areas and evacuation routes that had been identified in 2015 as newer modeling suggests that the identified evacuation routes will likely not survive even a moderate earthquake due to liquefaction. In 2019, Whatcom County completed and issued the Whatcom County Tsunami Action Plan which details response actions. Whatcom County is also now part of the State of Washington Inner Coast Working

Group.

-Whatcom County will continue to explore options for defining conservative estimates of tsunami inundation potential in areas not currently addressed by available tsunami modeling. When new modeling data becomes available from the Washington State Geological Survey addressing tsunami potential for the entire County, this information can be used to refine or replace conservative estimates. The identification of safe evacuation areas is critical to the development of preparedness plans for individual and communities. Access to safe evacuation areas should be served by multiple evacuation routes in the event that secondary seismic impacts such as landslides, liquefaction, or lateral spreading damage or destroy one or more options for accessing high ground.

Selected Works Cited:

Atwater, B. F., 1992, Geologic evidence for earthquakes during the past 2000 years along the Copalis River, southern coastal Washington: Journal of Geophysical Research, v. 97, no. B2, p. 1901-1919.

Atwater, Brian F., and Andrew L. Moore. 1992. "A Tsunami About 1000 Years Ago in Puget Sound, Washington." Science, 258(5088): 1614. https://doi.org/10.1126/science.258.5088.1614

Atwater, B. F.; Hemphill-Haley, Eileen, 1997, Recurrence intervals for great earthquakes of the past 3,500 years at northeastern Willapa Bay, Washington: U.S. Geological Survey Professional Paper 1576, 108 p.

Atwater, B. F., Nelson, A. R., Clague, J. J., Carver, G. A., Yamaguchi, D. K., Bobrowsky, P. T., Bourgeois, J., Darienzo, M. E., Grant, W. C., Hemphill-Haley, E., Kelsey, H. M., Jacoby, G. C., Nishenko, S. P., Palmer, S. P., Peterson, C. D., & Reinhart, M. A. (1995). Summary of Coastal Geologic Evidence for past Great Earthquakes at the Cascadia Subduction Zone. Earthquake Spectra, 11(1), 1–18. https://doi.org/10.1193/1.1585800

Bourgeois, Joanne; Johnson, S. Y., 2001, Geologic evidence of earthquakes at the Snohomish delta, Washington, in the past 1200 yr: Geological Society of America Bulletin, v. 113, no. 4, p. 482-494.

Eungard, D. W.; Forson, Corina; Walsh, T. J.; Gica, Edison; Arcas, Diego, 2018, Tsunami hazard maps of the Anacortes–Bellingham area, Washington—Model results from a ~2,500-year Cascadia subduction zone earthquake scenario: Washington Geological Survey Map Series 2018-02, 6 sheets, scale 1:30,000, 10 p. text. [http://www.dnr.wa.gov/ publications/ger_ms2018-02_tsunami_hazard_anacortes_bellingham.zip]

Gonzalez, F. I., compiler, 2003, Puget Sound tsunami sources—2002 workshop report: NOAA/Pacific Marine Environmental Laboratory Contribution No. 2526, 36 p.

Heaton, T. H.; Snavely, P. D., Jr., 1985, Possible tsunami along the northwestern coast of the United States inferred from Indian traditions: Seismological Society of America Bulletin, v. 75, no. 5, p. 1455-1460

Hyndman, R. D.; Wang, Kelin, 1993, Thermal constraints on the zone of major thrust earthquake failure—The Cascadia subduction zone: Journal of Geophysical Research, v. 98, no. B2, p. 2039-2060.

Jacoby, G. C.; Bunker, D. E.; Benson, B. E., 1997, Tree-ring evidence for an A.D. 1700 Cascadia earthquake in Washington and northern Oregon: Geology, v. 25, no. 11, p. 999- 1002

Ludwin, R. S., 2002, Cascadia megathrust earthquakes in Pacific Northwest Indian myths and legends: TsuInfo Alert, v. 4, no. 2, p. 6-10.

Peters, Robert; Jaffe, B. E.; Gelfenbaum, Guy; Peterson, C. D., 2003, Cascadia tsunami deposit database: U.S. Geological Survey Open-File Report 03-13, 25 p.

Priest, G. R.; Myers, E. P., III; Baptista, A. M.; Fleuk, Paul; Wang, Kelin; Kamphaus, R. A.; Peterson, C. D., 1997, Cascadia subduction zone tsunamis—Hazard mapping at Yaquina Bay, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report O-97-34, 144 p.Myers et al. 1999

Satake, Kenji; Shimazaki, Kunihiko; Tsuji, Yoshinobu; Ueda, Kazue, 1996, Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January 1700: Nature, v. 379, no. 6562, p. 246-249.

Satake, Kenji; Wang, Kelin; Atwater, B. F., 2003, Fault slip and seismic moment of the 1700 Cascadia earthquake inferred from Japanese tsunami description: Journal of Geophysical Research, v. 108, no. B11, 2535, DOI:10.1029/ 2003JB002521, p. ESE 7-1 - 7-17.

Titov, V. V.; Gonzalez, F. I., 1997, Implementation and testing of the Method of Splitting Tsunami (MOST) model: NOAA Technical Memorandum ERL PMEL-112 (PB98- 122773), 11 p.

Titov, V. V.; Synolakis, C. E., 1998, Numerical modeling of tidal wave runup: Journal of Waterway, Port, Coastal and Ocean Engineering, v. 124, no. 4, p. 157-171.

Williams, H. F. L.; Hutchinson, Ian, 2000, Stratigraphic and microfossil evidence for late Holocene tsunamis at Swantown Marsh, Whidbey Island, Washington: Quaternary Research, v. 54, no. 2, p. 218-227.

Williams, Harry & Hutchinson, Ian & Nelson, Alan. (2002). Multiple sources for late-Holocene tsunamis at Discovery Bay, Washington State, USA. Holocene. 15. 60-73. 10.1191/0956683605hl784rp.

Yamaguchi, D. K.; Atwater, B. F.; Bunker, D. E.; Benson, B. E.; Reid, M. S., 1997, Tree-ring dating the 1700 Cascadia earthquake: Nature, v. 389, no. 6654, p. 922-923

VOLCANOES

A. DEFINITIONS

Blast Zone The area immediately surrounding a volcano, up to several tens of kilometers, that is destroyed by a volcano's blast.

Lava Flow A stream of molten rock that pours or oozes from an erupting vent.

Lahar A mudflow or debris flow that originates from the slope of a volcano; pyroclastic flows can generate lahars by rapidly melting snow and ice.

Pyroclastic Flows High-density mixtures of hot, dry rock fragments and hot gases that move away from the vent that erupted them at high speeds.

Tephra General term for fragments of volcanic material, regardless of size, that are blasted into the air by explosions or carried up upward by hot gases in eruption columns or lava fountains.

Volcano A vent in the earth's crust through which magma (molten rock), rock fragments, associated gases, and ashes erupt, and also the cone built by effusive and explosive eruptions.

B. BACKGROUND INFORMATION

The Cascade Range (Cascades) extends more than 1,000 miles, forming an arc-shaped band extending from Southern B.C. to Northern California. The Cascades roughly parallels the Pacific coastline, and at least 17 major volcanic centers. Whatcom County's eastern boundary follows the crest of the Cascade Range.

The central and southern Cascades are made up of a band of thousands of much older, smaller, short-lived volcanoes that have built a platform of lava and volcanic debris. Rising above this volcanic platform are a few large younger volcanoes that dominate the landscape. The North Cascades, including Whatcom County, present younger (Quaternary) volcanoes overlying much older metamorphosed basement rock.

The Cascades volcanoes define the Pacific Northwest section of the "Ring of Fire," a fiery array of volcanoes that rim the Pacific Ocean. These volcanoes can be seen to the left in figure 4. Many of these volcanoes have erupted in the recent past and will most likely be active again in the future. Given an average rate of two eruptions per century during the past 12,000 years,

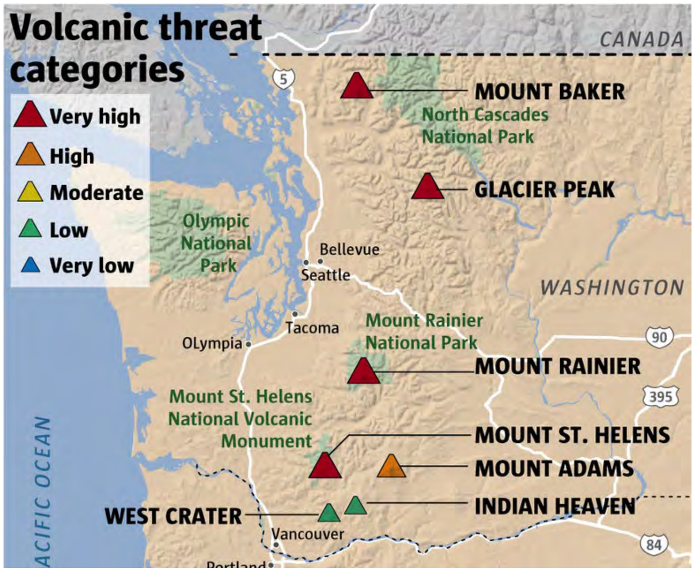


Figure 4. Washington Volcanoes and threat showing Mt. Baker as a major volcanic threat in Whatcom County. (Source: ESRI, USGS; created by Mark Nowlin/Seattle Times)

these disasters are not part of our everyday experience. The largest of the volcanoes in Washington State are Mount Baker, Glacier Peak, Mount Rainier, Mount Saint Helens, and Mount Adams. Eruptions from Mount Baker, located in the central portion of Whatcom County, and Glacier Peak, in Snohomish County, would severely impact Whatcom County. Mount Baker and Glacier Peak have erupted in the historic past and will likely erupt again in the foreseeable future. Due to the topography of the region and the location of drainage basins and river systems, eruptions on Mount Baker could severely impact large portions of Whatcom County. A Mount Baker eruption would generate lahars, pyroclastic flows, tephra or ash fall, and lava flows that would decimate affected areas, as shown in the map below. Glacier Peak, which is in Snohomish County, is of concern due to its geographic proximity to the County. Ash fall from an eruption at Glacier Peak could significantly impact Whatcom County.

