Hazard
Mitigation Plan

September 2015 Update

Summary

Volume 1
Risk Assessment

Volume 2
Planning Partner Annexes

Snohomish County
Emergency Management

Snohomish County

HAZARD MITIGATION PLAN SUMMARY

September 2015

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View the Snohomish County Hazard Mitigation Plan online at
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Executive Summary

WHAT IS THE HAZARD MITIGATION PLAN?

Snohomish County's Hazard Mitigation Plan (HMP) identifies and prioritizes actions to reduce or alleviate risks from natural hazards, which reduces loss of life, personal injury, and property damage to residents and businesses within the county. The hazard mitigation plan also enables Snohomish County, and partnering jurisdictions, to maintain eligibility for disaster-related federal grant assistance, in accordance with the federal Disaster Mitigation Act (2000). In addition, the HMP helps meet the planning requirements of FEMA's Community Rating System (CRS), which allows partners that participate in the CRS program to maintain or enhance their CRS classifications.

The Plan was developed and updated according to the requirements of Chapter 44 of the Code of Federal Regulations (44CFR) and was originally approved by FEMA Region X on April 27, 2005. The FEMA approval qualified the planning partners to pursue implementation funding under the Stafford Act. The planning area boundary is the Snohomish County boundary.

This update was prepared by a partnership of 31 local governments in Snohomish County (14 municipal governments, two tribal governments, and 15 special-purpose districts) and the county. Jurisdictions that did not participate in the plan update can link to the plan at a later date by following the linkage procedures cited in Chapter 7 of Volume 1. The City of Bothell and the City of Everett have their own emergency management programs and hazard mitigation plans.

PLAN GOALS AND OBJECTIVES

The following mitigation goals and objectives guided the 2015 HMP Update:

- Goal 1—Reduce natural hazard-related injury and loss of life.
- Goal 2—Reduce property damage.
- Goal 3—Promote a sustainable economy.
- Goal 4—Maintain, enhance, and restore the natural environment's capacity to absorb and reduce the impacts of natural hazard events.
- Goal 5—Increase public awareness and ability to respond to disasters.

TABLE ES-1. OBJECTIVES FOR NATURAL HAZARD MITIGATION PLAN UPDATE		
Objective Number	**Objective Statement**	**Goals for which it can be applied**
O-1	**Discourage growth within high risk areas,** where risks cannot be reduced to a tolerable level and within flood high risk areas where land uses are not water dependent, and encourage in designated low risk areas.	1, 2, 3, 4
O-2	**Relocate uses** where safety to life or vital ecosystem services cannot be assured.	1, 2, 3, 4
O-3	**Support risk reduction mitigation measures** on lands where life safety and ecosystem services can be assured to a tolerable level.	1, 2, 3, 4, 5
O-4	**Strengthen tools** such as the transfer and purchase of development rights (TDRs and PDRs) to remove threatened uses from hazardous areas or uses that degrade natural and beneficial functions.	1, 2, 3, 4
O-5	**Support actions that mitigate the causes of climate change** and adapt to expected impacts.	1, 2, 3, 4
O-6	**Provide incentives that support the mitigation of impacts** to critical manufacturing and manufacturing support facilities and operations.	1, 2, 3, 4
O-7	**Reduce the adverse impacts** of disasters on isolated communities.	1, 2, 3, 4, 5
O-8	Reduce the adverse impacts and **exploit the beneficial functions** of natural hazards to resource lands.	2, 3, 4
O-9	**Increase the resilience of critical infrastructures** to hazards (examples: roads, non-redundant facilities, pipelines, water and sewage treatment facilities, healthcare facilities, schools and emergency support facilities).	1, 2, 3

HAZARDS OF CONCERN

Earthquakes, extreme weather, large floods, landslides, and other hazards can impact buildings, infrastructure, human health, wellbeing, and access to basic goods and services. Although hazards present risk, the frequency and severity of potential impacts vary significantly among hazards. To address the disparity of impacts and prioritize county resources, a Steering Committee of stakeholders involved in the planning process identified and ranked hazards found in the county. The project team then conducted a risk assessment of the identified hazards, evaluating the potential loss of life, personal injury, economic injury, and property damage resulting from the hazards.

Hazards of highest concern to the county include earthquake, severe weather, and flood. Additional hazards of concern for the county include landslide, climate change, and dam failure. Dam failure was of concern in part due to the inclusion of levee failure within the hazard category. The hazards of least concern include volcano, avalanche, tsunami, and wildland fire. Table ES-2 shows the hazards of concern and risk ranking for the county, with “1” representing the highest risk and “9” the lowest risk to county residents. Some priorities of county sub-regions varied from that of the county as a whole.

TABLE ES-2. HAZARDS OF CONCERN AND RISK RANKING			
Hazard	**Ranking**	**Hazard**	**Ranking**
Climate Change	5	Landslide & Other Mass Movements	4
Avalanche	9	Severe Weather	2
Dam & Levee Failure	6	Volcano	9
Earthquake	1	Wildland Fire	8
Flooding	3	Tsunami & Seiche [1]	7

RISK ASSESSMENT

The risk assessment measures the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards. It allows emergency management personnel to establish early-response priorities by identifying potential hazards and vulnerable assets. A summary of the exposure and vulnerability is presented in Table ES-4.

No modeling is currently available to develop quantitative estimates of the effect of climate change on natural hazard risks. However, an understanding of the basic features of climate change allows for the following qualitative assessments of impacts on hazards of concern addressed in this hazard mitigation plan (Table ES-3). This overview serves as a basis for evaluating how risk will change as a result of future climate change impacts. The vulnerabilities identified in this plan update will ultimately be used to inform other aspects of emergency management planning, such as the Comprehensive Emergency Management Plan.

[1] Because best available tsunami modeling science was not available to incorporate into this update, tsunami hazard information is presented as a secondary hazard in the Earthquake hazard section. The County is building the tsunami modeling capacity so that updated and improved information can be presented in the 2020 Update.

TABLE ES-3. CLIMATE CHANGE EFFECTS ON HAZARDS		
Hazard	**Expected Change**	**Influencing Factors**
Avalanche	Uncertain	• Snowpack will change with more wet snow and less snow at lower elevations • Changes in forest structure and related snowpack anchoring
Dam/Levee Failure	Increased Impacts	More heavy winter rains will: • Increase number of dam design failures[2] • Increase exceedance of levee design capacity • Increase damage to levees
Earthquake	Uncertain Increased Secondary Impacts	• Reduction of glaciers from warming may effect continental plate uplift and earthquake activity • Increased soil saturation from winter storms and sea-level rise may increase soil instability
Flood	Increased Frequency and Magnitude Change in Seasonal Timing	• More precipitation as rain • More precipitation in winter
Landslide	Increased Impacts	• Heavier rainfall in winter months • Erosion from increased storm flows • Reduced steep slope anchoring from increased risk of summer wildfire • Erosion from sea-level rise
Severe Weather	Mostly Increased Impacts Decreased Cold Weather	• Increased winds • Increased rain in winter • Increased heat in summer
Tsunami	Increased Impacts	• Greater volume of water displaced onto land due to sea-level rise
Volcano/Lahar	Change Unlikely	• Reduction of glaciers from warming may effect continental plate uplift and volcanic activity
Wildland Fire	Increased Impacts	• Warmer drier summers • Increased forest damage from disease

[2] Dams are constructed with safety features known as "spillways." Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, often referred to as "design failures," result in increased discharges downstream and increased flooding potential.

TABLE ES-4. HAZARD RISK ASSESSMENT SUMMARY	
Hazard	**Exposure & Vulnerability**
Avalanche	• *People* – Recreational and professionals in avalanche areas are exposed. • *Property* – Unknown
Dam/Levee Failure	• *People* – A breach of the Tolt River Dam could affect over 7,300 people and a failure of the Culmback Dam could affect over 20,900 people. • *Property* – An estimated $2.38 billion worth of building-and-contents are exposed for the Culmback and Tolt River Dams.
Earthquake	• *People* – A Devil's Mountain event could displace up to 62 households, with over 36 persons needing short-term shelter. A South Whidbey Island Fault event could displace up to 8,750 households with over 5,023 persons requiring short-term shelter. • *Property* – For a 7.1-magnitude event on the Devil's Mountain Fault, the estimated damage potential is $2.7 billion. For a 7.4-magnitude event on the South Whidbey Island Fault, the estimated damage potential is $12.8 billion.
Flood	• *People* – An estimated 75,389 people live within the 100-year floodplain within the entire county. An estimated 75,389 people would need short-term shelter in a 100-year flood. • *Property* – It is estimated that a 100-year flood would cause up to $161.4 million in damages and a 500-year flood would cause $233.5 million in damages.
Landslide	• *People* – The estimated county population living in landslide risk areas may be as high as 60,000. • *Property* – There are 12,371 structures on parcels exposed to steep slopes, worth an estimated $3.5 billion. Ninety-five percent of the exposed structures are residential dwellings.
Severe Weather	• *People* – All residents in the county are exposed to severe weather. The most vulnerable include elderly, low-income, or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. • *Property* – All structures in the county are exposed. It is estimated that 20 percent of the residential structures were built without the influence of a building code with provisions for wind or snow loads.
Volcano/Lahar	• *People* – All residents are vulnerable to ash fallout. Approximately 14,609 people in the county reside in lahar zones. • *Property* – 5286 structures with an estimated value of $1.16 billion are located in the lahar zones.
Wildland Fire	• *People* – All residents are vulnerable to smoke. An estimated 127,784 people are living in Wildland Urban Interface Areas. • *Property* – The estimated total value of assets exposed is $9.72 billion.

COUNTY-WIDE HAZARD MITIGATION STRATEGIES

Hazard mitigation is the use of long- and short-term strategies to reduce or alleviate the loss of life, personal injury, and property damage that can result from a disaster. It involves strategies such as planning, policy changes, programs, projects, and other activities that can mitigate the impacts of hazards. The responsibility for hazard mitigation lies with many, including private property owners, business and industry, and local, state, and federal government.

The plan identifies 38 county-wide mitigation initiatives to address hazard-related risks (Table ES-5). For more detailed information on plan development, maintenance, the risk assessment, and mitigation initiatives, see HMP Volume 1 and Volume 2.

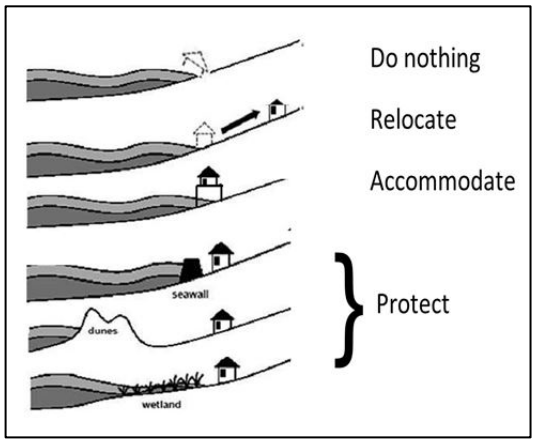


Figure ES-1 Hazard Mitigation Strategies

TABLE ES-5. HAZARD MITIGATION ACTION PLAN MATRIX (see Chapter 12)	
Item	**Description**
CW-1	Retrofit critical facilities that cannot be moved to low risk areas.
CW-2	Enhance and improve capital improvement programs, taxing, zoning and development approaches to promote mitigation and reduce exposure/vulnerability to natural hazards.
CW-3	Create and enhance public information programs that will result in actionable preparedness and mitigation measures.
CW-4	Promote community's ability to self-organize by developing social capital through strengthening of community networks. Strong neighborhoods can help promote risk reduction.
CW-5	Research the possibility of developing functional neighborhood-based micro infrastructure networks (micro grids) including the diversification, decentralization and redundancy of utilities. Such systems have increased operational resilience, decreased carbon emissions, and decreased life cycle costs.
CW-6	Preserve and strengthen communications systems.
CW-7	Support HMP and integrate HMP with other planning mechanisms, such as the Growth Management Act.
CW-8	Develop Departmental continuity of operations plans and neighborhood-based continuity plans (small businesses and neighborhoods).
CW-9	Provide incentives for eligible non-profits and private entities, including homeowners, to adapt to risks through structural and nonstructural retrofitting.
CW-10	Assure that services provided by critical facilities, including medical and emergency services, are available to at-risk communities with special emphasis on communities at risk of isolation.
CW-11	Map avalanche hazard areas and determine risk to residential, business, and public buildings and transportation routes.
CW-12	Increase public awareness of the avalanche hazard and promote instructional (actionable) guidance.
CW-13	Demonstrate leadership in greenhouse gas emissions reductions through leading by example and working with stakeholders.
CW-14	When updating the Comprehensive Plan and other plans, evaluate decisions through a climate change impact lens. (Many plans are based on historic information. This is particularly evident with flood projections. This practice can lead to inaccurate projections and plans that do not address future needs.)
CW-15	Adopt and implement land use and transportation policies, termed "Centers" in the General Policy Plan that reduce greenhouse gas emissions.
CW-16	Plan and prepare for climate impacts using best available science.
CW-17	Improve hazard mitigation planning for dam and levee failure.
CW-18	Improve dam and levee failure warning for vulnerable communities.
CW-19	Consider flood control structure maintenance that restores and maintains hydrologic ecosystems services of floodplains where feasible.

TABLE ES-5. (continued) HAZARD MITIGATION ACTION PLAN MATRIX	
Item	**Description**
CW-20	Maintain levees where accommodation though elevation and other flood risk-reduction measures is not possible.
CW-21	Support improved data collection and distribution for Glacier Peak seismic activity.
CW-22	Update and improve county flood hazard risk assessment data and methodology.
CW-23	Improve community ability to respond to a flood event.
CW-24	Promote strategies that accommodate flooding with minimal consequences within flood-prone areas where risks are not life threatening.
CW-25	Enable communities to recover development value of properties as they become more frequently flooded resulting from reduced upstream storage (e.g. increased development, reduced snowpack caused by climate change).
CW-26	Preserve and restore floodplain and watershed ecosystem functions and service - Functioning ecosystems provide flood risk reducing co-benefits. Such benefits can include storing water, reducing damaging flows, containing debris, recharging aquifers and removing pollutants.
CW-27	Utilize innovative methods to reduce increasing peak flood flows.
CW-28	Develop coordinated flood control district that has the ability to tax for flood control improvements.
CW-29	Isolate wastewater infrastructure from storm and flood waters.
CW-30	Develop an acquisition program for homes or other uses located within high-risk hazard areas (e.g., flooding, landslide, lahar, etc.)
CW-31	Enable communities to recover development value of properties in prioritized hazard areas (e.g., landslide and tsunami).
CW-32	Reduce risk to utility networks.
CW-33	Promote water conservation to minimize impacts of drought. Climate change projections warn of increasing summer drought risks.
CW-34	Improve communities' abilities to respond to a severe weather event.
CW-35	Revise existing plans to address updated assessments of tsunami risks from the Seattle and South Whidbey Island Faults.
CW-36	Evaluate increased landslide potential from a tsunami and need for increased setback in high-risk areas.
CW-37	Create evacuation routes for communities at risk of a lahar.
CW-38	Promote Firewise Program in communities and encourage Firewise risk reduction methods for parcels adjacent to forest resource lands. Firewise encourages and empowers neighbors to work together in reducing their wildfire risk.

Chapter 1: Introduction

WHY PREPARE THIS PLAN?

Snohomish County residents live in an environment with natural hazards. Hazards like extreme weather and flooding may occur relatively often, arising multiple times within a person's life, while other hazards like volcanic eruptions and large earthquakes are less frequent, occurring once or not at all in a person's life. Whether natural hazard events occur frequently or infrequently, natural hazards potentially present risks to human life, health, property, and wellbeing. Natural hazards may impact the economy, supply of basic goods and services, employment, ecosystem services, and general quality of life.

For example, on November 6, 2006, overbank flooding of several Snohomish County rivers caused damage to both public and private property. The severity of flooding caused levee damage and change of the river channels. County-wide damage costs exceeded $17.7 million. And, on January 11, 2014, high winds knocked out power to over 10,000 residents and exceeded $100,000 in damages.

Figure 1-1 Flood Damage

Snohomish County continues to update its Hazard Mitigation Plan (HMP) to better identify and prioritize actions to reduce or alleviate risks from natural hazards, which reduces loss of life, personal injury, and property damage to residents and businesses within the county. The hazard mitigation plan also enables Snohomish County, and partnering jurisdictions, to maintain eligibility for disaster-related federal grant assistance, in accordance with the federal Disaster Mitigation Act (2000). In addition, the HMP helps meet the planning requirements of FEMA's Community Rating System (CRS), which allows partners that participate in the CRS program to maintain or enhance their CRS classifications.

The Plan was developed and updated according to the requirements of Chapter 44 of the Code of Federal Regulations (44CFR) and was originally approved by FEMA Region X on April 27, 2005. The FEMA approval qualified the planning partners to pursue implementation funding under the Stafford Act. The planning area boundary is the Snohomish County boundary.

PLANNING PARTNERS

The 2015 update to the HMP was prepared by a partnership of 37 local governments in Snohomish County (18 municipal governments, two tribal governments, and 16 special-purpose districts) and the county (See Table 1-1). Jurisdictions that had previously participated in the Emergency Services Coordination Area (ESCA) planning effort in 2010 chose to join the partnership for the county's plan.

Jurisdictions that did not participate in the plan update can link to the plan at a later date by following the linkage procedures cited in Chapter 7 of Volume I. The school districts in Snohomish County have the option to participate through the Washington State Office of Superintendent of Public Instruction (OSPI) hazard mitigation effort. Snohomish School District is taking this option, and writing an annex to the State's plan, rather than participating in the Snohomish County effort. The City of Bothell and the City of Everett have their own emergency management programs and hazard mitigation plans.

TABLE 1-1.
PLANNING PARTNERS

City/Tribal/County	Special District
Arlington	Alderwood Water and Wastewater District
Brier	Cross Valley Water District
Darrington	French Slough Flood Control District
Edmonds	Highland Water District
Gold Bar	Marshland Flood Control District
Granite Falls	Mukilteo Water and Wastewater District
Index	Silver Lake Water and Sewer District
Lake Stevens	Snohomish County Dike District #2
Lynnwood	Snohomish County Fire District #1
Marysville	Snohomish County Fire District #3
Mill Creek	Snohomish County Fire District #5
Monroe	Snohomish County Fire District #12
Mountlake Terrace	Snohomish County Fire District #24
Mukilteo	Snohomish Health District
Snohomish	Snohomish PUD
Stanwood	Sultan School District
Stillaguamish Tribe of Indians	
Sultan	
Tulalip Tribes	
Woodway	
Snohomish County	

PLAN GUIDING PRINCIPLE, GOALS, AND OBJECTIVES

The plan uses a guiding principle, five goals, and nine objectives to guide plan development and mitigation-strategy identification and prioritization. The guiding principle focuses the range of objectives and actions to be considered. The guiding principle for the Snohomish County Hazard Mitigation Plan Update is as follows:

> *Through partnerships, reduce the vulnerability to natural hazards in order to protect the health, safety, welfare, and economy of the community.*

The following are the mitigation goals for this plan update:

- Goal 1—Reduce natural hazard-related injury and loss of life.
- Goal 2—Reduce property damage.
- Goal 3—Promote a sustainable economy.
- Goal 4—Maintain, enhance, and restore the natural environment's capacity to absorb and reduce the impacts of natural hazard events.
- Goal 5—Increase public awareness and ability to respond to disasters.