Photo of Mt. Baker in Whatcom County

Mount Baker, seen to the left, (3,285 meters; 10,778 feet) is an ice-clad volcano in the North Cascades of Washington State about 50 kilometers (31 miles) due east of the city of Bellingham. After Mount Rainier, it is the most heavily glaciated of the Cascades volcanoes: the volume of snow and ice on Mount Baker (about 1.8 cubic kilometers; 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.

C. RECENT HISTORY IN WHATCOM COUNTY

Eruptions in the Cascades have occurred at an average rate of 1 to 2 per Qwest during the past 4,000 years, and future eruptions are certain. Seven volcanoes in the Cascades have erupted within the past 225 years (see Table 6).

Table 6. History of Major Volcanic Eruptions in the Cascade Mountain Range in the Past 225 Years

Volcano	Eruption Type	Eruptions in the Past 225 Years	Recent Activity
Mount Baker	Ash, lava	1?	1792, 1843 to 1865, 1870?, 1880, and 1975 steam emission
Glacier Peak	Ash	1+?	Before 1800 (1750?)
Mount Rainier	Ash, lava	1?	Tephra between 1830 and 1854
Mount St. Helens	Ash, lava, Dome	2 eruptive periods	1980 to present
Indian Heaven Volcanic Field	Lava, scoria	None	8,000 years ago?
Mount Adams	Lava, ash	None	3,500 years ago
Mount Hood, Oregon	Ash, dome	2+?	1865, major eruption in the late 1700s

***Note**: Information obtained from WDNR*

Four of the eruptions listed in Table 6 would have caused considerable property damage and loss of life if they had occurred post-development of Whatcom County without warning and the next eruption in the Cascades could affect hundreds of thousands of people. The most recent volcanic eruptions within the Cascade Range occurred at Mount Saint Helens in Washington (1980 to 1986; 2004 to 2008) and at Lassen Peak in California (1914 to 1917).

We know from geological evidence that Mount Baker has produced numerous volcanic events in the past that, were they to occur today, would place Whatcom County communities at considerable risk. Volcanic hazards from Mount Baker result from a variety of different eruptive phenomena such as lahars, ash fall, tephra fall, and pyroclastic flows. Figure 5 displays a model of the inner workings and hazards associated with volcanoes.

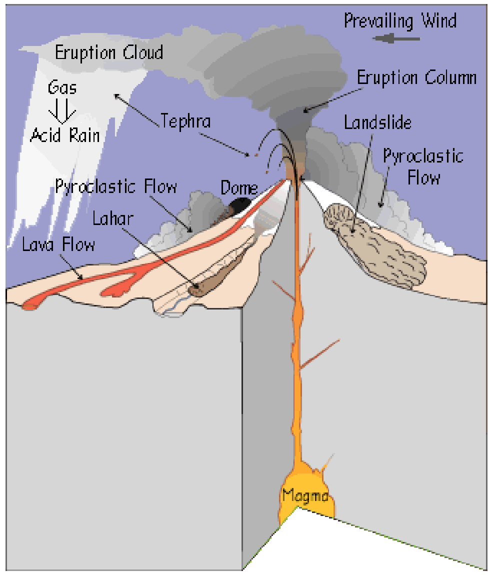


Figure 5 – Effects of a Volcano Eruption
(Diagram courtesy of USGS Cascade Volcano Observatory)

Geologic evidence in the Mount Baker area reveals a flank collapse near the summit on the west flank of the mountain that transformed into a lahar, estimated to have been approximately 300 feet deep in the upper reaches of the Middle Fork of the Nooksack River and up to 25 feet deep 30 miles downstream. This lahar may have reached Bellingham Bay. A hydrovolcanic (water coming into contact with magma) explosion occurred near the site of present-day Sherman Crater, triggering a second collapse of the flank just east of the Roman Wall. This collapse also became a lahar that spilled into tributaries of the Baker River.

Finally, an eruption cloud deposited several inches of ash as far as 20 miles downwind to the northeast. Geologic evidence shows lahars large enough to reach Baker Lake have occurred at various times in the past. 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 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 magma was moving up into the volcano. This volcanic activity gradually declined over the next 2 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.

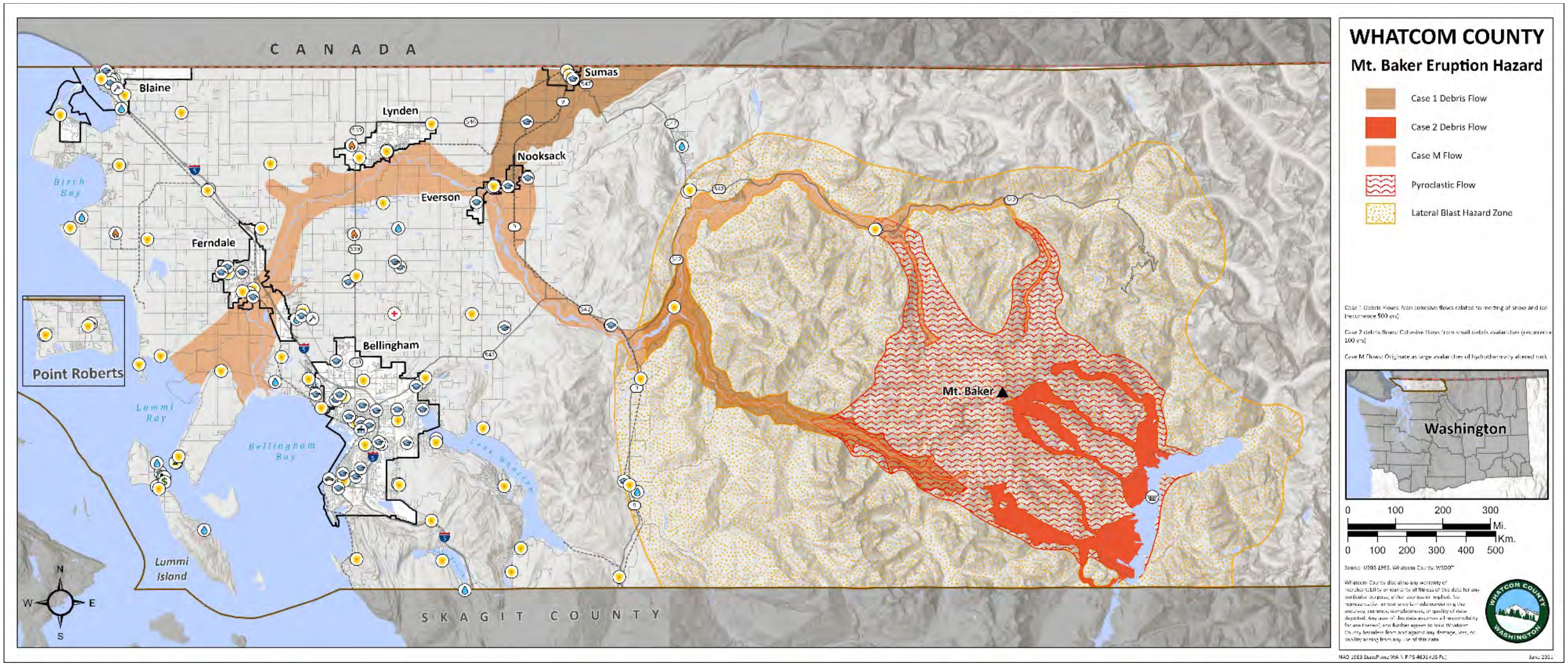
D. VULNERABILITY ASSESSMENT

Lahars are the primary threat from volcanic activity at Mount Baker. Originating from melted snow and ice, lahars could create torrents of ash, rock, and water. Flank collapses may also create volcanic landslides that may form into lahars. Lahars resulting from flank collapses can also be triggered by earthquakes, gravity, or increases in hydrovolcanic activity. Debris flows can remain hazardous for many years if the deposited material remobilizes from heavy rains.

Most cohesive debris flows will be small to moderate in volume and will originate as debris avalanches of altered volcanic rock, most likely from the Sherman Crater, Avalanche Gorge, or the Dorr Fumarole area. Small volume debris flows will pose little risk to most people, but moderate volume debris flows could travel beyond the flanks of the volcano.

The probability of either Mount Baker erupting, collapsing, or causing slides is low. However, volcanic activity from either mountain could result in massive destruction of property and probable loss of lives in or near the floods, lahars, earthquakes, landslides, and ash fall.

Exhibit A



Hazards from Future Activity of Mount Baker, WA (1995) data shows different volcanic flows. Case M flows originate as large avalanches of hydrothermally altered rock. Case 1 debris flows are non-cohesive flows related to melting of snow and ice, with a recurrence of 500 years. Case 2 debris flows are cohesive flows from small debris avalanches, with a recurrence of 100 years.