Achievement of these goals defines the effectiveness of a mitigation strategy. The goals are also used to help establish mitigation strategy priorities.

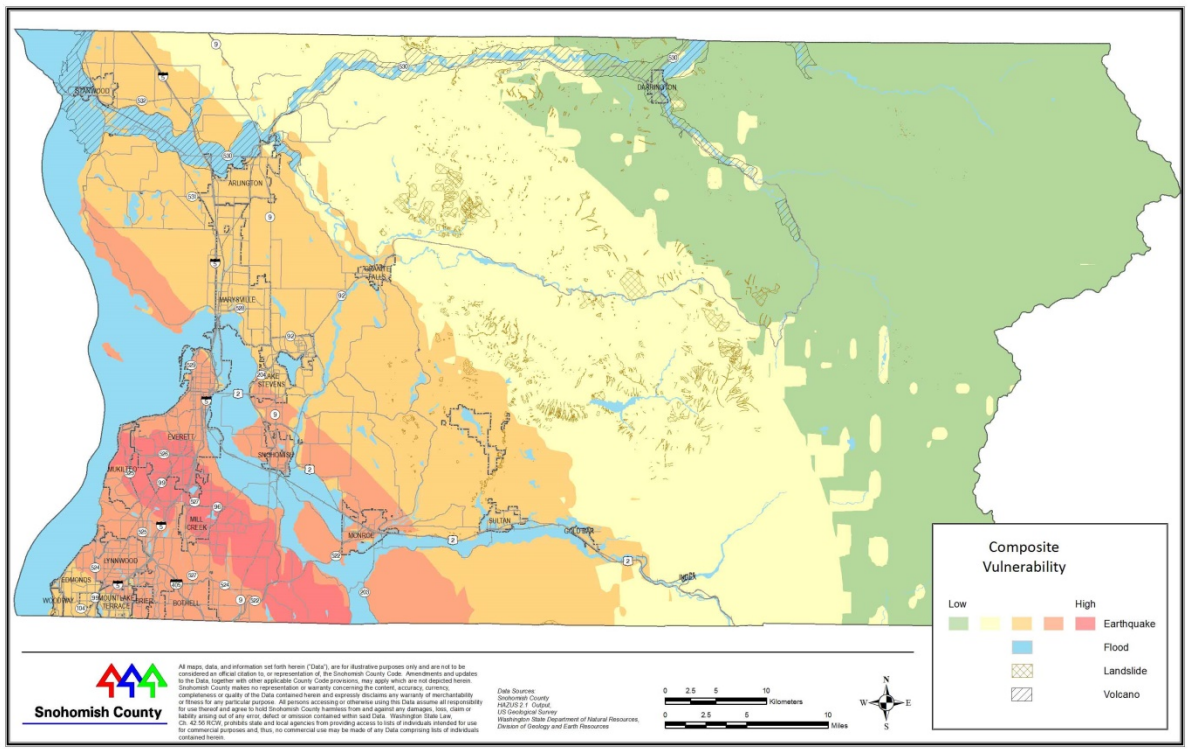
Plan objectives meet multiple goals, listed in Table 1-2. Effectiveness of any specific mitigation strategy is measured based on achievement of the objectives. The objectives also are used to help establish priorities.

TABLE 1-2. OBJECTIVES FOR HAZARD MITIGATION PLAN UPDATE		
Objective Number	**Objective Statement**	**Goals for which it can be applied**
O-1	**Discourage growth within high-risk areas** where risks cannot be reduced to a tolerable level and within flood high risk areas where land uses are not water dependent, and encourage in designated low risk areas.	1, 2, 3, 4
O-2	**Relocate uses** where safety to life or vital ecosystem services cannot be assured.	1, 2, 3, 4
O-3	**Support risk reduction mitigation measures** on lands where life safety and ecosystem services can be assured to a tolerable level.	1, 2, 3, 4, 5
O-4	**Strengthen tools** such as the transfer and purchase of development rights (TDRs and PDRs) to remove threatened uses from hazardous areas or uses that degrade natural and beneficial functions.	1, 2, 3, 4
O-5	**Support actions that mitigate the causes of climate change** and adapt to expected impacts.	1, 2, 3, 4
O-6	**Provide incentives that support the mitigation of impacts** to critical manufacturing and manufacturing support facilities and operations.	1, 2, 3, 4
O-7	**Reduce the adverse impacts** of disasters on isolated communities.	1, 2, 3, 4, 5
O-8	Reduce the adverse impacts and **exploit the beneficial functions** of natural hazards to resource lands.	2, 3, 4
O-9	**Increase the resilience of critical infrastructures** to hazards (examples: roads, non-redundant facilities, pipelines, water and sewage treatment facilities, healthcare facilities, schools, and emergency support facilities).	1, 2, 3

HAZARDS COVERED BY PLAN

A large earthquake (magnitude 8.0 or greater) in Snohomish County would likely lead to massive structural failure of property on water-saturated sands, silts, or gravelly soils. Levees built on these poor soils would likely fail. Older buildings would be significantly damaged and unreinforced masonry buildings may collapse. The earthquake may trigger landslides, mudslides, or fires that would further damage structures and injure occupants. In addition to injury, loss of life, and property damage, some communities/neighborhoods may become isolated, losing access to food, water, electricity, employment, financial services, and emergency services.

Similarly, extreme weather, large floods, landslides, and other hazards can impact buildings, infrastructure, human health, wellbeing, and access to basic goods and services. Although hazards present risk, the frequency and severity of potential impacts vary significantly among hazards. To address the disparity of impacts and prioritize county resources, a Steering Committee of stakeholders involved in the planning process identified and ranked hazards found in the county. The project team then conducted a risk assessment of the identified hazards, evaluating the potential loss of life, personal injury, economic injury, and property damage resulting from the hazards.



Map 1-1 Snohomish County Composite Vulnerability of Select Hazards

Hazards of highest concern to the county include earthquake, severe weather, and flood. Additional hazards of concern for the county include landslide, climate change, and dam failure. Dam failure was of concern in part due to the inclusion of levee failure within the hazard category. The hazards of least concern include volcano, avalanche, tsunami, and wildland fire. Table 1-3 shows the hazard of concern and risk ranking for the county, with "1" representing the highest risk and "9" the lowest risk to county residents. Some priorities of county sub-regions varied from that of the county as a whole. The risk ranking of the sub-regions is found in Chapter 19 of Volume 1.

TABLE 1-3. HAZARDS OF CONCERN AND RISK RANKING			
Hazard	**Ranking**	**Hazard**	**Ranking**
Climate Change	5	Landslide & Other Mass Movements	4
Avalanche	9	Severe Weather	2
Dam & Levee Failure	6	Volcano	9
Earthquake	1	Wildland Fire	8
Flooding	3	Tsunami & Seiche[3]	7

The risk assessment helps county emergency management personnel establish early-response priorities by identifying potential hazards and vulnerable assets. The process focuses on the following elements:

- Hazard identification—Use all available information to determine what types of disasters may affect a jurisdiction, how often they can occur, and their potential severity.
- Vulnerability identification—Determine the impact of natural hazard events on the people, property, environment, economy, and lands of the region.
- Cost evaluation—Estimate the cost of potential damage or damage costs that can be avoided by mitigation.

The risk assessment for this hazard mitigation plan evaluates the risk of natural hazards prevalent in Snohomish County and meets requirements of the DMA (44CFR, Section 201.6(c)(2)). Summary risk assessment information can be found in Chapters 3 through 11 of this document. HMP Volume 1 contains detailed risk assessment information, including city-specific impacts and cost evaluation.

[3] Because best available tsunami modeling science was not available to incorporate into this update, tsunami hazard information is presented as a secondary hazard in the Earthquake hazard section. The county is building the tsunami modeling capacity so that updated and improved information can be presented in the 2020 Update.

HAZARD MITIGATION INITIATIVES

Hazard mitigation is the use of long- and short-term strategies to reduce or alleviate the loss of life, personal injury, and property damage that can result from a disaster. It involves strategies such as planning, policy changes, programs, projects, and other activities that can mitigate the impacts of hazards. The responsibility for hazard mitigation lies with many, including private property owners, business and industry, and local, state, and federal government.

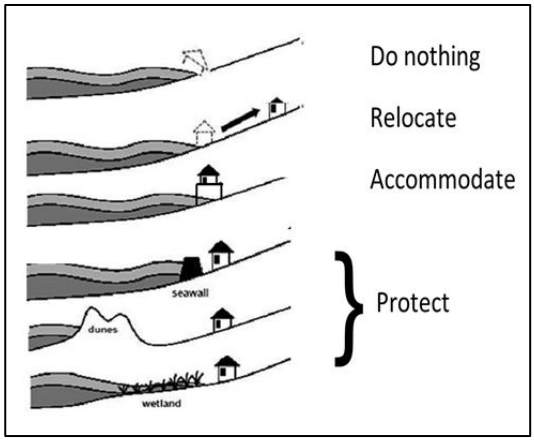


Figure 1-2 Hazard Mitigation Strategies

Depending on hazard risks, mitigation strategies will vary and several may be pursued at the same time. For example, early warning and education programs reduce injury and loss of life from floods. Retrofits may be necessary to sustain critical infrastructure like bridges that cannot be readily moved. And, preserving and restoring floodplain and watershed ecosystem functions and services reduce the damaging flows.

The plan identifies 38 County-wide mitigation initiatives to address hazard-related risks. With most initiatives, several action alternatives are presented to implement the initiative. Each initiative is presented in Chapter 12 of this document. Chapter 21 of Volume 1 also identifies for each initiative hazards addressed, objectives supported, and the County department that would lead implementation, funding sources, and time frame of implementation. HMP Volume 1 also contains benefit-cost analysis and prioritization of the mitigation Initiatives. HMP Volume 2 contains planning partner mitigation initiative information in the jurisdictional annexes.

WHERE TO FIND DETAILED PLAN DOCUMENTATION?

For more detailed information on plan development, maintenance, the risk assessment, and mitigation initiatives, see the two-volume HMP. The HMP is set up in two volumes so that elements that are jurisdiction-specific can easily be distinguished from those that apply to the whole planning area:

- Volume 1 includes all the required elements of 44CFR Section 201.6 that apply to the entire planning area. This includes the description of the planning process, public involvement strategy, goals and objectives, County-wide hazard risk assessment, County-wide mitigation initiatives, and a plan maintenance strategy. Maps cited in each chapter are provided at the end of the chapter. The following appendices are provided at the end of Volume 1:
    - Appendix A—A glossary of acronyms and definitions
    - Appendix B —Hazardous Materials and Pipeline hazard information
    - Appendix C—Hazard mitigation questionnaire and summary
    - Appendix D—Most recent progress report from 2010 to 2015 performance period

- Appendix E—Catalogs of Mitigation Alternatives from 2010 Plan
- Appendix F—Transfer of Development Rights and Purchase of Development Rights for Hazard Mitigation white paper
- Appendix G—Decentralized Water Retention Suitability – Snohomish County white paper
- Appendix H—Methods for flood return interval analysis
- Appendix I—Resolutions

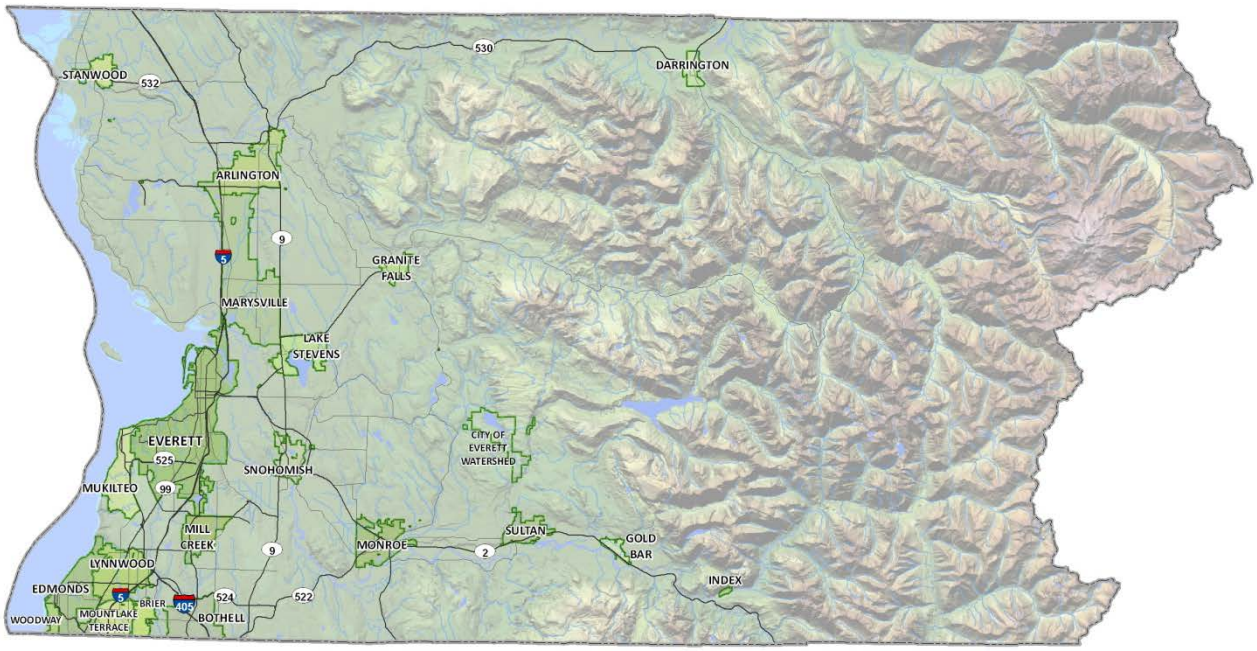
- Volume 2 includes all jurisdiction, district, and tribal-specific elements required by 44CFR Section 201.6. The planning partnership includes cities, tribal nations, the County, and special purpose districts participating in this process and adopting this plan. Jurisdiction-specific elements are included in annexes for each planning partner. Volume 2 also includes a description of the participation requirements for planning partners established by the Planning Committee, as well as instructions and templates that the partners used to complete their annexes. It also includes "linkage" procedures for eligible, non-participating jurisdictions that wish to join the Snohomish County Hazard Mitigation Plan.

All planning partners will adopt Volume 1 in its entirety, Chapter 1 of Volume 2, their own jurisdictional annex, and all Volume 2 appendices.

Chapter 2: Snohomish County Profile

INTRODUCTION

Snohomish County is located on Puget Sound in Western Washington (see Map 2-1). Given the mountainous geography in the eastern portion of the County, the bulk of Snohomish County's development and population resides along the narrow, westernmost Puget Sound lowlands. Skagit County to the north, Chelan County to the east, King County to the south, and Puget Sound and Island County to the west border the County.



Map 2-1 Main Features of Snohomish County

Snohomish County is third largest by population in the state. Its major cities are Everett, Marysville, Edmonds, and Lynnwood. Other cities include Arlington, Bothell (partly in King County), Brier, Gold Bar, Granite Falls, Lake Stevens, Mill Creek, Monroe, Mountlake Terrace, Mukilteo, Snohomish, Stanwood, Sultan, and Woodway. Snohomish County is also home to the incorporated Towns of Index and Darrington, as well as the Tulalip, Stillaguamish, and Sauk-Suiattle Tribes. Much of the population is located along the transportation corridors, which are also interspersed with commercial and industrial operations. Management and professional occupations, sales, and manufacturing are important base industries in the County. Snohomish County is the home of the Boeing Company's largest aerospace assembly plant.

Since a considerable portion of the land in Snohomish County consists of forestland, there is an abundance of recreational opportunity and access to natural resources. Snohomish County is a destination for those seeking golfing, boating, hiking, camping, fishing, and hunting activities.

GEOGRAPHICAL SETTING

Snohomish County covers an area of 2,196 square miles. The County's topography ranges from saltwater beaches, rolling hills, and rich river bottom farmlands in the west to dense forest and alpine wilderness in the mountainous east. More than half of the County is mountainous, with a number of peaks reaching elevations in excess of 6,000 feet and supporting glaciers and perennial snowfields. Glacier Peak (see Figure 2-1), at 10,541 feet, is the highest point in the County and one of the highest in the state. Sixty-eight percent of the County's land cover is forestland, 18 percent is rural, nine percent is urbanized, and five percent is agricultural.

Most of the County's communities are in the western lowlands near primary transportation corridors including Interstate 5, State Route 9, US Highway 2, and State Route 530. In addition to auto transportation, Snohomish County hosts multiple railways connecting the communities to Puget Sound and Canada. Many sections of the converted historic railways make up many portions of the recreational trail system, such as the Interurban Trail and Centennial Trail, while the Sound Transit commuter train and freight trains use the active railways.

The natural hazards affecting western Washington owe much of their character to the geologic formation of the region and glaciation. The Juan de Fuca Plate, a small, low-lying oceanic plate, is moving under the western edge of the North American Plate at the Cascadia Subduction Zone. This process causes earthquakes of considerable magnitude, the formation of the Cascade Mountain Range, and volcanoes, such as Glacier Peak.

The advance and retreat of glaciers in the region left behind deeply gouged channels, north-south oriented passages, and bays. Weather, waves, rivers, and gravity reworked the glacial sediment, molding landforms and shorelines into the beaches and bluffs that now edge the Puget Sound region.

The Cascade Mountain Range is 1,000-miles long, extending from northern California through Oregon and Washington to southern British Columbia. The Northern Cascade Range passes through the eastern two-thirds of Snohomish County. Glacier Peak, the only volcano in Snohomish County, is in the northeast quadrant of the County.

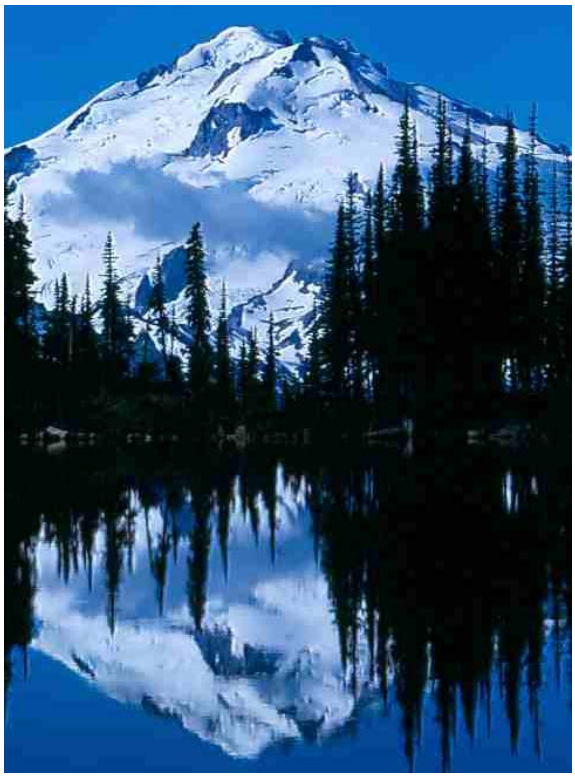


Figure 2-1 Glacier Peak

Many faults exist in the mountains and valleys in Snohomish County as the mountains continue building. Erosion of the Cascade Range over thousands of years has filled the valleys with alluvial sediment, creating broad, flat surfaces and soft soils. On hillsides, riverbanks, and coastal bluffs these soils are prone to erosion and landslides. Rivers cut through the valleys, transporting and redistributing nutrient-rich sediments throughout the productive floodplains. Though seismic activity in Snohomish County has been moderate to low, many active faults in the

County are capable of producing high-magnitude earthquakes that could damage critical infrastructure such as water mains, gas lines, roads, major highways, bridges, and railways, particularly in locations with soft soil.