Examples of hazards and "worst-case scenarios" in Whatcom County, including adjacent counties and Canadian Provinces, as follows:

1. Small to moderate collapse in the area of Sherman Crater may produce lahars flowing into Baker Lake and result in the following:
   - Raised level of Baker Lake
   - Baker Lake Dam failure
   - Flooding of the entire Skagit floodplain to Puget Sound
2. Large flank collapses or pyroclastic flows could result in the following:
   - Inundation of Skagit River Valley by displacement of water in reservoirs by lahars
   - North Fork, Middle Fork, and Nooksack River to Bellingham Bay could be inundated, and enough debris flow could be deposited in the stretch of river between Lynden and Everson to raise the riverbed enough to spill into the Sumas River or to divert the Nooksack River into the Sumas River Basin (such an event is considered high consequence but low probability)
   - Floodwaters could extend from Sumas into Huntingdon and Abbotsford, B.C.
   - Flooding all the way to Bellingham Bay
3. Hospitals: Bellingham's Saint Joseph Hospital and the Outpatient Center would be isolated from other communities
4. Transportation Routes: I-5 flooded at Nooksack and/or Skagit Rivers; Highway 9 flooded at Deming and Sedro Woolley (Skagit County); Mount Baker Highway (SR 542) flooded
5. Ash fall: will depend on direction of the wind (prevailing winds are toward the East); the ash may cause reduced visibility or darkness; air filters and oil filters in automobiles and emergency vehicles become clogged
6. Airports: All local airports may be impacted by ash fall
7. Railroad tracks, power lines, radio towers, highways, campgrounds, natural gas pipelines, and water supplies in these more remote areas may be inundated
8. Forest fires from ash and volcanic eruption may be expected

9. Earthquakes may occur
10. Lightning and thunderstorms often accompany volcanic eruptions
11. City of Bellingham's Middle Fork water supply diversion dam, tunnel, and pipeline to Lake Whatcom possibly buried and/or destroyed
12. Large numbers of farm animals, people, fish, and wildlife may be required to be relocated (temporarily or permanently), injured, or, if warning and guidance are not followed, killed.Those most vulnerable initially would be those nearest the pyroclastic, lahar, and lava flows, or heavy ash and rock fall during the eruption. Those people in this recreational area of forests and wildlife may be impossible to locate and rescue. Baker Lake and its dams are vulnerable and, if impacted, could cause extensive loss of property and lives downstream in Skagit County.

Photo of a lahar and damaged buildings.

Lahars flowing down and flooding the Nooksack, Baker, and Skagit Rivers may provide very little warning for evacuation to nearby populations. The potential destruction of a town in shown in the image above. Earthquakes accompanying an eruption may cause bridge or road damage and trigger landslides. Fine ash fall, even if only an inch thick, may make asphalt road surfaces slippery, causing traffic congestion on steep slopes or accidents at corners and junctions. Even a minor eruption or large flank collapse of Mount Baker could impact some populations physically, psychologically, and economically.

Secondary Volcanic Hazards

1. Flooding:
    a. Baker Lake and Lake Shannon – possibly dams destroyed
    b. Nooksack River from origins to Bellingham Bay
    c. Skagit River from Baker River junction throughout Skagit River Valley to Puget Sound
2. Transportation: severe disruption

3. Water lines, water reservoirs: contaminated or broken and depleted
4. Communication: landlines down, wireless phones overwhelmed
5. Electric power: some or all power lost from Mount Vernon to Lynden and possibly further in all directions
6. Gas and fuel pipelines: possibly broken
7. Toxic waste, sewer, and household chemicals in flood areas

E. MITIGATION STRATEGIES

Generally, technology and tell-tale signs of eruptions from volcanoes allow experts to predict volcanic activity, such as the predictions of the 1980 Mount Saint Helen's eruption that saved many lives. However, the magnitude and timing of volcanic activities cannot be precisely predicted, giving the public little to no warning to prepare for a volcano emergency. Because of this, the best way to mitigate against volcanoes is to educate and raise awareness of affected citizens. In 2013 Whatcom Division of Emergency Management, United States Geological Survey, and the Washington State Emergency Management Division participated in the US/ Columbia Volcanic Exchange. Best practices concepts were brought back from the participants, and a focused effort led to a completion of a public information campaign for the Northern Cascade volcanos.

The original hazard publication for Mt. Baker was published by the United States Geological Survey in 1997. An updated hazard publication is currently being produced by the USGS and will provide improved estimates of potential hazards. Estimates of lahar inundation depth, extent, and velocity will be modeled using modern techniques and will allow the development of improved evacuation routes and volcanic hazard management plans. Upon publication by the USGS, all existing volcanic emergency response plans should be updated to reflect the improved understanding of potential hazards.

In 2018 the Whatcom County Department of Emergency Management conducted the Mount Baker Volcano Exercise. This 5-day exercise was designed to simulate the likely sequence of events to be experienced during a multi-month volcanic event at Mount Baker, culminating in an eruption, emergency response, and post-event recovery. Representatives from the USGS Cascades Volcano Observatory devised the scenario as a likely analog to probable events at Mount Baker, and multiple agencies participated in a coordinated response. The purpose of the exercise was to test the ability of the current volcanic emergency plan to respond to the simulated event by evaluating the participants responses to the following six functional areas:

Small Communities, Interagency Response and Coordination, Elected Officials, Command, Control, Coordination & Communication, Search and Rescue, and Recovery. Lessons learned from the exercise have been or will be incorporated in future iterations of the Whatcom County DEM volcanic emergency response plan.

WILDLAND FIRES

A. DEFINITIONS

Structure Fire A fire of natural or human-caused origin that results in the uncontrolled destruction of homes, businesses, and other structures in populated, urban or suburban areas.

Wildland fire Fire of natural or human-caused origin that results in the uncontrolled destruction of forests, field crops and grasslands.

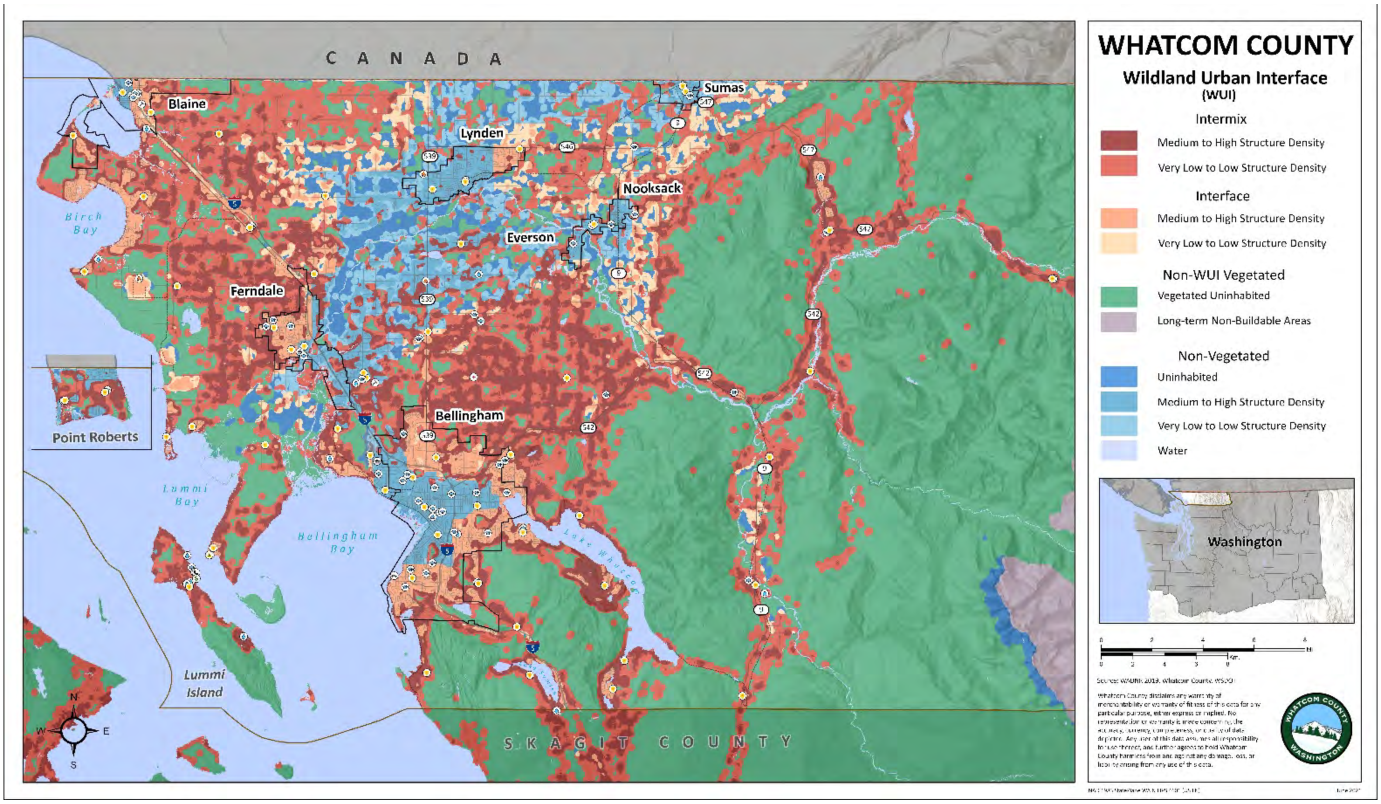
Wildland Urban interface A fire of natural of human-caused origin that occurs in, or near, forest or grassland areas, where isolated homes, subdivisions, and small communities are also located.

B. BACKGROUND INFORMATION

Image of a Wildland Fire.

Wildland fire is a serious and growing hazard over much of the United States, posing a great threat to life and property, particularly when it moves from forest or rangeland into developed areas. An image of a wildland fire can be seen to the left. However, wildland fire is also a natural process, and its suppression is now recognized to have created a larger fire hazard, as live and dead vegetation accumulates in areas where fire has been excluded. In addition, the absence of fire has altered or disrupted the cycle of natural plant succession and wildlife habitat in many areas. Consequently, United States land management agencies are committed to finding ways, such as prescribed burning, to reintroduce fire into natural ecosystems, while recognizing that firefighting and suppression are still important. USGS conducts fire-related research to meet the varied needs of the fire management community and to understand the role of fire in the landscape; this research includes fire management support, studies of post-fire effects, and a wide range of studies on fire history and ecology. Whatcom County's evolution over the years has resulted in greater numbers of residents either living in or immediately adjacent to wildlands.

Whatcom County's population has grown from 81,293 in 1970 to over 229,000 in 2019. While most of the growth has occurred in Whatcom County's cities, a significant number of homes and businesses have been built in a wildland interface or intermix fashion. The following Wildland-Urban Interface map demonstrates the density of these population centers. Large tracts of forest either abut or surround communities increasing the risk that an uncontrolled wildland fire will result in significant or even catastrophic loss. With few roads for ingress or egress, certain areas could be cutoff rather quickly.



Washington Department of Natural Resources (WA DNR) 2019 mapped data of Washington's Wildland Urban Interface (WUI). The WUI displays areas of WA where structures and wildland overlap with specific structure densities.