The primary river basins and rivers in the County include:

> The **Snohomish River Basin** covers approximately 1,856 square miles in King and Snohomish Counties. It contains over 2,700 miles of streams, making it the second-largest basin draining to Puget Sound. The **Skykomish** and **Snoqualmie Rivers** are the primary tributaries of the Snohomish River. They originate in the Cascade Mountains and flow west nearby several rural communities and state highways. The confluence of these two major rivers is at the City of Monroe, where they become the Snohomish River. The Snohomish River continues to the estuary near the City of Snohomish and reaches Puget Sound between the cities of Everett and Marysville.
>
> The **Stillaguamish River Basin** is about 700 square miles in area, with about 3,100 miles in stream length. Located in the northern half of the County, the Stillaguamish River drains approximately one-half of the County's land area. With basin streams originating in Skagit and Snohomish County, the "Stilly" is the fifth-largest tributary draining into Puget Sound.
>
> The **Sauk River**, in the northeastern corner of the County near Darrington, drains into the Skagit River about a mile beyond the County's northern boundary. There are over 460 lakes and reservoirs in Snohomish County. Of these, 207 are at elevations above 2,500 feet. These lakes serve as popular tourist attractions and recreational sites. The larger lakes include Lake Goodwin, Lake Stevens, Silver Lake, and Lake Ballinger. Lake Chaplin and Spada Lake are reservoirs with dams.

CLIMATE

The Cascade Range and ocean currents along Washington State's coast significantly influence Snohomish County's climate. Mild temperatures with heavier rain in the winter and occasional snow characterize the lowland climate, while lower temperatures and higher precipitation are normal at higher elevations. Daily coastal temperatures in the City of Everett average 62.8°F during July and 39°F in January. In the mountain valley town of Darrington, summer temperatures average 63.7ºF and winter temperatures are typically around 34.2°F.

Precipitation can occur any season of the year; however, most occurs during the fall and winter. Moisture from Pacific storms, the typical weather pattern, falls on the windward (western) side of the Cascade Range. The moisture in the air condenses and precipitates as it travels up and over the mountains. Normal precipitation varies significantly based on location in the County. The annual average precipitation in the City of Everett is 35 inches, which contrasts with 80.4 inches for the Town of Darrington and 165 inches in the Sultan Basin.

DEMOGRAPHICS

Snohomish County's population is growing. From 2010 to 2013, in the County's unincorporated areas the population grew at a rate of 3.4 percent, while the incorporated areas grew at a rate of 1.7 percent. Cities, post-recession, experiencing the strongest growth included Lake Stevens (3.2 percent), Marysville (3.5 percent), Bothell (3.7 percent), and Brier (3.7 percent). The City of Woodway in contrast has experienced a population decline (0.5 percent). The major growth in Bothell—in part—has been largely the result of annexations.

Snohomish County's estimated population for April 2013 was 730,500, making it the third largest of Washington's 39 counties. The County's largest city is Everett, which had an estimated 2013 population of 104,200. Marysville, the second-largest city, had over 62,000 residents, followed by Edmonds and Lynnwood. The County's smallest town is Index, which had 180 residents. Over 43 percent of County residents live in unincorporated areas. The County's total population will reach 955,281 by 2035, based on Office of Financial Management's (OFM) medium forecast.

Figure 2-2 illustrates Snohomish County's age distribution.

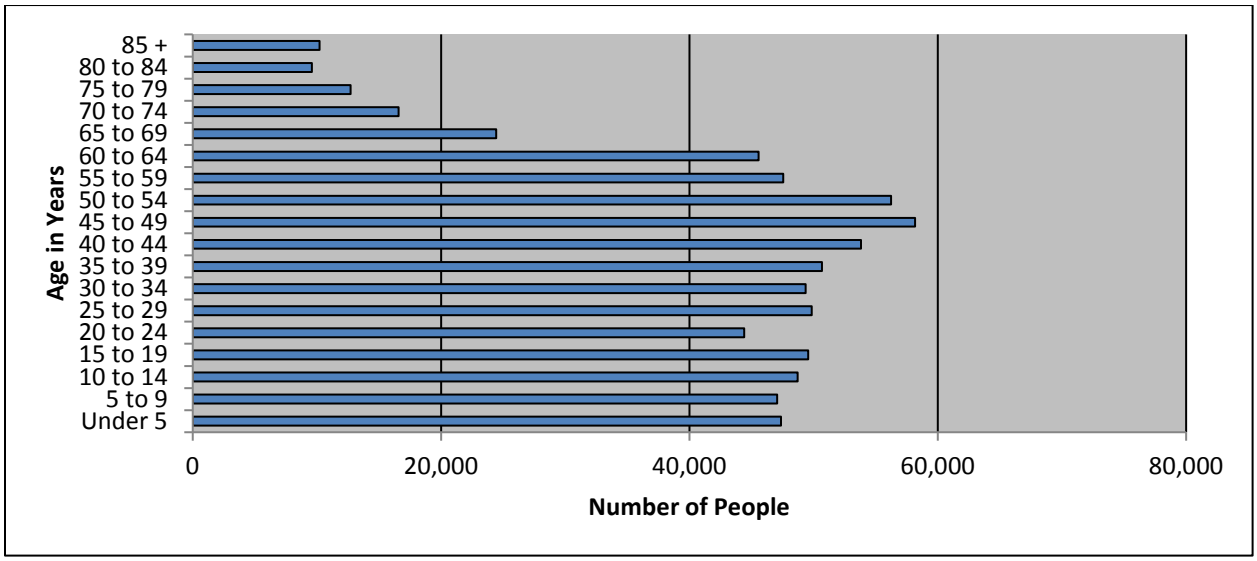


Figure 2-2 Snohomish County Age Distribution

ECONOMY

Snohomish County's economy is strongly based in the biotech industry, clean technology, and aerospace engineering and production. The County's highly technical-skilled workforce produces products ranging from airplanes to sustainable/green technology, and also conducts research for the cure of diseases. In spite of recent economic stresses, Snohomish County possesses many assets that contribute to the economic vitality of the region. The County is in the heart of the Puget Sound basin and is adjacent to the Seattle metropolitan area. Property prices in the County are considerably lower than those found to the south in King County. The Port of Everett provides direct deep-water access for shipping containers. The County's largest communities are located along Interstate 5, the state's major north-south corridor, which links numerous truck and transportation routes

throughout the Puget Sound. The BNSF Railway provides valuable rail service, for both freight and passengers to many locations in the country.

The County's unemployment trends have closely mirrored the state's, with the County's unemployment rates slightly higher than the State's from late 2008 through late 2011 (see Figure 2-3).

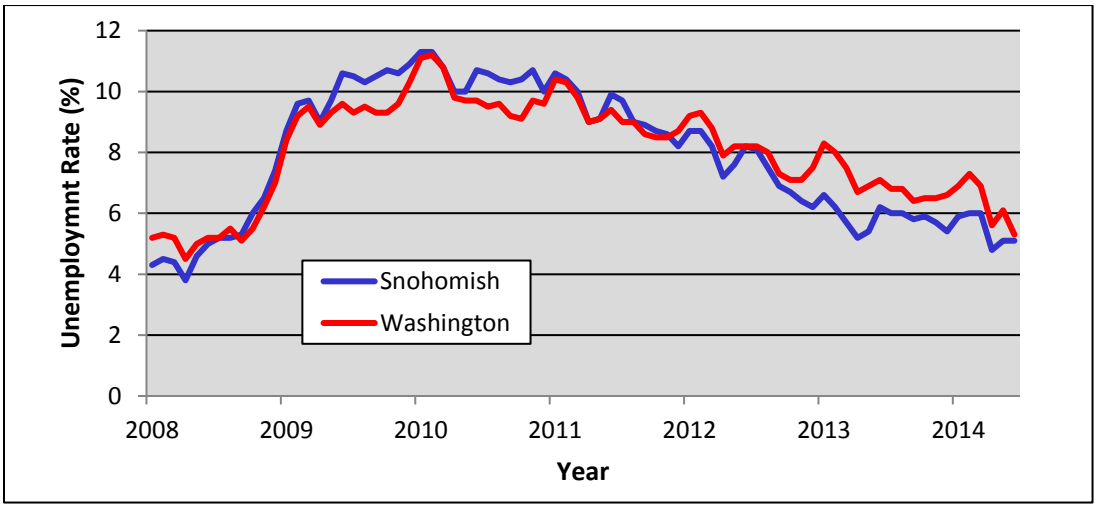


Figure 2-3 Snohomish County and Washington State Unemployment Rate, 2008-2014

Educational services, health care, and social assistance make up the largest industry in Snohomish County (18.9 percent). Manufacturing and then retail trade follow this. Less than one percent of the industry in the County is involved with businesses related to agriculture, forestry, fishing, hunting, and mining (see Figure 2-4).

Occupations for Snohomish County residents range from farming and ranching to high-tech manufacturing, military operations, and medical field professions. Major private employers include Boeing (with an estimated 40,000 employees), Providence Medical Center, Premera-Blue Cross, and the Tulalip Tribes. Major public employers in Snohomish County include the U.S. Naval Station, the State of Washington, and Snohomish County. Management and professional occupations make up over 36 percent of the County workforce, followed by sales and office and then service-related occupations (see Figure 2-5).

Production of aircraft and parts accounts for 69 percent of Snohomish County's manufacturing employment**.** The aerospace industry supports one of every three to six Washington State jobs, resulting in as many as 43,700 people employed in the aerospace field and related electronics industries. The County is the home of Boeing's largest commercial jetliner assembly operation, including production of the Boeing 747, 767, and 777 wide-body jets and the new 787. The market potential for new commercial airplanes over the next 20 years remains high, and Snohomish County has the skilled and experienced aerospace workers to meet the demand.

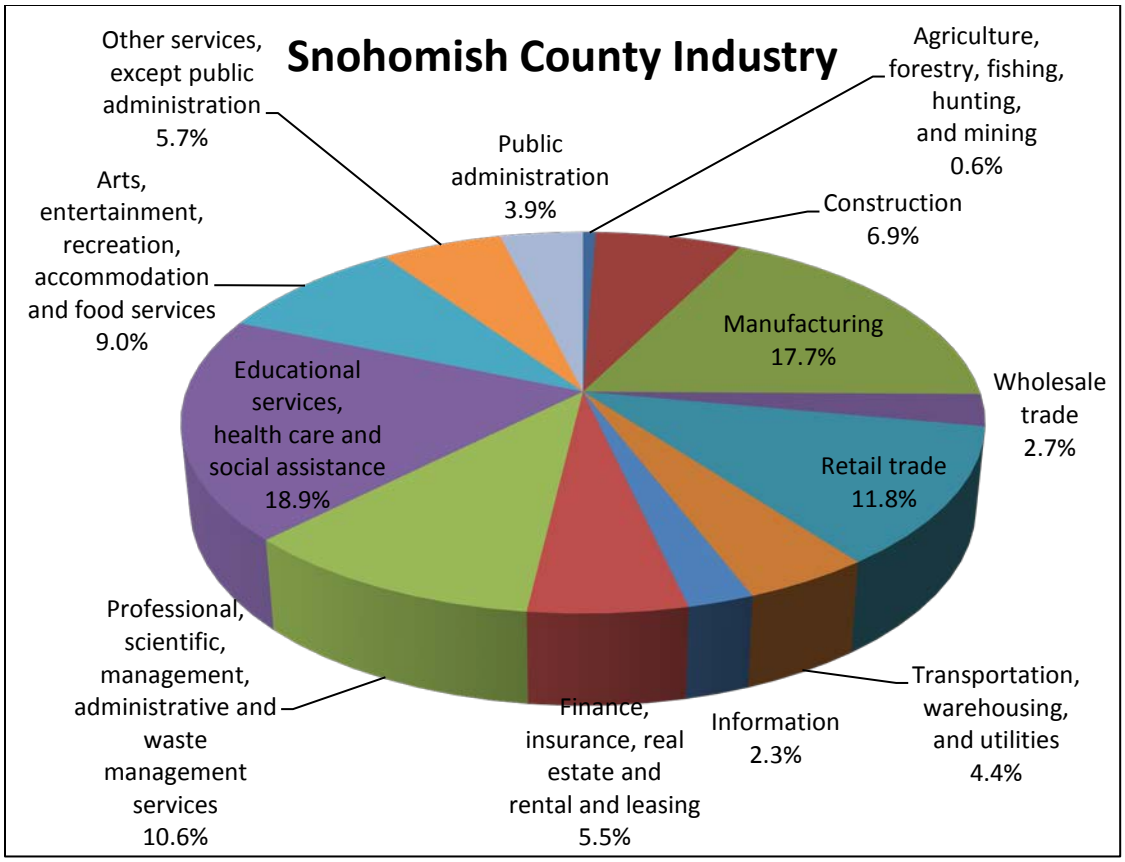


Figure 2-4 Industry in Snohomish County

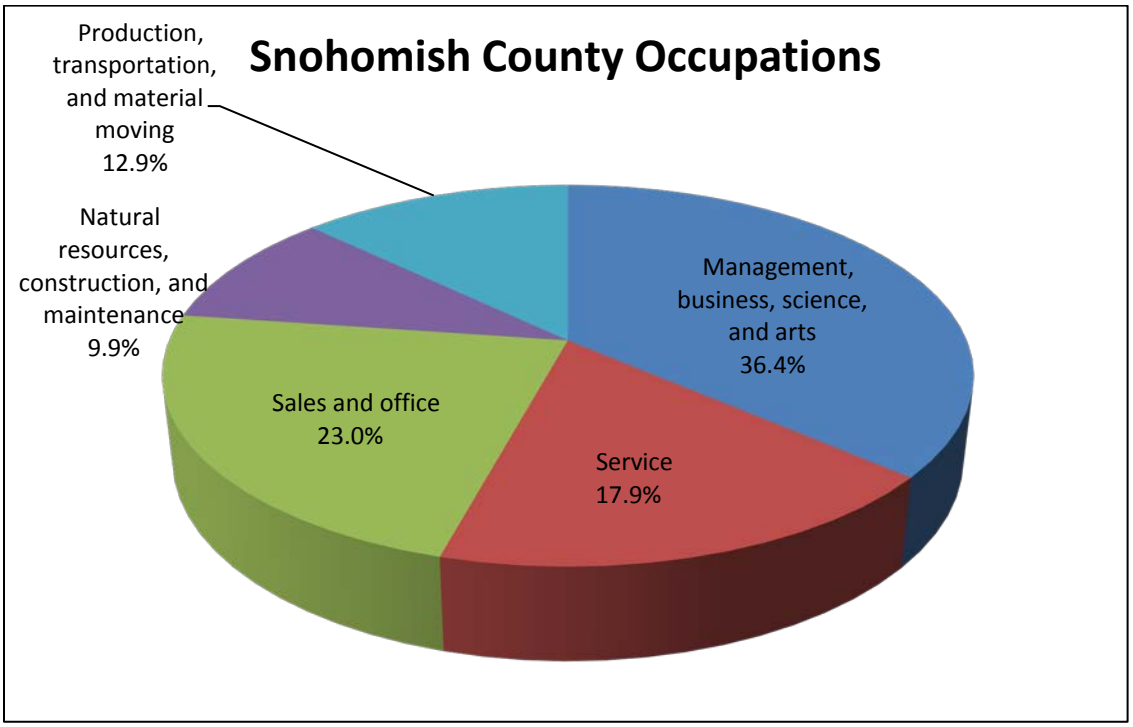


Figure 2-5 Occupations in Snohomish County

VULNERABLE POPULATIONS

People living near or below the poverty line, the elderly (especially older single men), the disabled, women, children, ethnic minorities, and renters all experience, to some degree, more severe effects from disasters than the general population. These vulnerable populations may vary from the general population in risk perception, living conditions, access to information, capabilities during a disaster event, and access to resources for post-disaster recovery. In addition, indicators of vulnerability, such as disability, age, poverty, and minority race and ethnicity, often overlap spatially, and often are in the geographically most vulnerable locations.

In the United States, individual households are expected to use private resources to prepare for, respond to, and recover from disasters to some extent. This means that households living in poverty are automatically disadvantaged when confronting hazards. Additionally, the poor typically occupy more poorly built and inadequately maintained housing. For example, in urban areas, the poor often live in older houses and apartment complexes, which are more likely to be made of unreinforced masonry, a building type that is particularly susceptible to damage during earthquakes.

Furthermore, residents below the poverty level are less likely to have insurance to compensate for losses incurred from natural disasters. This means that residents below the poverty level have a great deal to lose during an event and are the least prepared to deal with potential losses. The events following Hurricane Katrina in 2005 illustrate that personal household economics significantly impacts people's decisions on evacuation. Individuals who cannot afford gas for their cars will likely decide not to evacuate.

For 2008-2012, estimated per capita income is $31,310 and the median household income is $68,338 (in 2012 dollars, adjusted for inflation). About 9.8 percent of the households in Snohomish County are below the poverty level. It is estimated that there are 13,799 households with less than $10,000 in income and benefits per year, and 29,762 households with $10,000 to $25,000 in income and benefits per year. The weighted average poverty threshold for a family of four in 2012 was $23,050; and for unrelated individuals, $11,170.

ELDERLY AND YOUTH

The vulnerability of elderly residents can vary significantly based on health, age, and economic security. However, as a group, the elderly are more apt to lack the physical and economic resources necessary for response to hazard events and are more likely to suffer health-related consequences, making recovery slower. They are more likely to be vision, hearing, and/or mobility impaired, and more likely to experience mental impairment or dementia. Additionally, some elderly live in assisted-living facilities where emergency preparedness varies among facilities. Emergency managers typically identify these facilities as "critical facilities" because they require extra notice to implement evacuation. Elderly residents living in their own homes may have more difficulty evacuating from dangerous situations. This population group is more likely to need special medical attention, which may not be readily available during natural disasters due to isolation caused by the event. Specific planning attention for the elderly is an important consideration, given the aging of the American population.