C. RECENT HISTORY IN WHATCOM COUNTY

In terms of acres burned, 2020 ranked second to the record-setting 2015 fire season when over one million acres of land burned in Washington. In 2020, over seven hundred thousand acres of Washington land was charred by wildfire. During this same period, Whatcom County experienced several wildfires, the most notable one being the Goodell Fire in 2015. This fire started on August 10th by lightning and burned for the next several weeks consuming over 8,000 acres of timber and brush in rocky, mountainous terrain. Transmission lines from several hydroelectric power plants running alongside the Skagit River were threatened and evacuation of Seattle City Light staff were evacuated from Diablo and Newhalem. Campers in the area were also evacuated and the North Cascades National Park was closed as was a 90 mile stretch of Highway 20 connecting several communities on the east and west side of the Cascades. In April 2020, an 80-acre fire (Porter Creek Fire) burned for several days near Deming. A number of smaller wildfires have also burned in Whatcom County and threatened homes and other structures.

In some cases, two or more fires merged together, overwhelming resources and creating fires so large and complex that some were not fully extinguished until cooler, damp autumn weather moved into the region.

Changing Conditions

Changing weather patterns are creating conditions that leave western Washington's environment more conducive to wildfire. Figure 6 is a graphic showing these condition changes. Increasing temperatures, less rain falling in the summer, and earlier snow melt are resulting in drier fuels and forests in our area. Drought conditions lead to dry and dead fuels which mean our forests are becoming increasingly more flammable and homes in the wildland-urban areas are more at risk.

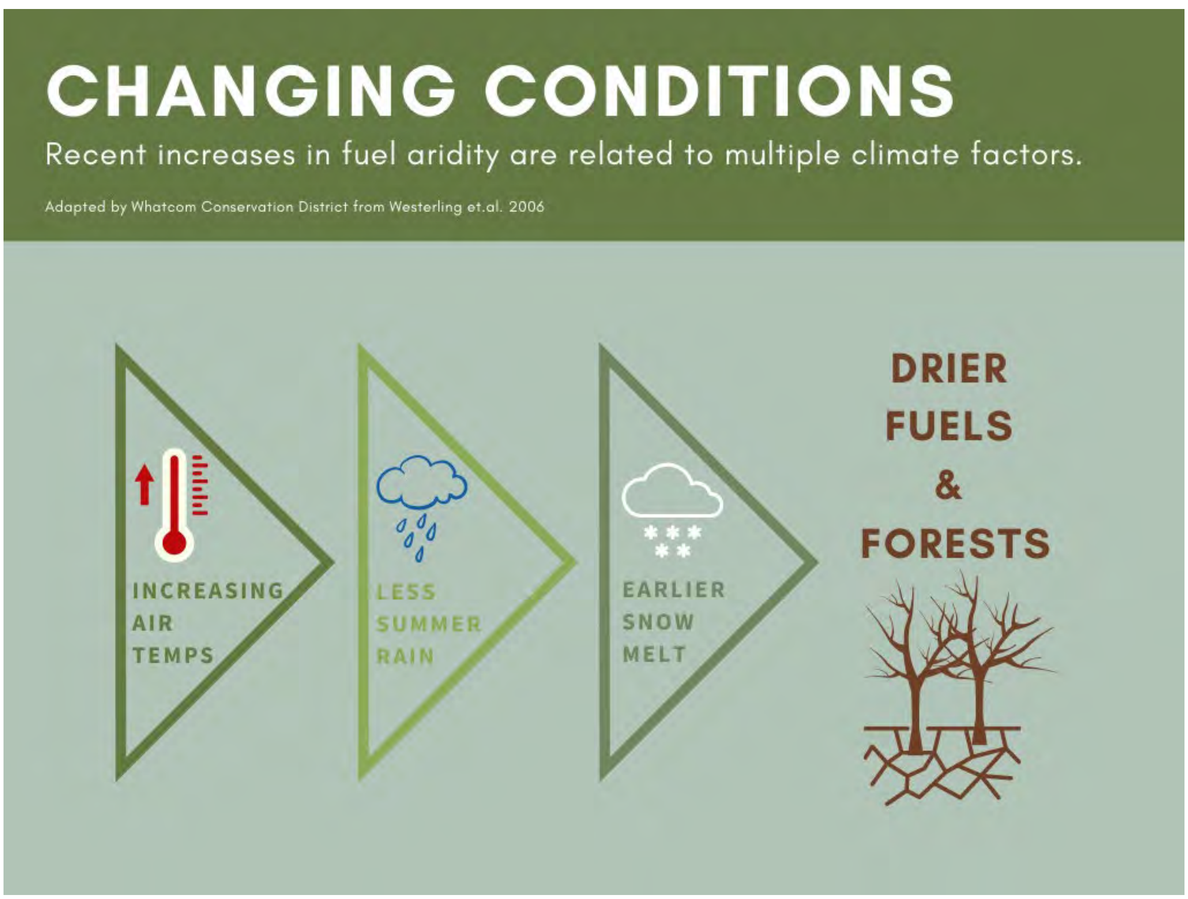


Figure 6 showing how changing yearly weather conditions leads to an increased risk of fire.

D. VULNERABILITY ASSESSMENT

The Washington Department of Natural Resources no longer uses the "Risk Assessment and Mitigation Strategies" tool which aided development of this wildfire section. The new modeling software-"Wildfire Prevention Spatial Assessment and Planning Strategies (WPSAPS)-is currently being developed by the Interagency Workgroup but has not yet been finalized or available for release in a draft form. Whatcom County will revisit and update this section during the annual review process when the new model is released. The revised section will be forwarded to the Washington State Hazard Mitigation Officer and FEMA at that time. In the meantime, the Risk Assessment and Mitigation Strategies (RAMS) remains the most authoritative source for developing wildfire hazard and associated mitigation strategies for Whatcom County.

Should a large wildland or wildland-urban interface fire occur in Whatcom County, the effects of such an event would not be limited to loss of property, valuable timber, wildlife and habitat, or recreational areas. The loss of large amounts of timber on steep slopes would increase the risk of landslides and mudslides during the winter months and the depositing of large amounts of mud and debris in streams and river channels could threaten valuable fish habitat for many years. In addition, the loss of timber would severely impact the watershed of the Skagit River and could drastically increase the vulnerability to flooding for many years.

WDNR, Northwest Region, has conducted a region-wide wildland fire hazard assessment utilizing the following method:

1. Risk Assessment and Mitigation Strategies (RAMS) was developed for fire managers to be an all-inclusive approach to analyzing wildland fire and related risks. It considers the effects of fire on unit ecosystems by taking a coordinated approach to planning at a landscape level. The steps involved in this process include the following:
    a. Identification of spatial compartments for assessment purposes:
        i. Whatcom County (county # 37) was subdivided into three risk assessment compartments based on Industrial Fire Precaution Level (IFPL) Shutdown Zones. Zone 653 represents the islands and tidal lowlands; Zone 656 represents the interior lowlands (roughly the Interstate 5 corridor); and Zone 658 represents the uplands to the Cascade Crest (roughly 1,500 feet elevation and above). Whatcom County risk assessment compartments are numbered using the county number (37) combined with the shutdown zone number. Using this scheme, the three risk assessment compartments within Whatcom County are numbered 37653, 37656 and

37658.

b. Assessment of significant issues within each compartment, which are related to:

   i. Fuels Hazards – The assessment of fuel hazards deals with identifying areas of like fire behavior based on fuel and topography. Given a normal fire season, how intense (as measured by flame length) would a fire burn? Under average fire season conditions, fire intensity is largely a product of fuel and topography.

   ii. Protection Capability – Determining fire protection capability for the purpose of this assessment involves estimating the actual response times for initial attack forces and how complex the actual suppression action may be once they arrive because of access, fuel profile, existence of natural or human-made barriers to fire spread, presence of structures, and predicted fire behavior.

      1. Initial Attack Capability – actual time of first suppression resource

      2. Suppression Complexity – access, fuel conditions, structure density, and so forth

   iii. Ignition Risk – Ignition risk evaluation will be completed for each compartment. Ignition risks are defined as those human activities or natural events which have the potential to result in an ignition. Wherever there are concentrations of people or activity, the potential for a human-caused ignition exists. After assessing the risks within an area, it is helpful to look at historical fires to validate the risk assessment. Historical fires alone, however, are not an accurate reflection of the risks within a given area. The objective of this effort is to determine the degree of risk within given areas.

      1. Compartment Ignition Risk is based on:

         a. Population Density

         b. Power Lines – distribution as well as transmission Industrial Operations – timber sale, construction project, fire use, mining, and so forth Recreation – dispersed, developed, OHV, hunting, fishing Flammables Other – fireworks, children, shooting, incendiary, cultural, power equipment Railroads

c. Transportation Systems – state, federal, public access

d. Commercial Development – camps, resorts, businesses, schools

iv. Fire History – Fire history will be completed for each compartment to reflect:

1. Fire location
2. Cause
3. Average annual acres burned
4. Average annual number of fire by cause

v. Catastrophic Fire Potential – An evaluation of fire history reflects the potential for an event to occur. An example is if large damaging fires occur every 20 years and it has been 18 years since the last occurrence, this would reflect a priority for fire prevention management actions.

1. Evaluate large fire history
2. What are the odds of a stand replacement type fire occurrence in that compartment? Unlikely Possible Likely

vi. Values – Values are defined as natural or developed areas where loss or destruction by fire would be unacceptable. The value elements include:

- Recreation – undeveloped/developed
- Administrative sites
- Wildlife/Fisheries – habitat existing
- Range Use
- Watershed
- Timber/Woodland
- Plantations
- Private Property
- Cultural Resources
- Special Interest Areas
- Visual Resources

- Threatened and Endangered Species
- Soils
- Airshed
- Other Necessary Elements

This evaluation process provides the basis for determining the *Whatcom County Wildland-Urban Interface Fire Risk Assessment Compartments* map. Additional information regarding the results of this process can be found in Appendix D, which contains excerpts from the RAMS Assessment.

RAMS risk assessment compartments were further broken down to identify Wildland-Urban Interface Hazards. Using 2010 Census data, individual areas were identified in the Wildland-Urban Interface and assessed using the National Fire Protection Association (NFPA) 299, Wildfire Hazard Assessment. The results of this assessment are depicted in the *Whatcom County Wildland-Urban Interface: Fire Risk Assessment* map, below. RAMS risk assessment is currently being updated, but new maps have not yet been released.

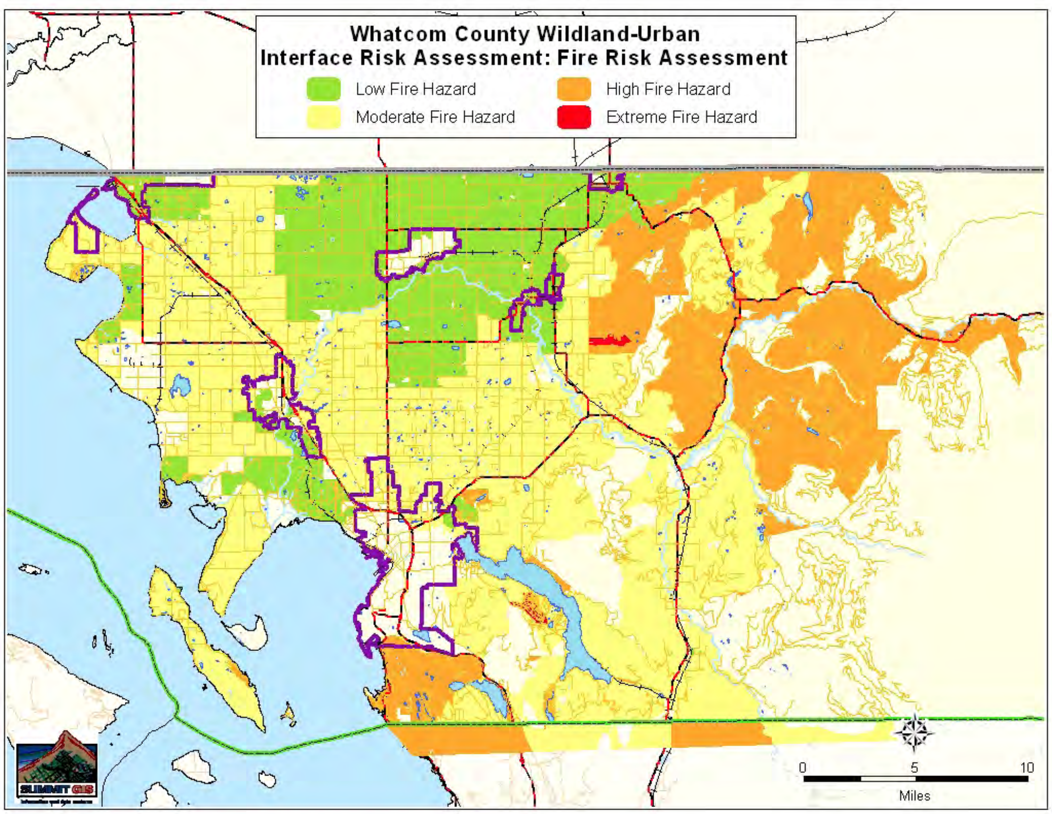


Figure 7. Interface Risk Assessment- Fire Risk Assessment map shows areas of the county at most risk of wildfire,

including the Chuckanut Mountains, and east County near Everson, Nooksack, Kendall and Glacier.

The NFPA 299 was further refined, to reflect Whatcom County Fire Manager's input, producing a map that reflects Landscapes of Like Risk (Communities at Risk). Areas that received a high to extreme risk ranking were grouped into landscapes and named. The result is depicted in the following map. These areas of Whatcom County are at highest risk of catastrophic loss to a Wildland fire.

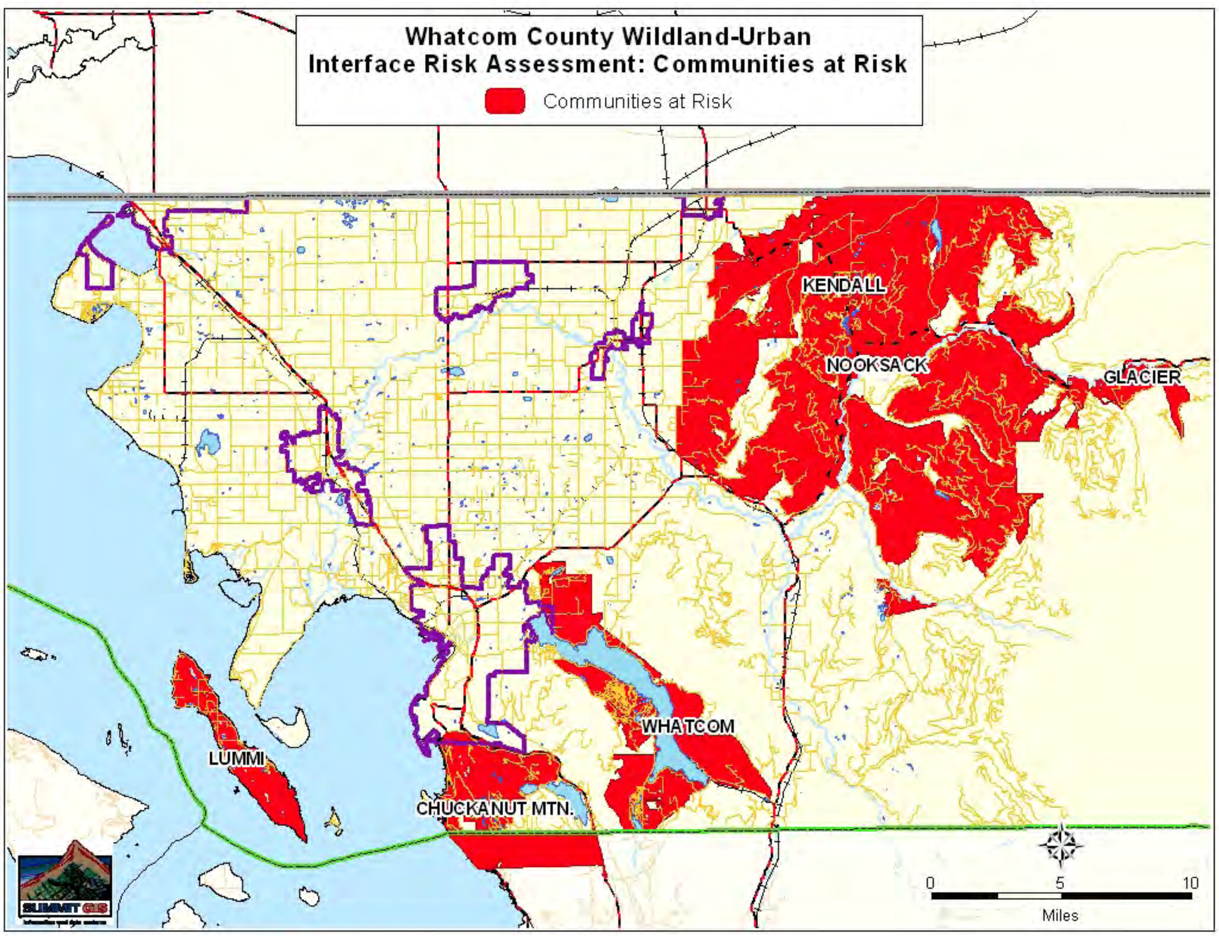


Figure 8. Interface Risk Assessment- Communities at Risk map shows communities most at risk of fire, including Lummi Island, communities around Lake Whatcom and in the Chuckanut Mountains, and the Kendall, Nooksack, and Glacier communities in east Whatcom County.

E. MITIGATION STRATEGIES

In cooperation with fire managers from WADNR, NW Region, three mitigation strategies were developed to address Whatcom County's fire hazards. Each is discussed below.

Inter-Agency Cooperation & Partnerships

Inter-agency cooperation and successful partnerships are is the key to a successful wildland fire mitigation strategy. In the case of wildland fire risk mitigation, continued development and enhancement of support between fire protection agencies will be emphasized. Working with local, state, and regional partners that are working in fire adaptation to share a unified message about wildland fire preparedness is a priority and includes participation in the NW Region Wildland Fire Local Coordinating Group and supporting Local Coordination group activities.

Support of actions proclaimed by the governor's office and the Whatcom County Executive's Office in relation to wildland fire prevention and preparedness, such as Wildfire Awareness Month and Community Wildfire Preparedness Day, should be made a priority. In addition, it is essential to support Whatcom County-----based community wildland fire preparedness programs such as Whatcom Conservation District's Wildfire Risk Reduction Program that provide a direct service to residents of Whatcom County.

County-Wide Wildland Fire Prevention

In the RAMS Compartments, where the wildland fire risk has been assessed at moderate, multi-agency cooperative fire prevention activities will occur during the summer months addressing the following:

- Public awareness of current fire danger
- Press releases
- Media opportunities for fire prevention news articles
- Radio and TV spots, as needed
- Use of burn restrictions, including bans, if necessary, during periods of high fire danger
- Use of Smokey Bear fire prevention programs targeting age-specific audiences during periods of extreme fire danger, or during significant wildland fire events
- Consideration of mobilizing Washington State Inter-agency fire prevention teams
- Use of other fire prevention tactics and strategies, as needed, and as conditions warrant

Wildland/Urban Interface (WUI) Communities at Risk Preparedness

As a result of efforts conducted by WADNR, the following list of Landscapes of Like Risk were established.