Children under 14 are particularly vulnerable to disaster events because of their young age and dependence on others for necessities. Very young children may additionally be vulnerable to injury or sickness because they do not understand the measures to take to protect themselves from hazards.

For 2008-2012, an estimated 11.2 percent of Snohomish County's population is 65 or older, and that 35.4 percent of the County's over-65 population has disabilities of some kind and 6.3 percent have incomes below the poverty line. Children under 18 account for 13.4 percent of individuals who are below the poverty line.

RACE, ETHNICITY AND LANGUAGE

Snohomish County's racial composition is predominately white. The largest minority population is Asian/Pacific Islander (See Figure 2-6). 14.7 percent of County residents are foreign born. In addition, the Census estimates that approximately 8.1 percent of the County's residents reported speaking English "less than very well."

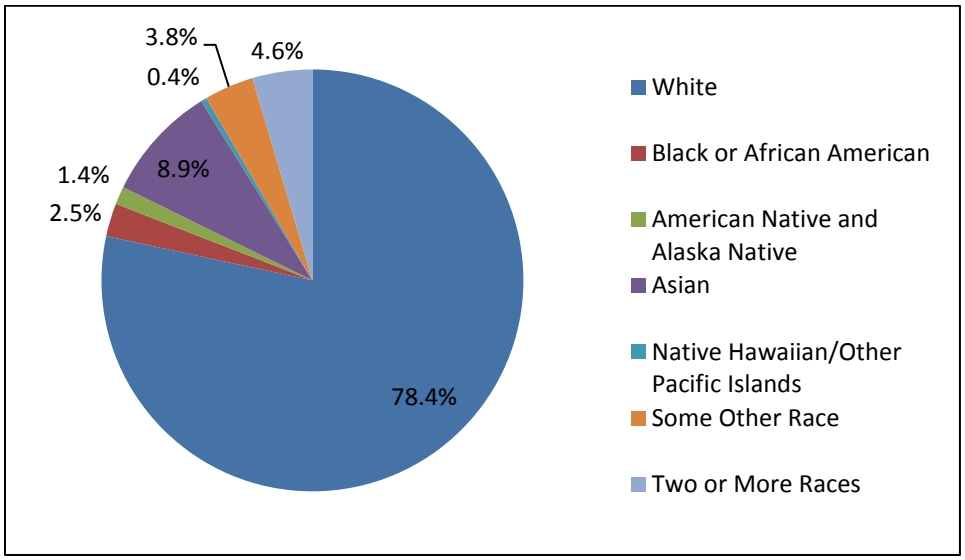


Figure 2-6 Snohomish County Race Distribution (2010)

DISABLED POPULATIONS

While the percentage of disabled in Snohomish County does not differ much from that of the state as a whole, the overall numbers are significant and warrant special attention from planners and emergency managers (see Table 2-1). According to 2010 U.S. Census ACS data, 13 percent of the County's population over the age of five have a disability.

TABLE 2-1.
DISABILITY STATUS OF NON-INSTITUTIONALIZED POPULATION

Age	Persons with a Disability	Percent of Age Group
Age under 18 years	6,383	3.7
Age 18 to 64 years	45,205	9.6
Age 65 years and over	28,456	35.4

Chapter 3: Climate Change Considerations for Hazard Mitigation

WHAT IS CLIMATE CHANGE?

Worldwide, average temperatures have increased more than 1.5°F from 1880 to 2012 with accelerated warming during the past two decades (IPCC, 2013). Average temperatures in the Pacific Northwest have increased about 1.3°F in the last century (Mote et al., 2014). Although this change may seem small, it can lead to large changes in climate and weather.

The warming trend and its related impacts are caused by increasing concentrations of carbon dioxide and other greenhouse gases in the earth's atmosphere. Greenhouse gases are gases that trap heat in the atmosphere, resulting in a warming effect. Carbon dioxide is the most commonly known greenhouse gas; however, methane, nitrous oxide, and fluorinated gases also contribute to warming. Emissions of these gases come from a variety of sources, such as the combustion of fossil fuels, agricultural production, and changes in land use. According to the U.S. EPA, carbon dioxide concentrations measured about 280 parts per million (ppm) before the industrial era began in the late 1700s and have risen 41 percent since then, reaching 394 ppm in 2012 (see Figure 3-1). Almost all of this increase is attributable to human activities (EPA, 2013f: IPCC, 2013).

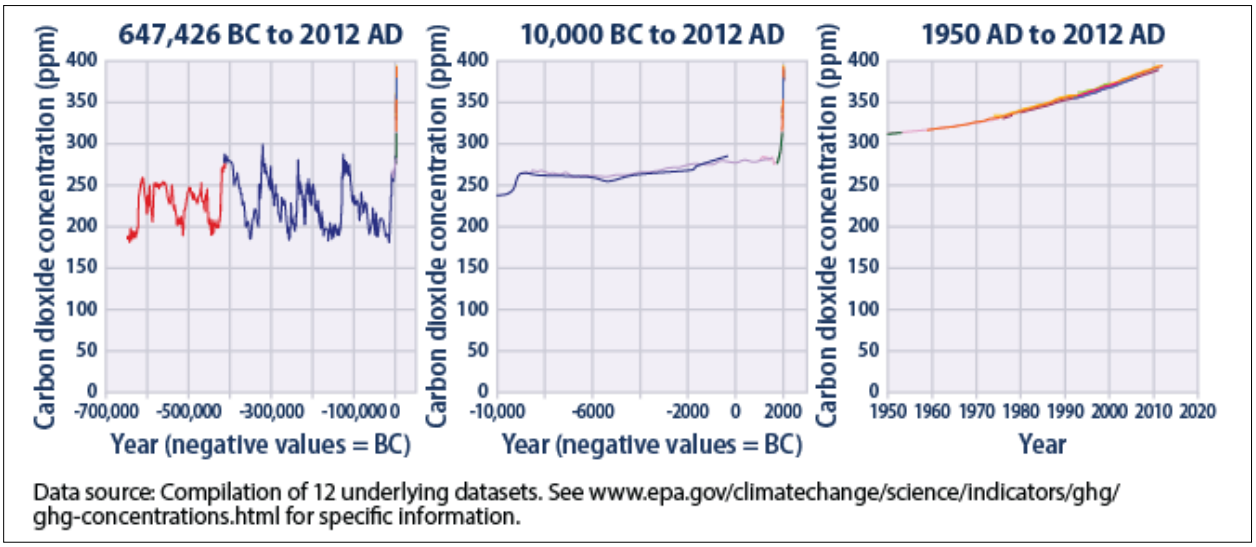


Figure 3-1. Global Carbon Dioxide Concentrations Over Time

Climate change will affect the people, property, economy, and ecosystems of Snohomish County in a variety of ways. Some impacts will have negative consequences for the region and others may present opportunities. The most important effect for the development of this plan is that climate change will have a measurable impact on the occurrence and severity of natural hazards.

HOW CLIMATE CHANGE AFFECTS HAZARD MITIGATION

For hazards affected by climate, past occurrence no longer predicts future behavior. For example, the frequency of flooding will not remain constant if broad precipitation patterns change over time. For this reason, an understanding of climate change is pertinent to efforts to mitigate natural hazards. Information about how climate patterns are changing provides insight on the reliability of hazard projections normally used in mitigation analysis. This chapter summarizes current understandings about projected climate change impacts in the Pacific Northwest in order to provide a context for the recommendation and implementation of hazard mitigation measures in Snohomish County.

FUTURE CLIMATE CHANGE IMPACTS IN THE PACIFIC NORTHWEST

CHANGE IN TEMPERATURE.

In the Pacific Northwest, warming is expected under all climate scenarios. Under a high greenhouse gas emissions scenario, by 2050 average annual temperatures are expected to increase between 3.1°F and 8.5°F, with much greater warming possible after mid-century (Figure 3-2). This warming is expected to occur during all seasons, with greater warming during the summer (Figure 3-3). Climate models also indicate an increased frequency of extreme heat events and a decrease of extreme cold events (Snover et al., 2013).

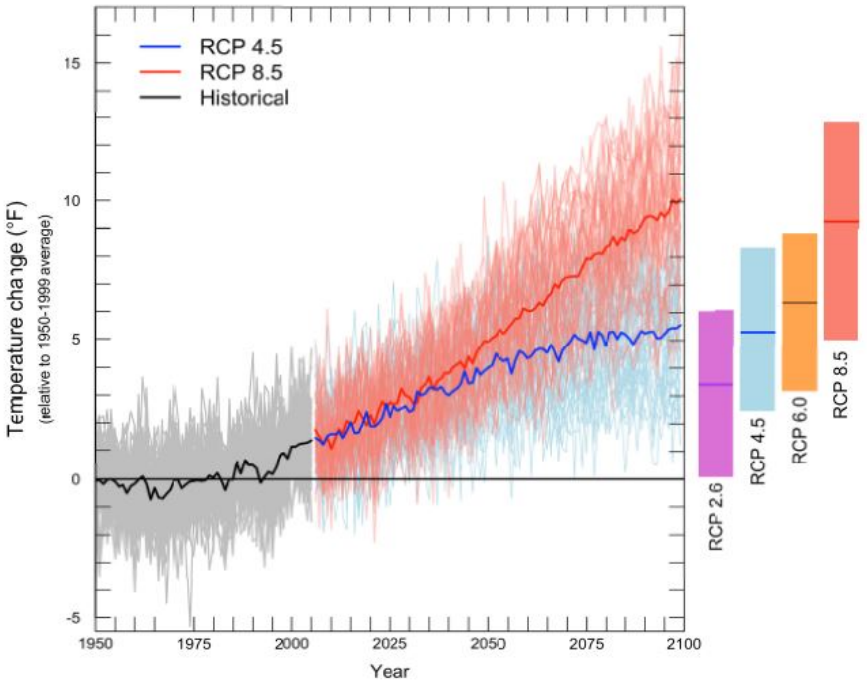


Figure 3-2 Pacific Northwest Projected Average Yearly Temperatures Relative to 1950–1999 Average (Snover et al., 2013). In this figure, the zero is the 1950 through 1999 average annual temperature. The colored lines represent the different future climate scenarios. And the thicker line represents the average from multiple runs of a scenario. The bars to the right of the figure show the mean, maximum, and minimum for each of the climate scenarios as an average of the final two decades of the century (Snover et al., 2013).

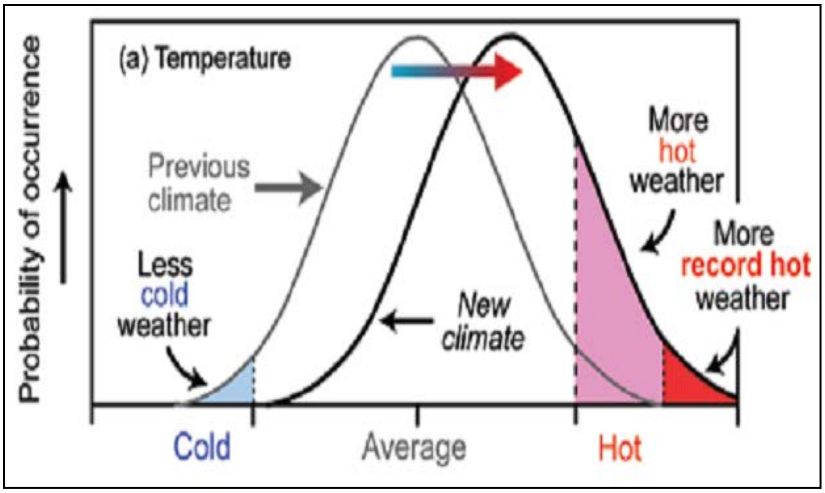


Figure 3-3 Change in Temperature Probability with Change in Climate

PRECIPITATION CHANGES

Between now and 2050, total precipitation per year is not expected to change very much, -4 to +14 percent. Most simulations indicate dryer summers, -6 to -8 percent by 2050.[4] By 2050, winter, spring, and fall precipitation is expected to increase slightly, 2 to 7 percent on average. However, individual simulations show as much as a 30 percent decrease during summer and increases during winter, spring, and fall (Snover et al. 2013).

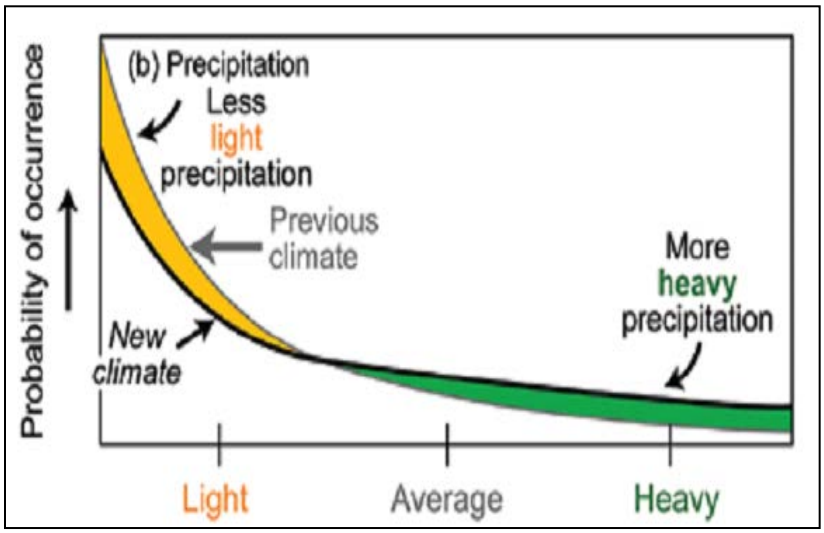


Figure 3-4 Severe Weather Probabilities in Warmer Climate

[4] Results are based on averages of low and high emissions scenarios.

WATERSHED CHANGES

With expected declines in spring snow pack, most Washington watersheds will be rain dominant by 2100 (Figure 3-5). As a result, the following changes are anticipated in the watersheds (Snover et al., 2013):

- Washington's average spring snowpack is expected to decline by -56 to -70 percent by the 2080s.[5] There is little information about the effects of climate change on Pacific Northwest glaciers. However, one study found that of the 12 glaciers monitored in the North Cascades, only 2 are expected to survive current climate conditions (Snover et al., 2013).

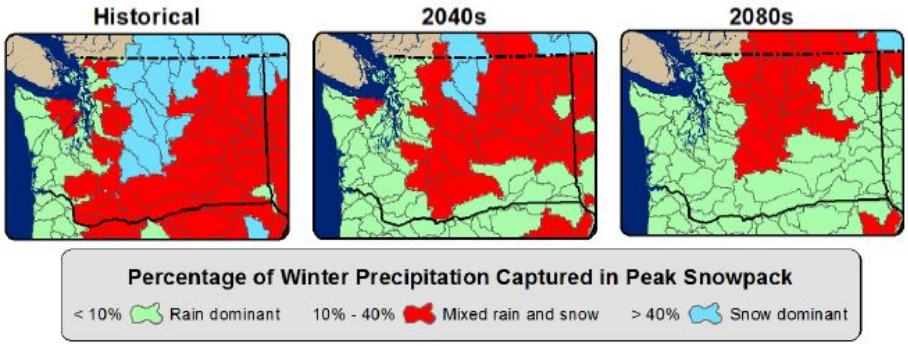


Figure 3-5 Washington State Changes of Hydrology with Warming (Snover et al., 2013)

- By the 2080s, peak stream flows are expected 4 to 9 weeks earlier in Puget Sound Watersheds. This reflects a change of rain-snow dominated watersheds to rain dominated watersheds. (Figure 3-6).

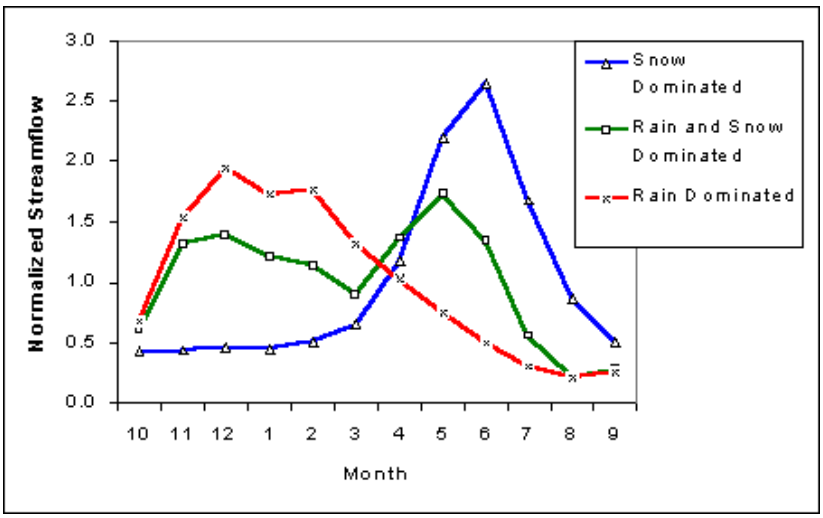


Figure 3-6 Hydrologic categories of Pacific Northwest Rivers (CIG, 2014). As the climate changes, the hydrologic system in Snohomish County will shift from rain and snow dominated to rain dominated, significantly affecting winter stream flow through flooding and summer stream flow through potential drought.

[5] Results are compared to the 1916 to 2006 average spring snowpack.

- The size of the 100-year flood is expected to increase 11 to 26 percent in rain dominant watersheds. It is less clear how climate change will effect flooding in mixed rain-snow watersheds. One-hundred-year flood volumes may decline or increase as much as -33 to 132 percent.[6] This does not take into account changes in heavy rainfall, which preliminary research indicates will be an increase in early fall heavy rain events.
- Summer low flows will decline in all watershed types, with an average decline in rain dominated watersheds of -14 percent, rain-snow mixed of -15 percent, and snow dominated of -6 percent.[7]
- The current 10-year flood will occur more often with a changing climate, and the current 100-year flood may also strike more often, leaving many communities at greater risk. If greenhouse gas emissions continue to grow unhindered, simulations show the following changes in Snohomish County rivers[8]:
  - In the 2040s, the average projected return interval for a 10-year flood is 4-5 years.
  - By the 2080s, the 10-year flood could be expected to occur every 2-3 years.

    By the 2040s, the 100-year flood has an average projected return interval of 28 years on the Sauk, 50 years on the South Fork of the Stillaguamish, 83 years on the Skykomish, and 32 years on the Snohomish rivers.
  - In the 2080s, for all four rivers studied, the average projected return interval for a 100-year flood is 10-16 years.

  Until there is clear evidence of substantial reduction in global greenhouse gas emissions, this mitigation plan recommends that these return intervals be used for planning purposes.

PRECIPITATION EXTREMES

There will be slightly more heavy rainfall events by the 2050s in the high greenhouse gas scenario. The number of days with over 1 inch of rain would increase from 6 to 20 percent[9] (Snover et al., 2013).