1. Lake Whatcom watershed
    a. Sudden Valley
    b. Northshore
    c. Homes/neighborhoods adjacent to City acquisition lands
2. Nooksack
3. Glacier
4. Lummi Island – Lummi Island Scenic Estates, a community on Lummi Island, has received national recognition for their mitigation activities under NFPA's Firewise USA program. Lummi Island as a whole is part of the Washington State Fire Adapted Communities Learning Network and is recognized as a community working to become more fire adapted
5. Columbia Valley/Kendall – Peaceful Valley Community is working toward becoming a nationally recognized Firewise USA site.
6. Chuckanut Mountain – Chuckanut Crest is actively working on community wildfire planning and preparedness

Communities located in the Landscapes of Like Risk should consider the following actions:

- Participation in the NFPA Firewise USA Program (www.firewise.org)
- Host wildfire preparedness workshops
- Increase homeowner awareness
- Facilitate community involvement and support
- Facilitate media involvement
- Sign up for individual wildfire home evaluations
- Use the NFPA Firewise USA program to:
    - Bring neighbors together to address shared risk
    - Provide a framework for community mitigation
    - Nationally recognize achievement
    - Receive access to grant funds for wildfire risk reduction projects

The Whatcom Conservation District can provide assistance to homeowners and communities in their understanding of wildfire, NFPA Firewise program efforts, and on-the-ground mitigation efforts. Services like free wildfire home evaluations and neighborhood wildfire risk assessments are provided through the Community Wildfire Risk Reduction Program at the Conservation District.

This page left intentionally blank.

SECTION 2.2 OTHER HAZARDS OF CONCERN

AVALANCHES

A. DEFINITIONS

Avalanche Masses of snow ice which move in swift motion down a mountainside or over a precipice. During the avalanche, earth, rock or other material such as trees may also be picked up. Avalanches can grow to be large, although they are not defined by their size, and depending on the situation even small avalanches can be dangerous.

B. BACKGROUND INFORMATION

Whatcom County has remote mountainous sections which receive high levels of snowfall during winter months. The maritime snowpack is traditionally deep, dense and prone to avalanches. Whatcom County is also a popular destination for winter recreationalists increasing the population exposure to avalanche.

In the future, WSDOT would like to build a new weather station in the Diablo Gorge area. This will help teams better anticipate avalanches and protect people using the mountain areas. The Northwest Avalanche Center (NWAC) offers a space for people to report observations of potentially dangerous avalanche conditions. Receiving input from the community is valuable to those who seek to keep residents and visitors safe from the risk avalanches present. You can submit a “field observation” here. You can also see observations submitted by other users here. By participating in NWAC’s field observations, you can keep yourself and your community members safe. Also located on the NWAC website you can see avalanche forecasts by mountain zone and a snow depth chart, so you can plan your travels more safely.

D. RECENT HISTORY IN WHATCOM COUNTY

2020 One skier in a party of three triggered and was caught and carried by a slab avalanche that released on a SE aspect around 5500' in an area of Mt. Herman known as East Gully above Bagley Lakes. The skier was carried up to 100' downhill before hitting and being pinned against a tree. He was able to free his left arm and immediately cleared his airway. His partners helped extract him. The skier suffered minor injuries but was fortunate enough to recover all of his gear and ski down unassisted.

2020 A skier was fully buried in an avalanche that occurred adjacent to the Mt. Baker Ski Area. The avalanche was triggered by a traveler from a different party. Mt. Baker Ski Patrol was on the scene immediately, located the victim quickly, dug them out, and cleared their airway. The individual survived and reported no injuries. The slab avalanche was 1 ft deep and at its widest point broke 500 feet across the slope.

2018 A single snowmobiler triggered and was caught, carried and killed in a large slab avalanche on Park Butte in the Mt. Baker National Recreation Area. The avalanche (HS-AMu-R3-D3-O) was triggered just below the summit on a NE aspect near 5400'. The victim was carried 1000' through a gully and sparse trees. The avalanche was 200 ft (60 m) wide and averaged 4' deep (1.2m). It failed on a 2 cm thick layer of facets above a firm rain crust.

2017 Widespread 1-2 ft storm slabs and larger 3-5 ft wind slabs were reported in the backcountry near Mt Baker on Saturday, March 4th. An incident occurred on Mt Herman when a large wind slab on an east aspect was triggered from a party above, partially burying two and completely burying one in a separate party at the base of the slide path. The impacted party was transitioning back to climbing skins when they were caught in the avalanche.

2017 The lead skier in a party of four triggered a D1.5 storm slab descending the north aspect of Table Mt. at 5000'. Skier was caught and carried a few hundred feet down slope and sustained minor injuries. The other members of the party were able to assist skier off slope and back to ski area boundary.

2016 Two skiers caught, 1 seriously injured and 1 killed by a wet slab (glide) avalanche in the Mt. Baker area.

2014 Two skiers in party, one caught by a natural avalanche while ascending on foot and carried several thousand feet, one fatality.

2009 One skier caught and partially buried with broken leg on Table Mountain near Mt. Baker Ski Resort. Helicopter lift off mountain.

2009 Mt. Baker Hwy. closed due to avalanche activity near town of Glacier.

2008 Five snowmobilers caught, three buried, two die near Church Mountain.

2006 Skier caught, buried and killed near Mt. Herman.

2005 Two snowboarders caught, buried and revived after 15 minutes.

2004 Six burials, three deaths in 2004 season, all within 5 miles of Mt. Baker Ski Resort.

C. VULNERABILITY ASSESSMENT

Avalanche incidents are primarily isolated to specific backcountry user groups. Mountainous roads, however, are susceptible to avalanches, in particular Hwy 542 (Mt. Baker Hwy) and Hwy 20. Hwy 20 is closed during most of the avalanche season; however, a large avalanche obstructing Hwy 542 has the potential to isolate hundreds to thousands at the Mt. Baker Ski Resort with limited services. Multi-agency networking, particularly between NWAC and WSDOT, allows for road crews to work proactively to reduce vulnerability to avalanches. With avalanche forecasting, which utilizes NWAC forecasting, Geographic Information Systems (GIS), and historical events (magnitude and return interval), road crews are able to close roadways and remotely trigger an avalanche using controlled detonations before they harm people. Even a small avalanche can be deadly to a person outside of their vehicle, which is why an abundance of caution and proactive action is necessary.

As most of Whatcom County is below the seasonal snowline, risk of avalanche incident is mainly limited to winter recreationalists. The threat to life from avalanches is extreme and Whatcom County traditionally will average at least one fatality a year due to avalanches. Actions are being taken to reduce the fatalities. WSDOT hosts an annual avalanche search and rescue training for operators avalanche prone areas. Furthermore, WSDOT is aiming to provide avalanche rescue gear to as many operator vehicles in avalanche prone areas, as possible in the coming years, along with quick reference cards so that these operators know how to safely work in an avalanche zone. Furthermore, plans for new avalanche retaining walls, like those seen on I-90, are being discussed.

DAM FAILURE

A. DEFINITIONS

Dam Failure The uncontrolled release of impounded water resulting in downstream flooding, which can affect life and property.

B. BACKGROUND INFORMATION

There are many dams for many different purposes throughout Whatcom County: Nooksack Diversion Dam which shunts water to Lake Whatcom from the South Fork of the Nooksack River[4]; dams for waste water reservoirs; flood-control dams; lakes dammed for recreational purposes; and hydroelectric projects on the Baker and Skagit Rivers. Dam failures can be caused by flooding, earthquakes, volcanic eruption, blockages, landslides, lack of maintenance, improper operation, poor construction, vandalism, or terrorism.

In 2020, the Middle Fork Nooksack Dam was removed. This removal was done safely with controlled detonations.

D. RECENT HISTORY IN WHATCOM COUNTY

There are no known occurrences of dam failures in Whatcom County.

C. VULNERABILITY ASSESSMENT

A failure of a dam can have many effects such as loss of life and damage to structures, roads, utilities, crops, and the environment. Economic losses also can result from a lowered tax base and interruption of electrical power production.

With regular dam inspection, maintenance, and repair, the risk of dam failure is low. However, if a geologic or terrorist event precipitated a failure, the effects could be dire on the

[4] Not to be confused with the recently removed diversion dam on the Middle Fork of the Nooksack.

downstream residents in addition to the loss of critical infrastructure.

A comprehensive analysis was performed in 2016 of dam failure modes and dam safety program. The tests showed the dams were safe.

DROUGHT

A. DEFINITIONS

Drought An extended period of months or years when a region notes a deficiency in its water supply. Generally, this occurs when a region receives consistently below average precipitation.

B. BACKGROUND INFORMATION

Droughts can be difficult to identify due to their typical long length. A drought's impact may not materialize for several years of less than average precipitation, or sudden droughts can have quick impacts if there is an extremely dry year or season. Near the beginning of a drought the agricultural sector is usually the first to be impacted. Although Whatcom County is traditionally a wet maritime climate there is potential and history of dry periods.

D. RECENT HISTORY IN WHATCOM COUNTY

2019 Washington State governor declares Whatcom County and 26 other counties as drought emergency.

2010 Mandatory water restrictions imposed across the City of Bellingham.

2001 Governor Gary Locke declares statewide drought emergency. First time in history for a state in the Pacific Northwest.

1997 Severe drought conditions existed statewide, lowest precipitation, snowpack and stream flows recorded.

1934-1935 Longest drought period recorded in Western Washington history.

C. VULNERABILITY ASSESSMENT

Droughts can have impacts on nearly everyone in a community. A lack of water reduces irrigation capabilities of farmers limiting the crop yield for the season/year and, critically, may reduce the availability of drinking water in the Lake Whatcom reservoir. Low water may also affect fishers, both recreational and commercial, as several native species require cooler waters to survive. Electricity prices can increase during a drought event due to the lack of hydroelectric capabilities of dams. Droughts can also increase vulnerability to other hazards such as fires and ecological epidemics.

Severe drought in Whatcom County could have long-reaching effects due to the large amounts of agriculture and fishery as well as usage of hydro-electric power, though the County's typically wet climate prevents impacts from being as severe as they would be in drier counties.

This page intentionally left blank.

SECTION 2.3 WHATCOM COUNTY STORM EVENTS DATABASE

The following events, all found within NOAA's National Centers for Environmental Information Storm Events Database, are events that occurred between 2010 and 2020. While the database contains 164 events for this time period, below are the events that have a non-zero record of deaths, injuries, or recorded damage value. Only 26 events met these criteria.

EVENT_ID	214457
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	04/02/2010 1304 PST-8 / 04/02/2010 1800 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($50000/ $0)
WFO	SEW
SOURCE	ASOS
EVENT_NARRATIVE	Bellingham (KBLI) recorded a 61-mph peak gust. Sandy Pt. Shores measured 38g58 mph at 231 PM and 236 PM. About 5,000 customers lost power.
EPISODE_NARRATIVE	A deep low passed just NW of Tatoosh Island. High wind was recorded on the coast and in a few inland zones. Strong wind was reported in other inland zones.

EVENT_ID	260893
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	11/15/2010 2024 PST-8 / 11/15/2010 2224 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES	(0/0)

(Direct/Indirect)	
DAMAGE (Property/Crops)	($40000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	Both Sandy Point and Cherry Point recorded sustained wind in excess of 40 mph 824 PM to 854 PM. A tree fell on a home and another on a car in the Bellingham area.
EPISODE_NARRATIVE	South winds of 20 to 30 mph and gusts to 45 mph occurred on the evening of November 15 in parts of western Washington and then after the cold front passed, strong onshore flow brought marginal high wind to a few zones, mainly near the Strait of Juan de Fuca.

EVENT_ID	273698
CZ_NAME_STR	WHATCOM CO.
BEGIN LOCATION	DIABLO
BEGIN/END DATE & TIME	12/12/2010 600 PST-8 / 12/13/2010 300 PST-8
EVENT_TYPE	Flood
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($100000/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	Parts of Highway 20 between Newhalem and Diablo were washed away by heavy rain and flooding.
EPISODE_NARRATIVE	The Stillaguamish River reached record level. There were several roads washed out in Kitsap County. 2 homes were damaged from mudslides.

EVENT_ID	347687
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	09/26/2011 1200 PST-8 / 09/26/2011 1600 PST-8
EVENT_TYPE	Strong Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($10000/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	Scattered power outages were reported in the Bellingham area. A car was damaged by fallen tree limbs. Several other trees fell over roadways.
EPISODE_NARRATIVE	Strong southerly winds brought high wind to the north coast and to the area around Lake Lawrence in the southwest interior. The central coast had about 9000 lose power, and the Bellingham area had scattered power outages and a car damaged by tree limbs.

EVENT_ID	350649
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	11/21/2011 2330 PST-8 / 11/22/2011 400 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($5000/ $0)

WFO	SEW
SOURCE	ASOS
EVENT_NARRATIVE	Bellingham, Cherry Point, and Ferndale all recorded high wind category winds of 40 mph sustained and/or gust 58 mph. In Birch Bay, the strong winds blew part of the roof off a manufactured home.
EPISODE_NARRATIVE	High wind occurred over the coast and northwest interior.

EVENT_ID	350662
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	11/27/2011 041 PST-8 / 11/27/2011 412 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($1000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	Cherry Point recorded 40 mph sustained wind. Ferndale had a 62-mph gust. A building which was in its framing stages was blown down near of Squalicum High School.
EPISODE_NARRATIVE	High wind occurred over the northwest interior.

EVENT_ID	396151
CZ_NAME_STR	WHATCOM CO.
BEGIN LOCATION	DEMING
BEGIN/END DATE & TIME	06/23/2012 1415 PST-8 / 06/23/2012 1415 PST-8
EVENT_TYPE	Thunderstorm Wind
DEATHS	(0/0)

(Direct/Indirect)	
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($1000/ $0)
WFO	SEW
SOURCE	NWS Storm Survey
EVENT_NARRATIVE	Damage survey indicated strong thunderstorm wind damage. A number of tree limbs and a few trees blown down. One power line was down near the junction of state route 9 and state route 542 east of Deming.
EPISODE_NARRATIVE	Thunderstorm wind caused minor damage.

EVENT_ID	396153
CZ_NAME_STR	WHATCOM CO.
BEGIN LOCATION	CLIPPER
BEGIN/END DATE & TIME	06/23/2012 1504 PST-8 / 06/23/2012 1504 PST-8
EVENT_TYPE	Thunderstorm Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($1000/ $0)
WFO	SEW
SOURCE	Trained Spotter
EVENT_NARRATIVE	Observer reports limbs of 8 to 10 inches diameter blown off trees as the storm went through. Also received half an inch of rainfall and one-eighth inch hail.
EPISODE_NARRATIVE	Thunderstorm wind caused minor damage.

EVENT_ID	423211
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	

BEGIN/END DATE & TIME	12/17/2012 700 PST-8 / 12/17/2012 1300 PST-8
EVENT_TYPE	Coastal Flood
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($100000/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	Birch Bay Cafe and Bistro suffered damage as waves pushed a large log through the large bay facing window. A nearby consignment shop was also damaged. About 15 homes and properties were also affected near Terrell Creek. In some cases, the water only got into the front yard, but in others it flooded garages and homes. Flooding closed about 4 miles about Birch Bay Drive.
EPISODE_NARRATIVE	High astronomical tides coincided with low pressure to cause record high tide levels throughout Puget Sound. Many homes and yards along the shoreline were flooded.

EVENT_ID	429156
CZ_NAME_STR	WHATCOM CO.
BEGIN LOCATION	BLAINE
BEGIN/END DATE & TIME	01/08/2013 2100 PST-8 / 01/08/2013 2200 PST-8
EVENT_TYPE	Debris Flow
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($5000/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	Heavy rain caused a mudslide near Semiahmoo Bay.
EPISODE_NARRATIVE	Two mudslides between Jan 8th and 9th caused minor damage in King and Whatcom counties.

EVENT_ID	433529
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	02/25/2013 654 PST-8 / 02/25/2013 854 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($10000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	Sandy Point Shores reported sustained wind of 40+ mph, with gusts as high as 62 mph, for a few hours. A power line was downed in southern Whatcom County.
EPISODE_NARRATIVE	There were a few hours of high wind in three of four northwest interior zones.

EVENT_ID	492737
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	01/03/2013 700 PST-8 / 01/03/2013 900 PST-8
EVENT_TYPE	Coastal Flood
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($1000/ $0)
WFO	SEW
SOURCE	Emergency Manager
EVENT_NARRATIVE	Near Birch Bay, minor coastal flooding damaged some outdoor furniture.
EPISODE_NARRATIVE	Near Birch Bay, minor coastal flooding damaged some outdoor furniture.

EVENT_ID	540612
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	10/21/2014 2224 PST-8 / 10/22/2014 206 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(1/0)
DAMAGE (Property/Crops)	($80000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	Several sites--Sandy Point Shores, Cherry Point, and Ferndale--recorded sustained wind of 40-42 mph with gusts up to 62 mph.||Blaine homeowners Charley and Donna Robbins, who are both in their 70s, said a horrendous windstorm swept through town on Wednesday, knocking several trees into their house. ||The couple was able to get out of the way as one tree crashed through their roof, though Charley suffered a rib injury. They say the estimate to fix their house is $80,000.
EPISODE_NARRATIVE	High wind affected the north coast, San Juans, and western Whatcom County during the night of October 21-22.

EVENT_ID	542363
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	11/06/2014 833 PST-8 / 11/06/2014 1754 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE	($200000/ $0)

(Property/Crops)	
WFO	SEW
SOURCE	C-MAN Station
EVENT_NARRATIVE	Ferndale had gusts 58-60 mph from 833 Am to 1210 PM. Bellingham had 40 mph sustained wind at 952 AM. Sandy Point Shores had 40-41 mph sustained wind 444 PM to 514 PM. Cherry Point had sustained wind 40 mph 454 PM to 554 PM. About 10,000 customers lost power.
EPISODE_NARRATIVE	A deep but filling low moved northeast across central Vancouver Island. The KPDX-KBLI gradient reached about +10 with the KOLM-KBLI portion about 2/3 of that. There was brief high wind in several zones. |At the stormï¿½ï¿½ï¿½s peak, more than 14,000 Puget Sound Energy customers were without electricity, with the worst outages in Whatcom, Skagit and Island counties. On Thursday evening, more than 3,000 Seattle City Light customers were without power, most from an outage in Shoreline caused by a downed tree. ||From a Seattle Times article:||A storm with high winds Thursday caused power outages across the Puget Sound region and downed power lines and trees, including one that injured a semitruck driver in Snohomish County and another that trapped a man in North Seattle. |Gusts of more than 40 mph were reported in the Seattle area, with a peak of 44 mph recorded about three miles west of Des Moines, according to the National Weather Service. |The strongest winds were recorded in the northern interior and North Coast from a ï¿½ï¿½ï¿½pretty vigorous systemï¿½ï¿½ï¿½ that came in from the Pacific Ocean, meteorologist Johnny Burg said. The weather service issued a high-wind warning for the area. Destruction Island, off the North Coast, reported gusts of 63 mph, while Paine Field in Everett had a peak of 51 mph and a sustained wind of 39 mph. |A tree fell on a semi on Highway 530 near Oso on Thursday afternoon and trapped the driver inside, according to the State Patrol. The man was airlifted to Harborview Medical Center with critical injuries. Highway 530 just west of 310th Street Northeast was blocked in both directions for about an hour before it opened to alternating

	traffic around 5 p.m. ||Firefighters in Seattleï¿½ï¿½ï¿½s Bitter Lake neighborhood rescued a man trapped by a downed tree there. The man was taken to Harborview in stable condition with no visible injuries, according to the Seattle Fire Department. ||Fallen trees were reported from Bellevue to Bainbridge Island to Sedro-Woolley and were responsible for many of the Seattle City Light and Puget Sound Energy outages throughout the day. ||At the stormï¿½ï¿½ï¿½s peak, more than 14,000 Puget Sound Energy customers were without electricity, with the worst outages in Whatcom, Skagit and Island counties. On Thursday evening, more than 3,000 Seattle City Light customers were without power, most from an outage in Shoreline caused by a downed tree. ||Washington State Ferries canceled two afternoon runs between Port Townsend and Coupeville because of high winds.