FOREST FIRES

Due to increased summer temperature and decreased summer precipitation, forest fires will burn much larger areas. The median area burned in the Northwest per year could more than double to 1.1 million acres by the 2040s and increase to 2 million acres by the 2080s, under a medium greenhouse gas scenario.[10] The changes in climate may result in more burned area west of the Cascades. Under one high greenhouse gas scenario, the forest area burned west of the Cascades could increase 150 to 1000% by 2100 (Snover et al., 2013).[11]

[6] Results are compared with historical flood flows from 1916 through 2006.
[7] Results are compared with historic flows from 1916 through 2006.
[8] Using several climate scenarios, the University of Washington's Climate Impacts Group (CIG) determined projected flood return intervals, due to climate impacts, at select sites on the Sauk, South Fork Stillaguamish, Skykomish, and Snohomish Rivers.
[9] Results are compared to the historical 1871 to 2000 average.
[10] Results are compared to the historical mean annual area burned of 0.5 million acres from 1916 to 2006.
[11] Results are compared to historical areas burned from 1971 to 2000.

OCEAN CHANGES

Warmer temperatures result in the melting of glaciers and ice sheets. This melting means that less water is stored on land and thus there is a greater volume of water in the oceans. Water also expands as it warms, and the heat content of the world's oceans has been increasing over the last several decades. In addition, the oceans' absorption of carbon dioxide results in more acidic seawater.

Ocean warming. Coastal ocean surface temperatures are projected to rise by about 2°F by the 2040s (Snover et al., 2013). [12]

Sea-level rise. Sea-level rise will vary in different locations along the Washington coast, because some areas in Washington State, like the Olympic Peninsula, are experiencing tectonic uplift. Sea level along the Washington coast could increase 4 to 56 inches by the end of the century. Based on a medium climate scenario, sea level in Puget Sound would increase 6 to 50 inches by 2100 (Snover et al., 2013). The impacts of sea-level rise could include the following: increased coastal community flooding, coastal erosion and landslides, seawater well intrusion, and lost wetlands and estuaries.

Ocean acidity. As the ocean absorbs increasing amounts of carbon from the atmosphere it becomes more acidic. As carbon dioxide concentration increases in the atmosphere this will continue (Snover et al., 2013).

RESPONSES TO CLIMATE CHANGE

MITIGATION AND ADAPTATION

Communities and governments worldwide are working to address, evaluate, and prepare for climate changes that are likely to impact communities in coming decades. Generally, climate change discussions encompass two separate but interrelated considerations:

- **Mitigation**—Mitigation refers to attempts to reduce or eliminate sources of greenhouse gas emissions or to increase carbon sinks (this term is used in a different way in climate change discussions as compared to the emergency management term "hazard mitigation").
- **Adaptation**—Adaptation refers to adjustments in natural or human systems in response to the actual or anticipated effects of climate change and associated impacts.

Mitigation and adaptation are related, as the world's ability to reduce greenhouse gas emissions will affect the degree of adaptation that will be necessary. Some initiatives and actions can both reduce greenhouse gas emissions and support adaptation to future conditions.

[12] Results are compared to the average historical temperature from 1970 through 1999.

RESPONSE TO CLIMATE CHANGE IN SNOHOMISH COUNTY

Snohomish County has been a leader in working to address climate change. The county has engaged in the following planning strategies and efforts to address greenhouse gas emissions and the expected impacts that climate change will have on people, property, the economy, and ecosystems:

- Executive Order 07-48: Order Regarding Climate Change and Sustainability
- The Snohomish County Green Ribbon Taskforce
- 2013 Snohomish County Sustainable Operations Action Plan
- The Snohomish County General Policy Plan

Snohomish County government is not alone in the effort to address the sources and impacts of climate change. The State of Washington has adopted greenhouse gas reduction requirements that aim to reduce emissions to 1990 levels by 2020, to 25 percent below 1990 levels by 2035, and to 50 percent below 1990 levels by 2050 (RCW 47.01.440). In Vision 2040, the Puget Sound Regional Council, of which Snohomish County is a member, adopted regional guidance for reducing greenhouse gas emissions. Planning for the impacts caused by climate change, Vision 2040 commits the region to comply with state directives regarding the reduction of greenhouse gases and calls on jurisdictions to include climate impact analysis during State Environmental Policy Act reviews (PSRC, 2008). Additionally, as of 2013, the cities of Edmonds, Everett, and Lynwood are signatories to the U.S. Mayors' Climate Protection Agreement.

POTENTIAL CLIMATE CHANGE IMPACT ON HAZARDS

Although no modeling is currently available to develop quantitative estimates of the effect of climate change on natural hazard risks, an understanding of the basic features of climate change allows for the following qualitative assessments of impacts on hazards of concern addressed in this hazard mitigation plan. This overview serves as a basis for evaluating how risk will change as a result of future climate change impacts. The vulnerabilities identified in this plan update will ultimately be used to inform other aspects of emergency management planning, such as the Comprehensive Emergency Management Plan.

TABLE 3-1. CLIMATE CHANGE EFFECTS ON HAZARDS		
Hazard	**Expected Change**	**Influencing Factors**
Avalanche	Uncertain	• Snowpack will change with more wet snow and less snow at lower elevations • Changes in forest structure and related snowpack anchoring
Dam/Levee Failure	Increased	More heavy winter rains will: • Increase number of dam design failures[13] • Increase exceedance of levee design capacity • Increase damage to levees
Earthquake	Uncertain Increased Secondary Impacts	• Reduction of glaciers from warming may effect continental plate uplift and earthquake activity • Increased soil saturation from winter storms and sea level rise may increase soil instability
Flood	Increased Frequency and Magnitude Change in Seasonal Timing	• More precipitation as rain • More precipitation in winter
Landslide	Increased	• Heavier rain fall in winter months • Erosion from increased storm flows • Reduced steep slope anchoring from increased risk of summer wild fire • Erosion from sea-level rise
Severe Weather	Mostly Increased Decreased Cold Weather	• Increased winds • Increased rain in winter • Increased heat in summer
Tsunami	Increased	• Greater volume of water displaced onto land due to sea level rise
Volcano/Lahar	Change Unlikely	• Reduction of glaciers from warming may impact continental plate uplift and volcanic activity
Wildland Fire	Increased	• Warmer drier summers • Increased forest damage from disease

[13] Dams are constructed with safety features known as "spillways." Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events, often referred to as "design failures," result in increased discharges downstream and increased flooding potential.

Chapter 4: Avalanche

GENERAL BACKGROUND

Avalanches occur when stress on a snowpack exceeds the strength of the snowpack. Most avalanches are naturally triggered, where the weather (wind, snow, rain, or sun) stresses the snowpack to its breaking point. However, most accident victims are caught by human-triggered avalanches.

Avalanches can occur whenever a sufficient depth of snow is deposited on slopes steeper than about 20 degrees, with the most dangerous coming from slopes in the 35- to 40-degree range. Avalanche-prone areas can be identified with some accuracy, since they typically follow the same paths year after year, leaving scarring on the paths. However, unusual weather conditions can produce new paths or cause avalanches to extend beyond their normal paths.

Snowpack stability depends on the strength of snow layers, how well the different layers bond together, and friction with the ground. When the force on the snow is greater than the strength of a layer or the bounds between layers or the ground, the snow will slide.

HAZARD PROFILE

Avalanches in Washington State have killed 67 people between 1985 and 2014. Avalanches regularly close SR-2 above Index, as well as many of the smaller access roads at higher elevations. Currently, most avalanche deaths are of recreationalists traveling and people working in avalanche terrain. In 92 percent of avalanche accidents, the victim or someone in the victim's party triggers the avalanche.

During fall, winter, and spring, the mountains in the eastern half of Snohomish County often receive significant snow accumulation and are prone to avalanches. Figure 4-1 shows general avalanche hazard areas in Washington State, including the easternmost portion of Snohomish County. More detailed avalanche terrain maps for the county do not exist at this time.

DEFINITIONS

Avalanche—Any mass of loosened snow or ice and/or earth that suddenly and rapidly breaks loose from a snowfield and slides down a mountain slope, often growing and accumulating additional material as it descends.

Slab avalanche—The most dangerous type of avalanche, occurring when a layer of coherent snow ruptures over a large area of a mountainside as a single mass. Like other avalanches, slab avalanches can be triggered by the wind, by vibration, or even by a loud noise, and will pull in surrounding rock, debris, and even trees.

Climax avalanche—An avalanche involving multiple layers of snow, usually with the ground as a bed surface.

Loose snow avalanche—An avalanche that occurs when loose, dry snow on a slope becomes unstable and slides. Loose snow avalanches start from a point and gather more snow as they descend, fanning out to fill the topography.

Powder snow avalanche—An avalanche that occurs when sliding snow has been pulverized into powder, either by rapid motion of low-density snow or by vigorous movement over rugged terrain.

Surface avalanche—An avalanche that occurs only in the uppermost snow layers.

Wet snow avalanche—An avalanche in wet snow, also referred to as a wet loose avalanche or a wet slab avalanche. Often the basal shear zone is a water-saturated layer that overlies an ice zone.

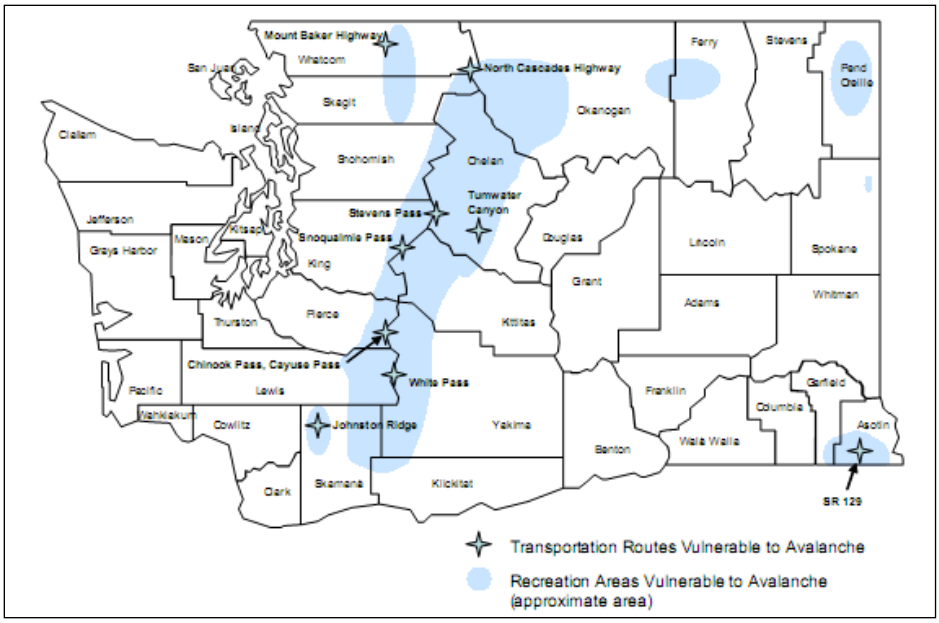


Figure 4-1 Areas Vulnerable to Avalanche

At lower elevations of the Cascades, the avalanche season begins in November and continues until the last remnants of snow have melted in early summer. In the high alpine regions, the hazard continues year-round.

A number of weather and terrain factors determine avalanche severity and danger:

Weather:

- Storms—a large percentage of all snow avalanches occur during and shortly after storms.
- Rate of snowfall—Snow falling at a rate of 1 inch or more per hour rapidly increases avalanche danger.
- Temperature—storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
- Wet snow—rainstorms or spring weather with warm, moist winds, and cloudy nights can warm the snow cover, resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.

Terrain:

- Ground cover—large rocks, trees, and heavy shrubs help anchor snow.
- Slope profile—dangerous slab avalanches are more likely to occur on convex slopes.
- Slope aspect—leeward slopes are dangerous because windblown snow adds depth and creates dense slabs. South-facing slopes are more dangerous in the springtime.
- Slope steepness—snow avalanches are most common on slopes of 30 to 45 degrees.

The effects of climate change on avalanche risk are uncertain. There will be reduced low-elevation snow accumulations, snow that falls may be wetter, and changes in vegetation may affect anchoring.

An avalanche can occur with little or no warning time. However, with proper training an assessment of the terrain, weather and snow pack can provide one with information on how likely a slope will avalanche.

A national program to rate avalanche risk has standardized terminology and provides a common basis for recognizing and describing hazardous conditions. This North American Avalanche Danger Scale relates degree of avalanche danger (low, moderate, considerable, high, extreme) to descriptors of avalanche probability and triggering mechanism, degree, and distribution of avalanche hazard, and recommended action in back country. Figure 4-2 shows key elements of the danger scale.

North American Public Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level		Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	4 5	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	4 5	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	3	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	2	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	1	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

Figure 4-2 North American Avalanche Danger Scale

This information, updated daily, is available during avalanche season from the joint NOAA/US Forest Service Northwest Avalanche Center (NWAC) and is available from the Internet, NOAA weather wire, and Department of Transportation sources.

EXPOSURE AND VULNERABILITY

Most mountainous areas in the county are part of the Mount Baker-Snoqualmie National Forest and other protected forests. The county does not have terrain specific avalanche information. However, because most of the avalanche hazard area is uninhabited or has minimal development, the exposure is low to people and property. There are no known critical facilities in the county exposed to avalanches. Avalanches also can change rivers or streams, potentially harming water quality, fisheries, and spawning habitat.

People working in the mountains, such as miners and loggers, are exposed and vulnerable, as are recreational users, such as hikers, back-country skiers, and people traveling on exposed mountain roads and railroads. As more people move to the region, there will be more human activity during the winter in the mountains, which will result in greater exposure and vulnerability.

In most winters, snow slides can close any of the pass highways between western and eastern Washington. Although costs associated with removing avalanches from SR-2 are borne by the state Department of Transportation, the county's road network and substantial commercial activity are also dependent upon the connectivity provided by this main highway. The BNSF Railway follows essentially the same east-west route as SR-2.

A more detailed avalanche risk assessment is located in Chapter 11 of Volume 1.

SCENARIO

In a worst-case scenario, heavy snows cause multiple and ongoing avalanches near Stevens Pass, resulting in multi day road closures and impacts to recreational users, property, and the BNSF railroad. Road and weather conditions can prevent evacuation of injured people. In addition, damage to a train carrying hazardous cargo can affect environmentally sensitive areas. Local economies that benefit from winter recreationists lose revenue and freight is not able to cross the Cascade Range.

ISSUES

The major questions for the county in managing avalanche related risks are:

- Where in the county are there property, roads, and recreational trails exposed to avalanches?
- How can the county best educate the growing number of people traveling and recreating in avalanche terrain?

The U.S. Forest Service, National Park Service, National Weather Service, and Washington Department of Transportation currently have programs to monitor avalanche zones and forecast avalanche danger. However, there is no effective way to keep the public out of avalanche-prone areas, even during times of highest risk. A coordinated effort is needed among state, county, and local law enforcement, fire, emergency management, public works agencies, and media to provide winter snow pack and avalanche risk information to the public.

With a goal of increasing public awareness of avalanche risk of people traveling in avalanche terrain, Cascade Backcountry Ski Patrol launched a pilot project of new avalanche awareness signs (see Figure 4-3).[14] These new "Are You Beeping?" beacon check stations includes simple public information, a solar powered BCA Beacon

Figure 4-3 Avalanche Awareness Sign

[14] Project was developed in cooperation with Ski Patrol Avalanche Rescue Team, King County Search and Rescue, NWAC, the US Forest Service, Washington State Department of Transportation, local ski resorts, and others in the snow science industry.

Checker™, trail beam and motion sensors, instrumentation for temperature/humidity, Zigbee wireless mesh capabilities, and a micro-controller for logging of all data to the cloud and the NWAC for tracking. The signs are being located at popular winter trailheads in areas with known avalanche risk. Future capabilities include Recco™ and cellular sensors for additional analysis are being added. More information on this program is available at: http://areyoubeeping.org/.

Chapter 5: Dam Failure

GENERAL BACKGROUND

Dams considered in this plan are those facilities that meet the following criteria:

- The facility meets the federal definition of "dams" established by the Association of State Dam Safety Officials (ASDSO) Model State Dam Safety Program (National Inventory of Dams, July 2005):
  "Any artificial barrier, including appurtenant works, which impounds or diverts water, and which (1) is twenty-five feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the barrier, or from the lowest elevation of the outside limit of the barrier, if it is not across a stream channel or watercourse, to the maximum water storage elevation; or (2) has an impounding capacity at the maximum water storage elevation of fifty acre-feet or more."
- The facility has an Emergency Action Plan (EAP) meeting FEMA specified requirements in response to the National Dam Safety Program, which was formally established by the Water Resources and Development Act of 1996.

Dams typically fail from the following (see Figure 5-1):

- Overtopping of the primary dam structure;
- Foundation defects due to differential settlement;
- Failure due to piping and seepage;
- Failure due to conduit and valve problems; and
- Other miscellaneous causes.

Many dam failures in the U.S. have been secondary results of other disasters, such as earthquakes, landslides, storms, snowmelt, or sabotage. The most likely disaster-related causes of dam failure in Snohomish County are earthquakes, excessive rainfall, and landslides. Poor construction, lack of maintenance and repair, and deficient operational procedures are preventable or correctable by a program of regular inspections. Terrorism and vandalism are serious concerns that all operators of public facilities must plan for; these threats are under continuous review by public safety agencies.

DEFINITIONS

Dam—any artificial barrier and/or any controlling works, together with appurtenant works that can or do impound or divert water. (WAC 173-175-030)

Dam Failure—an uncontrolled release of impounded water due to structural deficiencies in the water barrier.

Emergency Action Plan (EAP)—a formal document that identifies potential emergency conditions at a dam and specifies preplanned actions to be followed to minimize property damage and loss of life. The EAP specifies actions the dam owner should take to moderate or alleviate the problems at the dam. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show the emergency management authorities the critical areas for action in case of an emergency. (FEMA 64)

High Hazard Dam—dams assigned the high hazard potential classification are those where failure or operational issues will probably cause loss of human life. (FEMA 333)

Significant Hazard Dam—those dams where failure or operational issues result in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure. (FEMA 333)

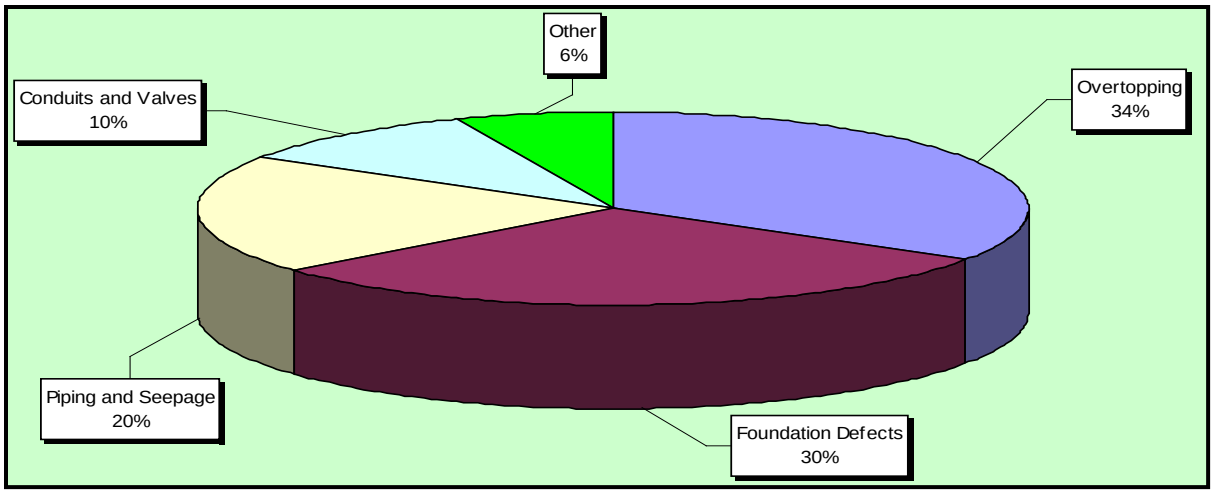


Figure 5-1 Historical Causes of Dam Failure

Two federal agencies play significant roles in ensuring the safe operation and maintenance of dams identified under the National Dam Safety Program: the U.S. Army Corps of Engineers and the Federal Energy Regulatory Commission (FERC).

HAZARD PROFILE

The Department of Ecology Dam Safety Office maintains records of dam accidents in Washington. Between 1918 and 2003, 15 notable dam failure events occurred in Washington. Two of these events occurred in Snohomish County (see Table 5-1).

TABLE 5-1.
NOTABLE DAM FAILURE INCIDENTS IN SNOHOMISH COUNTY

Project Name	Location	Date	Lives Lost	Nature of Failure
North Star Sand and Gravel Dam	Everett	12/1967	0	40-foot-high dam was washed out by overtopping due to lack of a spillway.
North Star Sand and Gravel Dam	Everett	12/1967	0	A new 25-foot-high dam was built, which also failed, washing out railroad tracks and derailing a passing train. No casualties or fatalities were reported.

According to the Washington Department of Ecology, there are 58 dams in Snohomish County. Of these, six meet the parameters identified by the Steering Committee for discussion in this plan. Table 5-2 lists these facilities. The Tolt River Dam is in King County, but is included in the list because it has a significant inundation area within Snohomish County.

TABLE 5-2. HIGH HAZARD DAMS IN SNOHOMISH COUNTY									
Name	**Hazard Class[a]**	**Water Course**	**Owner**	**Year Built**	**Dam Type**	**Crest Length (feet)**	**Height (feet)**	**Storage Capacity (acre-feet)**	**Drainage area (sq. mi.)**
Cedar Way Stormwater Detention Dam	1B	Lyons Creek	Christopher T. Webber	1985	Earth Fill	175	30	25	1.63
Chaplin Lake North Dam	1B	Woods Creek	City of Everett	1940	Earth Fill	800	35	2200	2.6
Chaplin Lake South Dam	1A	Chaplin Creek	City of Everett	1930	Earth fill	900	75	16,200	2.6
Culmback Dam	1A	Sultan River	Snohomish Co. PUD	1965	Rock Fill	480	270	200,000	74.50
Everett Reservoir #3	1B	Pigeon Creek	City of Everett	1923	Earth Fill	1500	22	61	0.00
Tolt River Dam	1A	South Fork Tolt River	Seattle Public Utilities	1962	Earth Fill	980	213	672,000	18.80
a. Downstream Hazard Class 1A: > 300 lives at risk, 1B: 31 to 300 lives at risk, 1C: 7 to 30 lives at risk									

At this time, EAPs that include dam failure inundation mapping are not available for every dam in the county. The risk assessment is limited to Snohomish County PUD's the Culmback Dam and Seattle City Light's South Fork Tolt River Dam, because these facilities have high quality inundation mapping. The Culmback Dam Failure Inundation Map (Map 5-1) shows the approximate extent and location of downstream flooding should the Culmback Dam fail. The approximate location and extent of a probable maximum flood breach scenario for the Tolt River Dam is shown in Map 5-2.

Dam failure events are infrequent, coinciding with events that may cause them, such as earthquakes, landslides, and excessive rainfall and snowmelt. Two notable dam failure incidents have occurred in Snohomish County since 1918 as indicated in Table 5-1. Both of these events occurred well before federal and state dam safety programs were established. These types of events are not likely to occur in today's current regulatory and dam safety oversight environment.

Although infrequent, dam failure can be catastrophic to all life and property downstream. Past dam failure events in Snohomish County and Washington State have led to significant economic and environmental impacts.

Warning time for dam failure varies depending on the cause of the failure. In events of extreme precipitation or anticipated massive snowmelt, evacuations can be planned with sufficient time. Depending on the location of the population and critical facilities downstream, a structural failure due to earthquake may allow only very limited warning time. A dam's structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is

depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections formed during dam construction are forced apart by the escaping water. The time for breach formation ranges from a few minutes to a few hours (U.S. Army Corps of Engineers, 1997).

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure include landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat.

Climate change is unlikely to increase the occurrences of structural dam failure. However, spillway overflow events, often referred to as "design failures," may increase. This would result in increased discharges downstream and flooding potential. Climate change would also increase the occurrence of floodwaters exceeding levee capacity and the risk for structural levee failure.

EXPOSURE AND VULNERABILITY

The exposure and vulnerability analyses focuses on the two principal dams of concern for which inundation data are available: Culmback Dam and Tolt Dam. Due to lack of inundation information for levee failure, no exposure or vulnerability analyses were conducted for the levees in the county. Although the inundation areas would be different, the type of exposure and vulnerability would be similar to that of dam failure.

All populations within dam failure inundation zones would be exposed and vulnerable to the effects of a dam failure. A breach of the Tolt River Dam could affect over 7,300 people and a failure of the Culmback Dam could affect over 20,900 people. Dam capacity, the number of evacuation routes available to populations living in areas of potential inundation, and warning time all affect the ability to leave the area safely. The most vulnerable include the elderly and young, who may be unable to get themselves out of the inundation area, and those who may not have adequate warning.

An estimated 6,618 structures are within the combined inundation areas of the Culmback and Tolt River Dams, exposing $2.38 billion worth of building-and-contents exposure to dam failure. The City of Monroe has the greatest exposure with 2,539 buildings in the inundation zones and over $1.42 billion of exposed assets. Additional development in the inundations zones would increase the population and assets exposed to dam failure.

Inundation from dam failure would affect roads, bridges, communications facilities, heath care facilities, schools, government facilities, and other critical facilities. Damage to transportation facilities could isolate some communities. Failure of the less regulated dams of Snohomish County would affect fewer of the critical facilities of Snohomish County; however, quantifying for assessment is not possible without further development of inundation maps. Dam failure could also pollute local waterways, and damage fish and wildlife habitat. Any facilities that house or process hazardous materials within the identified dam inundation areas may also threaten the environment.

A more detailed dam failure risk assessment is located in Chapter 12 of Volume 1.

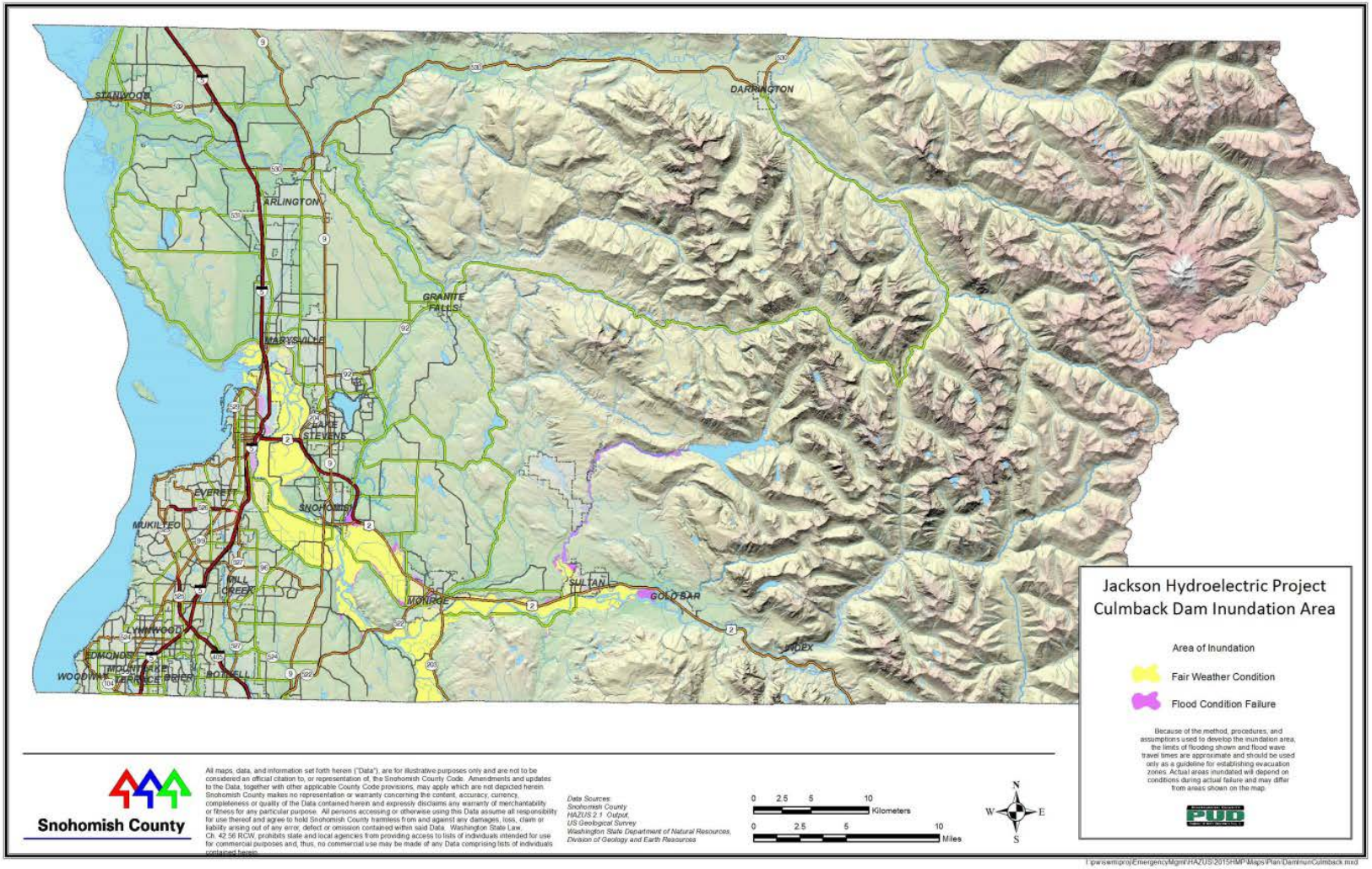
SCENARIO

In a worst-case scenario, a shallow earthquake with a magnitude of 7.5 could be strong enough to cause a failure of some Snohomish County dams. An earthquake of this magnitude could lead to liquefaction of soils around the dams. This could occur without warning in the middle of the night when residents in riverfront homes and campers are asleep and unprepared to evacuate. It should be noted that some of the more highly regulated dams within the county, such as the Culmback and Tolt, have been designed and certified to withstand a "maximum creditable earthquake" (MCE). The MCE for Culmback Dam has been determined to be a 7.5 magnitude event. Therefore, the probability of this worst case scenario impacting these higher regulated facilities would be less than those regulated to lesser standards.

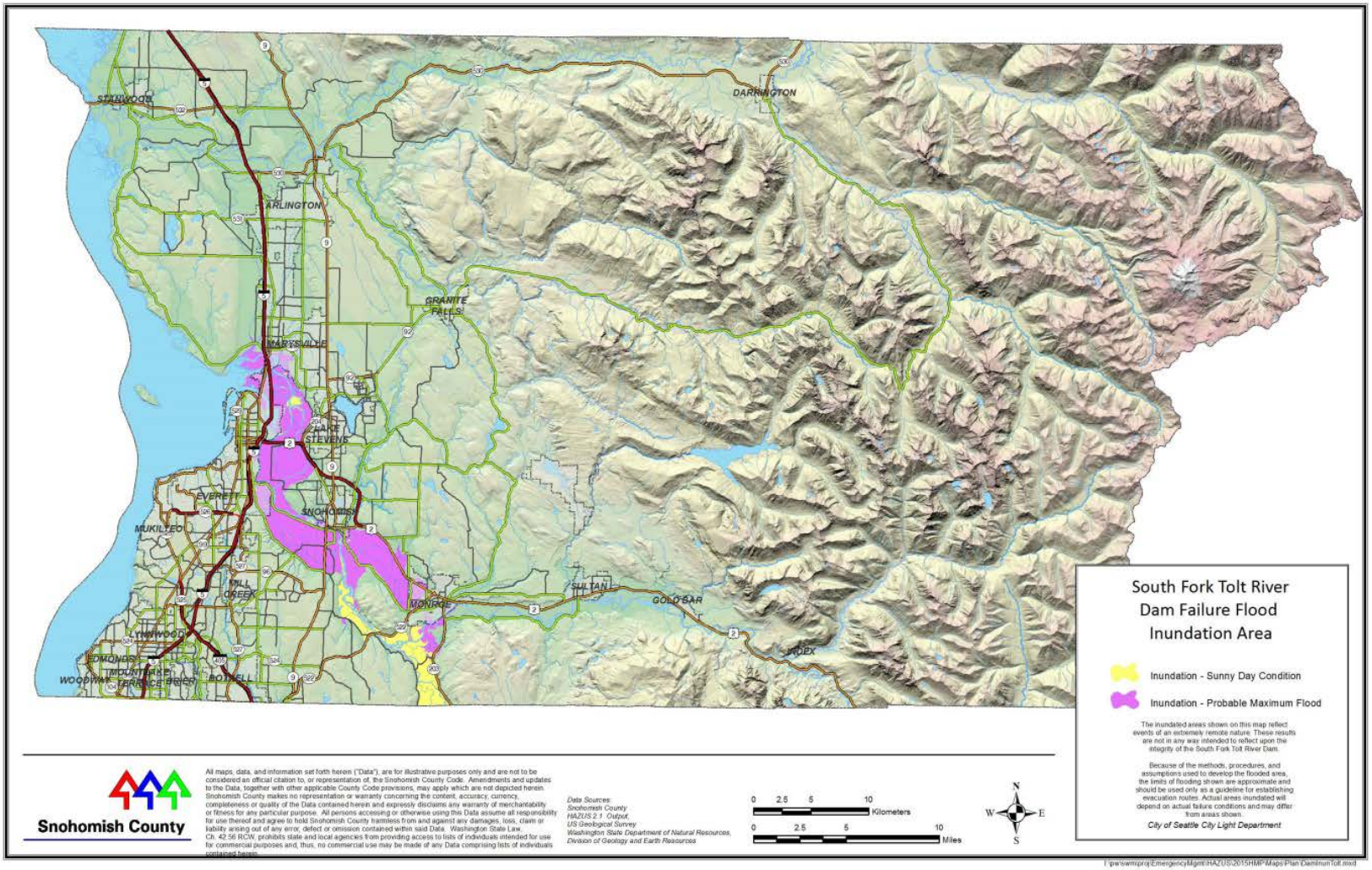
ISSUES

The most significant issue associated with dam failure involves the properties and populations in the inundation zones. Flooding as a result of a dam failure would significantly impact these areas. There is often limited warning time for dam failure. These events are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, which limit their predictability and compound the hazard. Important issues associated with dam failure hazards include the following:

- Federally regulated dams have an adequate level of oversight and sophistication in the development of Emergency Action Plans for public notification in the unlikely event of failure. However, State-regulated dams whose failure would pose a true threat to the people, property, and economy of Snohomish County need to be clearly identified.
- Mapping for federally regulated dams is already required and available; however, mapping for State-regulated dams that estimates inundation depths is needed to better assess the risk associated with dam failure from these facilities.
- Most dam failure mapping required at state and federal levels requires determination of the probable maximum flood. While the probable maximum flood represents a worst-case scenario, it is generally the event with the lowest probability of occurrence. Mapping of dam failure scenarios for State-regulated dams that are less extreme than the probable maximum flood, but have a higher probability of occurrence, can be valuable to emergency managers and community officials downstream of these high hazard facilities. This type of mapping can illustrate areas potentially impacted by more frequent events to support emergency response and preparedness actions.
- The concept of residual risk associated with structural flood control projects should be considered in the design of capital projects and the application of land use regulations.
- Addressing security concerns and the need to inform the public of the risk associated with dam failure is a challenge for public officials.



Map 5-1 Culmback Dam Inundation Area



Map 5-2 Tolt River Dam Inundation Area

Chapter 6: Earthquake

GENERAL BACKGROUND

The Puget Sound region is seismically active, with hundreds of earthquakes occurring each year. Most are so small that only sensitive instruments can detect them. However, at least 20 damaging earthquakes have occurred in Western Washington during the past 125 years. Large quakes in 1946, 1949, 1965, and 2001 killed 16 people and caused more than $2 billion in damage. The Pacific Northwest has been studied extensively in recent years, yielding valuable new insights. It is now generally agreed that three source zones exist for Puget Sound quakes: a shallow (crustal) zone; the Cascadia Subduction Zone; and a deep, intra-plate "Benioff" zone. These are shown in Figure 6-1. More than 90 percent of Pacific Northwest earthquakes occur along the boundary between the Juan de Fuca plate and the North American plate.

DEFINITIONS

Earthquake—The shaking of the ground caused by an abrupt shift of rock along a fracture in the earth or a contact zone between tectonic plates. Earthquakes are typically measured in both magnitude and intensity.

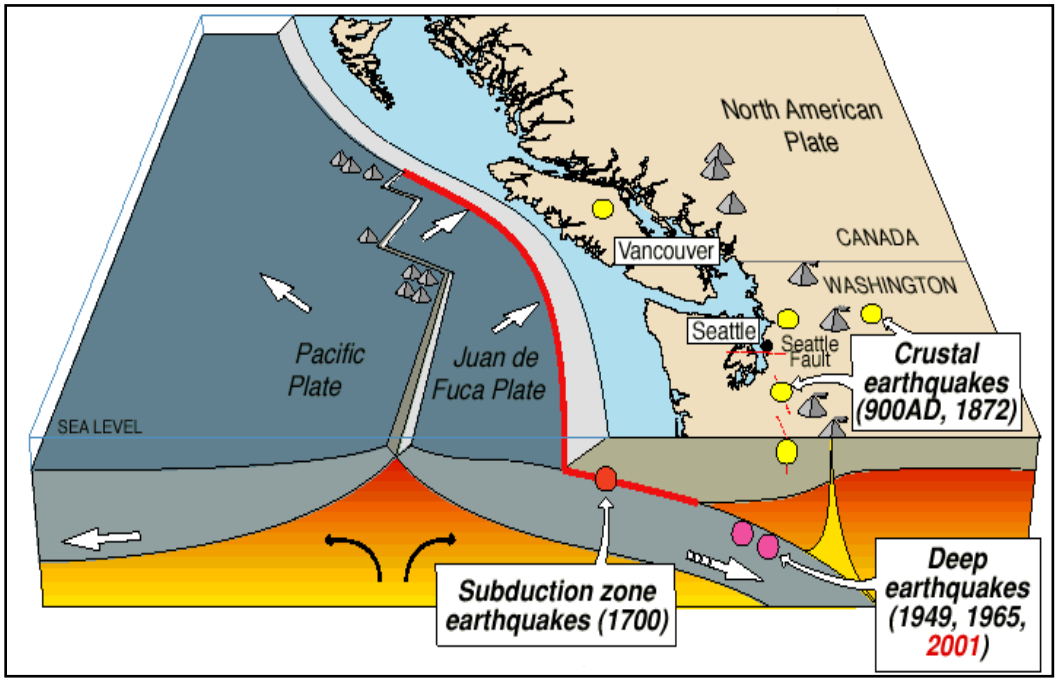


Figure 6-1 Earthquake Types in Western Washington

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

Earthquakes are classified according to the amount of energy released as measured by magnitude or intensity scales. Currently the most commonly used are the **moment magnitude**, or **Mw**, and the modified Mercalli intensity. Table 6-1 compares the moment magnitude scale to the modified Mercalli intensity scale.