EVENT_ID	593403
CZ_NAME_STR	WESTERN WHATCOM (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	08/29/2015 1043 PST-8 / 08/29/2015 1243 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/2)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($250000/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	Two elderly people died in their home near Everson after inhaling a generatorï¿½ï¿½ï¿½s exhaust fumes during the weekend power outage.
EPISODE_NARRATIVE	High wind struck parts of Western Washington beginning around mid-morning on Saturday August 29th and continued into the afternoon hours. Widespread tree damage and power outages occurred, about 450,000 in total. Storm force winds developed over the coastal waters and Northern Inland waters.

	Solid Gale force winds occurred on the remaining waters. Ferry service between Port Townsend and Coupeville was suspended because of the windstorm. ||A tree feel on an automobile in Gig Harbor resulting in 1 death. At least 23 car collisions reported around Puget Sound by news media, possibly weather related. Highway 99 closed for a few hours through downtown Seattle was weather-related according to media and Seattle Police. Numerous reports of trees or branches on roadways. Widespread power outages. Power outages examples: 161,000 Puget Sound Energy and 58,000 Seattle City light customers. ||A 10-year-old girl was killed in SeaTac when a falling tree branch hit and killed her. |Two elderly people died in their home near Everson after inhaling a generatorï¿½ï¿½ï¿½s exhaust fumes during the weekend power outage.

EVENT_ID	603539
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	11/17/2015 1124 PST-8 / 11/17/2015 1324 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($250000/ $0)
WFO	SEW
SOURCE	COOP Observer
EVENT_NARRATIVE	Lynden had 62 mph at 1124 AM. Some Puget Sound Energy customers lost power.
EPISODE_NARRATIVE	Windy conditions lasted for several hours over most of western Washington. There were about 370,000 power outages reported throughout western Washington.

EVENT_ID	608906
CZ_NAME_STR	CASCADES OF WHATCOM AND SKAGIT COUNTIES (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	42393 1230 PST-8 / 42393 1230 PST-8
EVENT_TYPE	Avalanche
DEATHS (Direct/Indirect)	(1/0)
INJURIES (Direct/Indirect)	(1/0)
DAMAGE (Property/Crops)	($0/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	Mark Panthen, 36, of Bellingham, died Sunday afternoon after two avalanches on the north slope of the mountain, next to the Mount Baker Ski Resort.|A man who was skiing with Panthen called an employee of the resort from a cellphone around 12:45 p.m., saying Panthen was injured and needed help.|There were two avalanches within 15 minutes. The avalanches were at 4,200 feet.|Using a helicopter, emergency responders confirmed Panthen died around 2:20 p.m., authorities said. They provided aid to the other skier, who suffered a head injury.
EPISODE_NARRATIVE	Mark Panthen, 36, of Bellingham, died Sunday afternoon after two avalanches on the north slope of the mountain, next to the Mount Baker Ski Resort. ||A man who was skiing with Panthen called an employee of the resort from a cellphone around 12:45 p.m., saying Panthen was injured and needed help.

EVENT_ID	615026
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	03/10/2016 002 PST-8 / 03/10/2016 913 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES	(0/1)

(Direct/Indirect)	
DAMAGE (Property/Crops)	($350000/ $0)
WFO	SEW
SOURCE	ASOS
EVENT_NARRATIVE	The Bellingham ASOS had 41g67 mph for several hours. A CWOP west of Bellingham recorded 41 mph before failing. Sandy Point Shores had 40g58 mph for several hours. A spotter 6 miles northeast of Bellingham reported an 80-mph gust. A Home Depot building in Bellingham was damaged.|Three fishermen were rescued by the U.S. Coast Guard early Thursday, when their commercial fishing boat broke free from its moorage in a windstorm. The boat had been moored near Bellingham Cold Storage. One fisherman injured his foot after he had to jump in the water.
EPISODE_NARRATIVE	High wind occurred for several hours on the coast and over the north interior. Power out to about 50000 customers. Hood Canal bridge closed for 2 hours. Ferry service suspended. A 75-year-old fishing boat was destroyed when it broke free from its moorage and was pounded against some rocks.

EVENT_ID	615033
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	03/13/2016 1434 PST-8 / 03/13/2016 1914 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($90000/ $0)
WFO	SEW
SOURCE	ASOS
EVENT_NARRATIVE	The Bellingham ASOS reported 36g58 mph. A CWOP west of Bellingham measured 50g67 mph over several hours. Sandy

	Point Shores recorded 44g68 mph over nearly five hours.
EPISODE_NARRATIVE	About 250,000 people lost power. A 42-year-old man died when his car was hit by a tree in Seattle's Seward Park. Several homes were damaged. Scaffolding at the UW was reduced to a pile of rubble by the winds. The Hwy 520 bridge and Hood Canal Bridge were closed for several hours, as was parts of I-405. There was minor damage to the 520 bridge draw span. A semi-truck was toppled on the Tacoma Narrows bridge, halting traffic. Downed trees blocked two lanes of southbound 405 in Snohomish County. Washington State Ferries canceled or delayed several routes.

EVENT_ID	673026
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	01/04/2017 204 PST-8 / 01/04/2017 404 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($153000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	Sandy Point Shores recorded a gust of 58 mph. Puget Sound Energy responded to a number of power outages.
EPISODE_NARRATIVE	Brief high wind occurred at Sandy Point Shores.

EVENT_ID	666304
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	01/10/2017 1014 PST-8 / 01/11/2017 234 PST-8
EVENT_TYPE	High Wind

DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($208000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	An unusually large number of sites recorded high wind. These include Sandy Point Shores, 38g67 mph; Ferndale, 21g60 mph; Lynden, 41g54 mph; Maple Falls, 60 mph gust; Lummi Island, 70 mph gust; and Everson, 65 mph gust. Puget Sound Energy responded to a number of power outages in the area.
EPISODE_NARRATIVE	In a strong Fraser River outflow pattern, high wind occurred in western Whatcom County and the San Juan Islands.

EVENT_ID	677905
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	02/08/2017 1400 PST-8 / 02/09/2017 1600 PST-8
EVENT_TYPE	Ice Storm
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($700000/ $0)
WFO	SEW
SOURCE	Official NWS Observations
EVENT_NARRATIVE	A multitude of observational sources (NWS spotters, CoCoRaHS, etc) show that 1 to 3 inches of snow fell across Western Whatcom County followed immediately by heavy freezing rain, resulting an ice sheet up to a half inch thick on top of new and older snow. The result was treacherous road conditions, power outages, and closures of businesses and schools.
EPISODE_NARRATIVE	A Pacific frontal system combined with sub-freezing easterly flow

	across the Cascades passes and Fraser outflow brought a major episode of snow and freezing rain to the Cascades and Western Whatcom County. All three Washington Cascades passes (Stevens Pass, Snoqualmie Pass, and White Pass) were closed to traffic in both directions for almost 24 hours due to snow and accumulating ice, avalanche danger, and slides of snow and trees. In Western Whatcom County snow became covered with a sheet of ice as thick as a half inch as precipitation changed to freezing rain.

EVENT_ID	706935
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	08/01/2017 2000 PST-8 / 08/10/2017 600 PST-8
EVENT_TYPE	Heat
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(5/0)
DAMAGE (Property/Crops)	($0/ $0)
WFO	SEW
SOURCE	Newspaper
EVENT_NARRATIVE	The heat wave resulted in 1 fatality due to heat-related causes, plus five other berry pickers treated for dehydration.
EPISODE_NARRATIVE	An extended period of unseasonably hot weather impacted Western Washington from the 1st through the 10th of the month. A male berry picker at a farm 1 mile east of Sumas in Whatcom County fell ill on the 3rd and later died. At least 5 other pickers were treated for dehydration.

EVENT_ID	721279
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)

BEGIN LOCATION	
BEGIN/END DATE & TIME	10/18/2017 1015 PST-8 / 10/18/2017 1415 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($800000/ $0)
WFO	SEW
SOURCE	ASOS
EVENT_NARRATIVE	KBLI had sustained wind 30 mph or greater from 1015 AM to 215 PM. Highest sustained wind was 33 mph with a peak gust of 53 mph. This verifies the high wind warning for this first event of the season, when lower criteria for high wind are in effect.
EPISODE_NARRATIVE	High wind was forecast over the two coast zones and four northwest interior zones. Since this was the first event of the season, wind speeds somewhat less than typical high winds were forecast, but impacts were expected to be similar to what higher winds would cause later in the season.

EVENT_ID	723713
CZ_NAME_STR	WESTERN WHATCOM COUNTY (ZONE)
BEGIN LOCATION	
BEGIN/END DATE & TIME	11/13/2017 1413 PST-8 / 11/13/2017 1723 PST-8
EVENT_TYPE	High Wind
DEATHS (Direct/Indirect)	(0/0)
INJURIES (Direct/Indirect)	(0/0)
DAMAGE (Property/Crops)	($250000/ $0)
WFO	SEW
SOURCE	Mesonet
EVENT_NARRATIVE	Ferndale recorded a 69-mph gust. Lynden recorded a 61-mph gust. Sandy Point Shores recorded 41 mph sustained wind, gusting to 59 mph. KBLI recorded a peak gust of 58 mph. A CWOP near Bellingham recorded 40 mph sustained wind, gusting to 58 mph.
EPISODE_NARRATIVE	A strong Pacific weather system moved through Western Washington and produced wind gusts up to 70 mph in many parts of the region. The strong winds blew down some trees, knocked power out to as many as 200,000 through the area, delayed or cancelled ferry service, and produced heavy rain amounts that produced some local urban flooding. The peak of the wind event occurred between 2 and 7 PM, adversely impacting the afternoon and evening commute. A tree fell on a vehicle in Renton, killing the 32-year-old female driver and seriously injured a passenger. Another tree fell onto a mobile home in Port Orchard, seriously injuring a 15-year-old girl. Power restoration cost just over $7 million.

This page left blank intentionally.