Another element of earthquake hazard assessment is the calculation of expected ground motion. The most commonly mapped ground motion parameters are the horizontal and vertical peak ground accelerations (PGA) for a given soil or rock type. Maps of PGA values form the basis of seismic zone maps that are included in building codes, including the International Building Code and its predecessor the Uniform Building Code. Table 6-2 summarizes damage potential by PGA factors compared to the Mercalli scale.

The impact of an earthquake on structures and infrastructure is largely a function of ground shaking, liquefaction, and distance from the source of the quake. Liquefaction generally occurs in soft, unconsolidated sedimentary soils.

HAZARD PROFILE

Hundreds of earthquakes occur in the Puget Sound region each year. While the majority of these events register a magnitude of 3 or lower on the Richter scale, earthquakes measuring up to 7.1 have been recorded. Recent studies suggest that earthquakes of a Magnitude 8 or greater have occurred in the region and that similar seismic events are possible in the future. Several major faults are located in the vicinity. Small shallow earthquakes (up to Magnitude 4) associated with these faults are likely. Shallow earthquakes of greater magnitude are expected to occur infrequently in this area.

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

TABLE 6-1. EARTHQUAKE MAGNITUDE AND INTENSITY		
Magnitude (Mw)	**Intensity (Modified Mercalli)**	**Description**
1.0—3.0	I	I. Not felt except by a very few under especially favorable conditions
3.0—3.9	II–III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it is an earthquake. Standing cars may rock slightly. Vibrations similar to the passing of a truck.
4.0—4.9	IV–V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like a heavy truck striking building. Standing cars rocked noticeably.
5.0—5.9	VI–VII	VI. Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken.
6.0—6.9	VIII—IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary buildings, with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	X and higher	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

TABLE 6-2. MERCALLI SCALE AND PEAK GROUND ACCELERATION COMPARISON		
Mercalli Scale	**Potential Damage**	**Estimated PGA**
I	None	0.017
II-III	None	0.017
IV	None	0.014-0.039
V	Very Light	0.039-0.092
VI	None to Slight; USGS-Light	0.02-0.05
	Unreinforced Masonry-Stair Step Cracks; Damage to Chimneys; Threshold of Damage	0.04-0.08
		0.06-0.07
		0.06-0.13
		0.092-0.18
VII	Slight-Moderate; USGS-Moderate	0.05-0.10
	Unreinforced Masonry-Significant; Cracking of parapets	0.08-0.16
		0.10-0.15
	Masonry may fail; Threshold of Structural Damage	0.1
		0.18-0.34
VIII	Moderate-Extensive; USGS: Moderate-Heavy	0.10-0.20
	Unreinforced Masonry-Extensive Cracking; fall of parapets and gable ends	0.16-0.32
		0.25-0.30
		0.13-0.25
		0.2
		0.35-0.65
IX	Extensive-Complete; USGS-Heavy	0.20-0.50
	Structural collapse of some un-reinforced masonry buildings; walls out of plane. Damage to seismically designed structures	0.32-0.55
		0.50-0.55
		0.26-0.44
		0.3
		0.65-1.24
X	Complete ground failures; USGS- Very Heavy (X+); Structural collapse of most un-reinforced masonry buildings; notable damage to seismically designed structures; ground failure	0.50-1.00

PAST EVENTS

Historically, Snohomish County earthquake activity has been slightly above the Washington State average. It is 268 percent greater than the overall U.S. average.

The following are the four most significant earthquakes on record for Snohomish County:

- **1872, 75 Miles Northeast of Everett**—This shallow earthquake had a magnitude of 7.4 on the Richter scale. It occurred approximately 75 miles northeast of Everett near Mount Baker and just east of the Cascade crest (largest recorded earthquake in Washington). No record of any fatalities in Snohomish County.

- **1949, Nisqually Delta Area North of Olympia**—This earthquake had a magnitude of 7.1 on the Richter scale. The Snohomish County zone that experienced the most intense effects is along the South Stillaguamish River valley from Granite Falls to Arlington, and along the Snohomish and Skykomish River valleys from Everett to Snohomish and Monroe. Within this area, the effects included fallen chimneys and building cornices; cracked plaster; broken water and gas mains; damaged docks, bridges, and water storage tanks; cracked ground and pavement; and landslides, mudflows and debris slides.

- **1996, Duvall**—This earthquake had a magnitude of 5.6 on the Richter scale. Near the epicenter, merchandise fell off shelves and at least one resident reported a cracked chimney. In Snohomish County, 16,000 residents were reportedly without power for several hours as a result of breakers tripping in four substations. There was, however, no report of physical damage to electrical power facilities.

- **2001, Nisqually Delta Area North of Olympia**—This earthquake had a magnitude 6.8 on the Richter scale. Snohomish County had combined public and private sector damage between $2 million and $3 million. There were 13 minor injuries. A few older unreinforced masonry structures suffered significant damage, but there were no building collapses in the county. The greatest shaking and highest percentage of damaged structures were in the main river valleys and communities along the rivers: Darrington, Sultan, Monroe, and Snohomish.

CASCADIA SUBDUCTION ZONE

In western Washington, the primary plates of interest are the Juan De Fuca and North American plates. The Juan De Fuca plate moves northeast with respect to the North American plate at a rate of about an inch and a half per year. The boundary where these plates converge, the Cascadia Subduction Zone, lies approximately 50 miles offshore of the west coastline and extends from the middle of Vancouver Island in British Columbia to northern California. As it collides with the North American plate, the Juan De Fuca plate slides beneath the continent and sinks into the earth's mantle. The sliding of one plate below another is called "subduction." Subduction zone earthquakes occur as a direct result of the convergence of these two plates. Earthquakes at subduction zone boundaries produce the world's greatest earthquakes. A subduction earthquake off the coast of Washington or Oregon where the plates converge would typically have a minute or more of strong ground shaking at Magnitude 8 to 9.5 on the Richter scale. Usually, damaging tsunamis and numerous large aftershocks immediately follow these types of earthquakes.

There are no reports of such earthquakes in the Cascadia Subduction Zone off the Oregon or Washington coast since the first written records of permanent occupation by Europeans in 1833. However, scientific evidence suggests that there may have been as many as five of these energy releases in the past 2,000 years, with an irregular recurrence interval of 150 to 1,100 years. Written tsunami records from Japan, correlated with studies of partially submerged forests in coastal Washington and Oregon, give a probable date for the most recent of these huge quakes as January 26, 1700.

BENIOFF DEEP ZONE

Western Washington can experience deep earthquakes of Magnitude 6 to 7.4 on the Richter scale. This occurs within the Juan de Fuca plate at depths of about 30 to 40 miles. As the Juan de Fuca plate moves beneath North America, it becomes denser than the surrounding mantle rocks and breaks apart, causing Benioff zone earthquakes. The largest Benioff zone earthquakes occur where the Juan de Fuca plate begins to bend even more steeply downward, forming a knee.

The largest of these events recorded in modern times were the 7.1-magnitude Olympia earthquake in 1949 and the 6.8 magnitude Nisqually earthquake in 2001. Strong shaking during the Olympia earthquake lasted about 20 seconds. During the Nisqually quake, shaking lasted from about 30 seconds to more than 2 minutes. Since 1870, there have been seven deep earthquakes in the Puget Sound basin with measured or estimated magnitudes of 6.0 or larger. The epicenters of all of these events have been within about 50 miles of each other between Olympia and just north of Tacoma. Scientists estimate the recurrence interval for this type of quake to be 30 to 40 years for magnitude 6.5, and 50 to 70 years for magnitude 7.0. Because of their depth, intra-plate earthquakes are least likely to produce significant aftershocks.

CRUSTAL ZONE

The third source zone is the crust of the North American plate. These are known as shallow earthquakes. Shallow earthquakes with a magnitude of 7 or more on the Richter scale can happen anywhere in the Puget Sound region. Such earthquakes have the potential to cause greater loss of life and property than any other kind of disaster. Fortunately, great crustal quakes do not seem to happen very often, perhaps no more than once every 1,000 years.

The structure of the crust in the Puget Sound area is complex, with large sedimentary rock-filled basins beneath Tacoma, Seattle, and Everett. The Seattle basin is the deepest, at about 5 to 6 miles. In addition to the 1872 Mount Baker earthquake, seismologists have found evidence that a devastating crustal quake occurred on a fault near Seattle approximately 1,100 years ago. The Duvall Fault near Lake Margaret on the King-Snohomish County border has produced two Magnitude 5.3 earthquakes in the past 70 years (1932 and 1996). How many other crustal faults pose significant earthquake hazards to the Puget Sound region is not yet known, but geologists and geophysicists are studying the South Whidbey Island Fault and the Olympia Fault for evidence of young earthquakes. In addition, a potential Everett Fault has been identified and is currently being researched.

Crustal earthquakes are the least predictable of Puget Sound's seismic threats and are the most likely to be followed by significant aftershocks. Following a great crustal earthquake of Magnitude 7.0 or more, one of the greatest dangers to human life is that buildings or other structures damaged in the initial shock but still in use and believed safe could collapse in a strong aftershock.

MAPS OF EARTHQUAKE IMPACT IN SNOHOMISH COUNTY

The impact of an earthquake is largely a function of the following components:

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

Mapping that shows the impacts of these components was used to assess the risk to earthquakes within the planning area. While the impacts from each of these components can build upon each other during an earthquake event, the mapping looks at each component individually, so each map is mutually exclusive of the other. For example, liquefaction classifications have no direct correlation to soil classifications. The mapping used in this assessment is described below.

A shake map is a representation of ground shaking produced by an earthquake. An earthquake produces a range of ground shaking at sites throughout the region depending on the distance from the earthquake; the rock and soil conditions at sites; and variations, due to complexities in the structure of the earth's crust, in the propagation of seismic waves from the earthquake. Color-coded maps are derived from empirical relations between peak ground motions and Modified Mercalli intensity.

Earthquake scenarios describe the expected ground motions and effects of specific hypothetical large earthquakes for a region. For the Snohomish County planning area, shake maps are available for two scenarios:

- Devil's Mountain Fault Scenario—This scenario is for a Magnitude 7.1 event with a shallow depth and epicenter 14 miles northeast of Arlington. This scenario is illustrated in Map 6-1.
- South Whidbey Island Fault Scenario—The South Whidbey Island Fault scenario is for a Magnitude 7.4 event with a depth of 0 miles and an epicenter 2 miles northeast of Langley. This scenario is illustrated in Map 6-2.

A program called the National Earthquake Hazard Reduction Program (NEHRP) creates maps based on soil characteristics so that locations potentially subject to liquefaction may be identified. Soils susceptible to liquefaction can lose their shear strength and flow or behave as liquid, thereby damaging structures that derive their support from the soil. Soil liquefaction maps are useful tools to assess potential damage from earthquakes. Map 6-3 shows the liquefaction susceptibility in Snohomish County.

FREQUENCY AND SEVERITY

The USGS estimated that a Cascadia Subduction Zone earthquake has a 10 to 15 percent probability of occurrence in 50 years, and a crustal zone earthquake has a recurrence interval of about 500 to 600 years. In general, it is difficult to estimate the probability of occurrence of crustal earthquake events. Earthquakes on the South Whidbey Island and Seattle Faults have a 2 percent probability of occurrence in 50 years. A Benioff zone earthquake has an 85 percent probability of occurrence in 50 years, making it the most likely of the three types. There is not yet enough information on the Devil's Mountain Fault-North Whidbey Fault complex to determine the probability of occurrence of an event on this complex.

The severity of an earthquake can be expressed in terms of intensity or magnitude. Shake maps for the Devil's Mountain Fault (Map 6-1) and South Whidbey Island Fault (Map 6-2) illustrate intensity of ground shaking. The potential magnitude, in the most extreme scenarios, of earthquakes in Snohomish County by type is as follows:

- Cascadia Subduction Zone—9.0 for approximately 4 minutes with aftershocks
- Benioff—7.2 with no aftershocks
- Crustal (North Whidbey-Devil's Peak Complex, South Whidbey Island, possible Everett Fault)—7.4 with some aftershocks

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

SECONDARY HAZARDS

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

Tsunamis are another significant secondary hazard of earthquakes. A tsunami consists of a series of high-energy waves that radiate outward like pond ripples from an area where a generating event occurs. The waves arrive at shorelines over an extended period.

No written records exist of damaging waves in Puget Sound. However, verbal accounts among the Snohomish Tribe and geological evidence on Whidbey Island and at West Point in Seattle provide evidence of tsunamis in Puget Sound. In addition, area lakes have experienced seiches in historical times.

The Washington Department of Natural Resources (DNR), working with the National Oceanic and Atmospheric Administration (NOAA) and the National Tsunami Hazard Mitigation Program, have modeled tsunami impacts in Puget Sound using computer models of earthquake-generated tsunamis from nearby seismic sources. NOAA is currently in the process of modeling impacts of waves felt from a magnitude 9.0 Cascadia Subduction Zone earthquake, and recently introduced in January of 2015 preliminary numerical modeling of Puget

DEFINITIONS

Seiche—A standing wave in an enclosed or partly enclosed body of water, normally caused by earthquake activity; can affect harbors, bays, lakes, rivers, and canals.

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

Sound ports that demonstrates significant impacts to maritime resources from strong currents and the associated drag forces.

However, Snohomish County would not likely see significant tsunami impacts from seismic events, due to the shadow effects of Whidbey Island. Additionally, it is not anticipated that official tsunami inundation maps for the Snohomish County coastline will be completed in the near future. Any future update will utilize the best data available to update this risk assessment.

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

- Hazard Identification: To truly measure and evaluate the probable impacts of tsunamis on planning, new hazard mapping based on probabilistic scenarios likely to occur for Snohomish County needs to be created. The science and technology in this field are emerging. For tsunami hazard mitigation programs to be effective, probabilistic tsunami mapping will need to be a key component.
- Using the newly completed numerical modeling from DNR and NOAA for a Cascadia Subduction event, determine where strong currents and wave height would impact the shoreline and then map this information.
- Present building codes and guidelines do not adequately address the impacts of tsunamis on structures, and current tsunami hazard mapping is not appropriate for code enforcement.
- As tsunami warning technologies evolve, the tsunami warning capability within the planning area will need to be enhanced to provide the highest degree of warning to planning partners with tsunami risk exposure.
- With the possibility of climate change, the issue of sea level rise may become an important consideration as probable tsunami inundation areas are identified through future studies.
- Special attention will need to be focused on the vulnerable communities in the tsunami zone and on hazard mitigation through public education and outreach.

CLIMATE CHANGE IMPACTS

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

The secondary impacts of earthquakes could be magnified by climate change. Soils saturated by repetitive storms could fail during seismic activity due to the increased saturation. Steep slope failure may increase where changes in river hydrology or sea level weaken slope stability. Dams storing increased volumes of water due to changes in the hydrograph could fail during seismic events. Fire risks associated with earthquakes could be significantly enhanced by drought conditions triggered by climate change. There are currently no models available to estimate these impacts.

EXPOSURE AND VULNERABILITY

POPULATION

Earthquakes could impact anyone in Snohomish County. Although the vulnerability is low, cities are more at risk than rural areas due to higher density. Towns are also more vulnerable because they are typically located in small valleys alongside streams, which typically have softer soils. In addition, people in buildings built prior to seismic safety measures are more vulnerable in an earthquake.

Three population groups are particularly vulnerable to earthquake hazards:

- **Linguistically Isolated Populations**—6,072 persons are listed as being linguistically isolated (they do not speak English as their native language) in the census block groups on NEHRP D, E, and F soils. This is about 2.4 percent of the people in these census block groups.

- **Population below Poverty Level**—15,225 people are listed as being below the poverty level within the census block groups on NEHRP D, E, and F soils. They make up about 2 percent of the total county population. These people are vulnerable because they may not have the financial ability to secure or improve their homes to prevent or mitigate earthquake damage. Poorer residents are also less likely to have insurance to compensate for losses in earthquakes.

- **Population over 65 Years Old**—29,040 people are over 65 years old in the census block groups on NEHRP D, E, and F soils. This makes up about 4 percent of the total county population. This population group is vulnerable because they are more likely to need special medical attention, which may not be available due to isolation caused by earthquakes. Elderly residents also have more difficulty leaving their homes during earthquake events and could be stranded in dangerous situations. About 6 percent of the over-65 population has income below the poverty line and is extremely vulnerable.

PROPERTY

According to the Snohomish County Assessor, there are approximately 284,482 buildings in Snohomish County, with a total replacement value of $56.5 billion. The majority of these buildings (93 percent) are residential. Since all structures in the planning area are susceptible to earthquake impacts to varying degrees, this represents the exposure to seismic events within the County.

Approximately 58 percent of the planning area's structures were constructed before the Uniform Building Code was amended in 1994 to include seismic safety provisions. And, approximately 5 percent of the structures were built before 1933, when there were no building permits, inspections, or seismic standards. Thus, these buildings are at greater risk of earthquake damage.

Loss estimates for the planning area were generated for the Devil's Mountain Fault and South Whidbey Island Fault. Losses include structural and non-structural categories. Structural losses represent damage to individual structures. Non-structural losses represent the cost of contents, inventory, relocation, income loss, rental loss, and wage loss. A summary of results is as follows:

- For a 7.1-magnitude event on the Devil's Mountain Fault, the estimated damage potential is $2.7 billion, or 5.6 percent of the total structural value for the planning area.
- For a 7.4-magnitude event on the South Whidbey Island Fault, the estimated damage potential is $12.8 billion, or 26.4 percent of the total structural value for the planning area.
- A Devil's Mountain event could displace up to 62 households, with over 36 persons needing short-term shelter. A South Whidbey Island Fault event could displace up to 8,750 households with over 5023 persons requiring short-term shelter.
- A Devil's Mountain fault event could generate as much as 110,000 tons of debris, and a South Whidbey Island Fault event could generate over 4.89 million tons of debris.

CRITICAL FACILITIES AND INFRASTRUCTURE

All critical facilities in Snohomish County are exposed to the earthquake hazard. Figure 6-2 illustrates the number of each type of facility exposed.

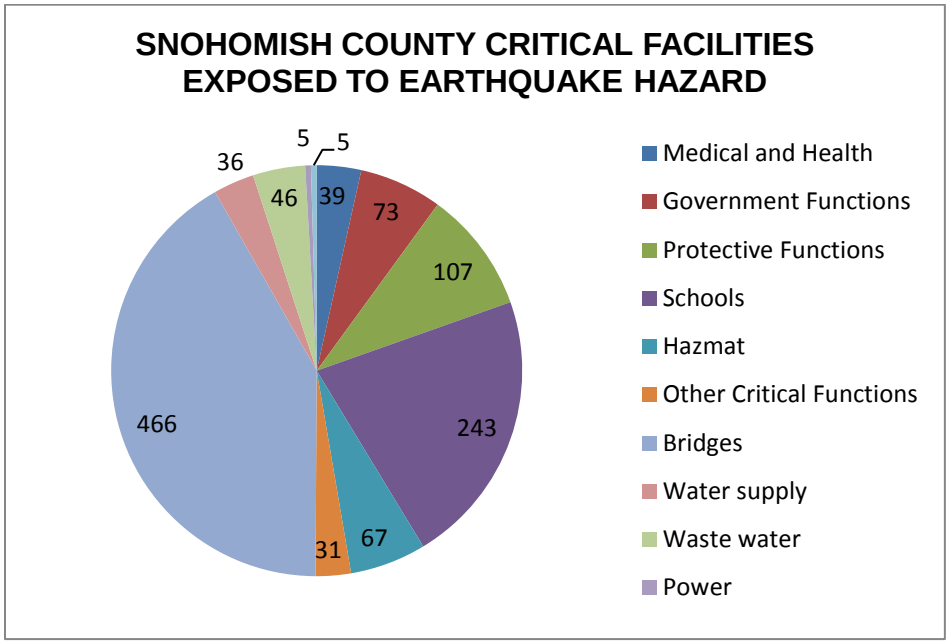


Figure 6-2 Critical Facilities Exposed to Earthquake in Snohomish County

The critical facilities identified for this plan include hazardous material sites. Hazardous material releases from fixed facilities and transportation-related releases can occur during an earthquake event. Transportation corridors such as I-5, SR-2, SR-9 and the BNSF railroad can be disrupted during an earthquake and release materials into the surrounding environment. Facilities holding hazardous materials are of particular concern because of possible isolation of neighborhoods surrounding them. There are 62 businesses that have Tier II hazardous materials on NEHRP D soils and 87 on NEHRP E and F soils, and 12 that are within 500 feet of a pipeline. During an earthquake, structures storing these materials could rupture and leak into the surrounding area, a river, or Puget Sound, having a disastrous effect on the environment.

A South Whidbey Island Fault event has the largest potential impact on the planning area. The County expects 289 critical facilities to be extensively or completely damaged from this earthquake event, including 84 bridges, 61 schools, and 11 medical and health facilities. This means the loss of emergency services, access, and basic goods and services for communities hardest hit by the earthquake.

ENVIRONMENT

Environmental problems as a result of an earthquake can be numerous. Earthquake-induced landslides in landslide-prone areas can significantly impact surrounding habitat. It is also possible for streams to be rerouted after an earthquake. This can change the water quality, possibly damaging habitat and feeding areas. There is a possibility of streams fed by groundwater drying up because of changes in underlying geology.

FUTURE TRENDS IN DEVELOPMENT

Snohomish County's 2012 buildable lands report was adopted in June of 2013. The methodology applied to this report excludes areas designated as "critical areas" from consideration as buildable lands, due to the scope of regulations affecting such areas.

Based on these findings, Snohomish County and its planning partners appear to be equipped to deal with future growth and development. The geologic hazard portions of the planning area are regulated pursuant to Growth Management Act mandates as well as provisions stipulated for seismic risk under the International Building Code. Development will occur in the planning area, but it will be regulated such that the degree of risk will be reduced through building standards and performance measures.

A more detailed earthquake risk assessment is located in Chapter 13 of Volume 1.

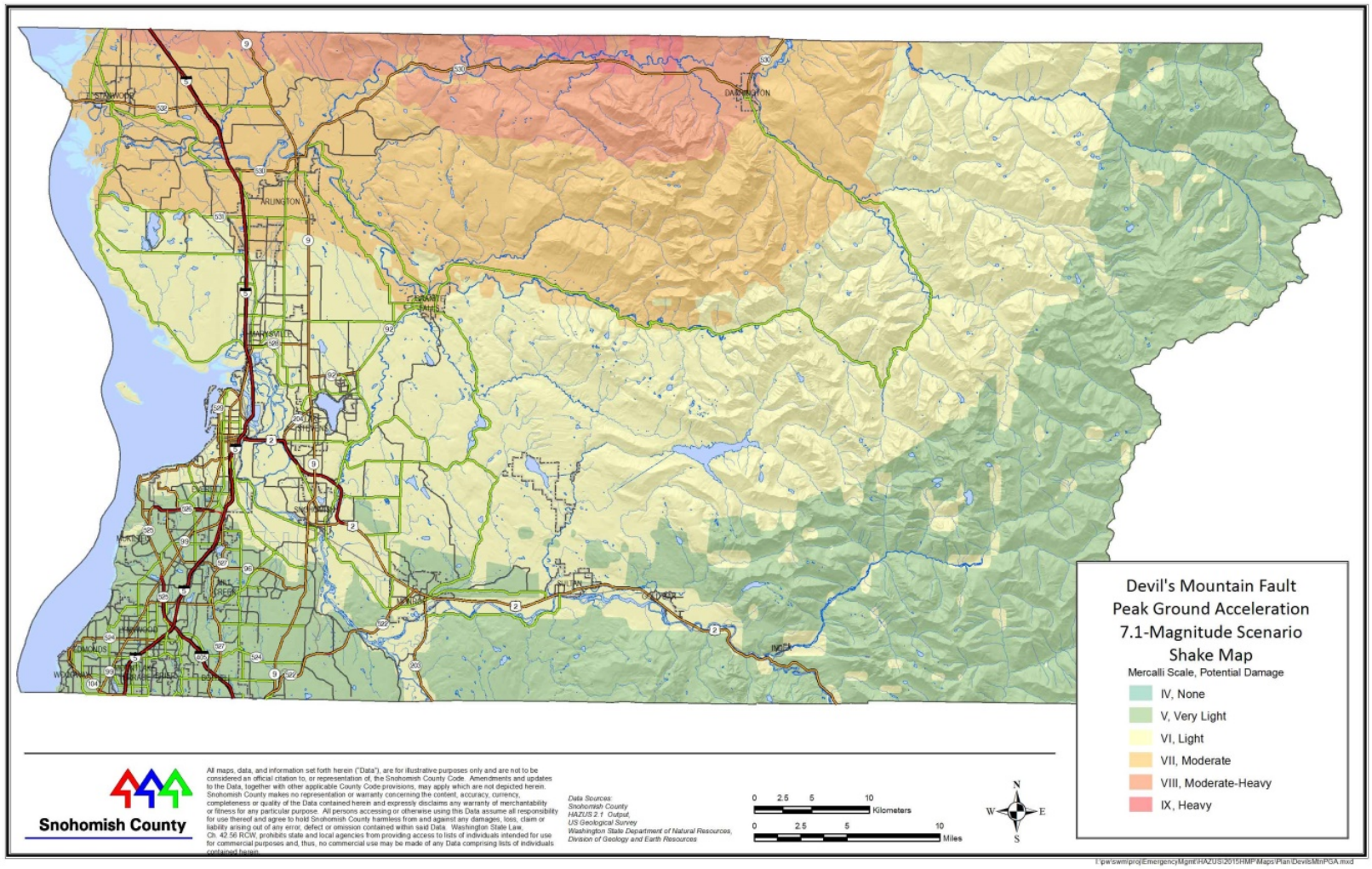
SCENARIO

A crustal zone earthquake affecting Snohomish County could have a magnitude of 8.0 or higher. Potential warning systems could give approximately a 40-second notice that a major earthquake is about to occur. This would not provide adequate time for preparation. An earthquake of this magnitude would lead to massive structural failure of property on NEHRP C, D, E, and F soils. Levees and revetments built on these poor soils would likely fail, representing a loss of critical infrastructure. This event would cause secondary hazards including landslides and mudslides that would further damage structures. River valley hydraulic-fill sediment areas are also vulnerable to slope failure, often as a result of loss of cohesion in clay-rich soils. Soil liquefaction would occur in water-saturated sands, silts, or gravelly soils.

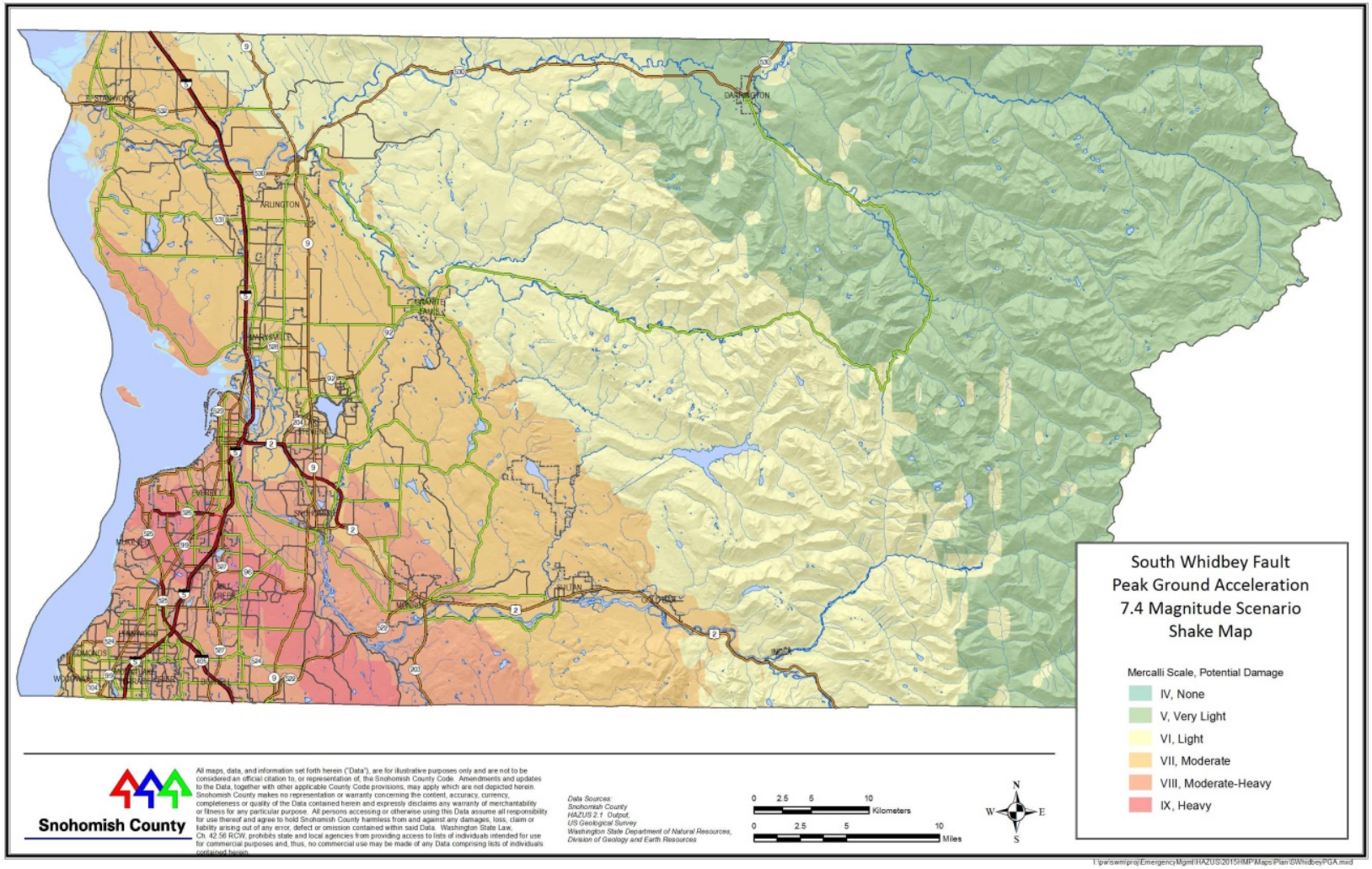
ISSUES

Important issues associated with an earthquake include but are not limited to the following:

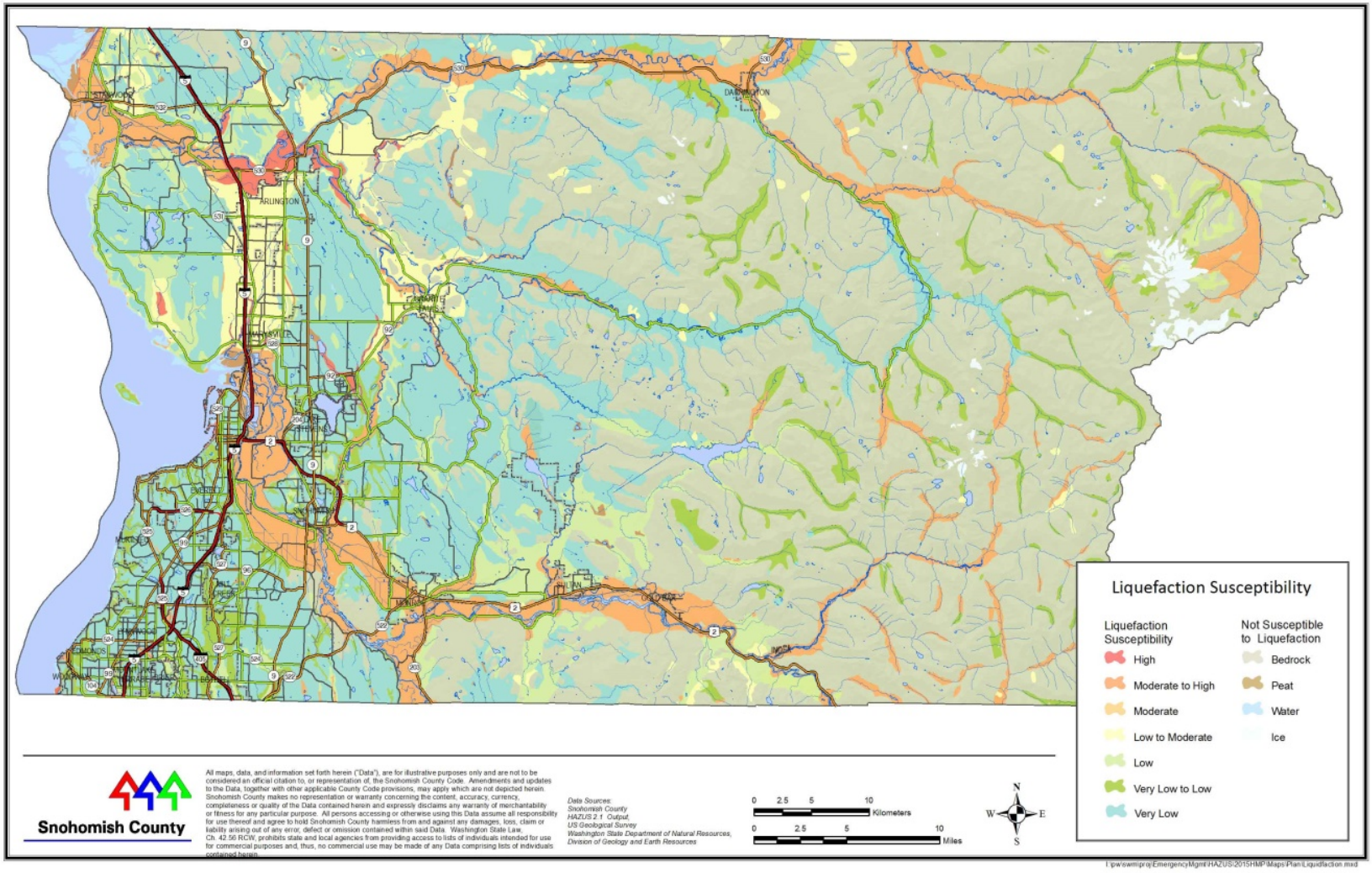
- Appropriate geotechnical standards should be established that take into account the probable impacts from earthquakes in the design and construction of new or enhanced facilities.
- The county has over 114 miles of earthen levees and revetments on soft, unstable soil. These soils are prone to liquefaction, which would severely undermine the integrity of these facilities.
- Earthquakes could trigger other natural hazard events such as dam failures, landslides, or volcanic activity, which could severely impact county facilities.
- A worst-case scenario would be the occurrence of a large seismic event during a flood or high-water event. Levee failures would happen at multiple locations, increasing the impacts of the individual events.



Map 6-1 Devil's Mountain Fault Scenario



Map 6-2 South Whidbey Fault Scenario



Map 6-3 Soil Liquefaction Susceptibility

Chapter 7: Flood

GENERAL BACKGROUND

A floodplain is low land adjacent to a river, creek, or lake. The extent to which a floodplain becomes inundated during a flood depends partly on the magnitude of the flood and partly on the surrounding landscape. Floodplains can support ecosystems that are rich in biological quantity and diversity.

Flooding is the most common natural hazard in Washington and affects lives in the State every winter and spring. River monitoring, forecasting, and warning methods allow for planning of responses to potential floods, but flood-inundation maps needed by local planning agencies to assess flooding and floodplain issues are significantly outdated in some areas. Flood frequency and magnitude are the basis for many planning decisions, but limited databases and changing conditions make determination of 100-year floods and other frequency discharges an uncertain science.

Historically, human activities tended to concentrate in floodplains for a number of reasons: water is readily available, land is fertile and suitable for farming, transportation by water is easily accessible, and land is flatter and easier to develop. But human activity in floodplains frequently interferes with the natural function of floodplains. It can affect the distribution and timing of drainage, thereby increasing flood problems. Human development can create local flooding problems by altering or confining drainage channels. This increases flood potential in two ways: it reduces the stream's capacity to contain flows, and it increases flow rates or velocities downstream during all stages of a flood event. It is possible for human activities to interface with the floodplain as long as those activities strive to mitigate their adverse impacts on floodplain functions.

DEFINITIONS

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

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

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

Return Period—The average period of time in years between occurrences of a particular hazard (equal to the inverse of the annual frequency of occurrence).

NATIONAL FLOOD INSURANCE PROGRAM

The National Flood Insurance Program (NFIP) makes federally backed flood insurance available to homeowners, renters, and business owners in communities participating in the program. For most communities participating in NFIP, FEMA has prepared a detailed Flood Insurance Study with base flood elevations and the boundaries of the 100- and 500-year floodplains on Flood Insurance Rate Maps (FIRMs).

Snohomish County entered the NFIP on March 15, 1984. Currently, 19 jurisdictions in Snohomish County participate in the NFIP (see Section 14.6). Participants in the NFIP must, at a minimum, regulate development in

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

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

Snohomish County and all participating cities in the planning area are currently in compliance and good standing with the provisions of the NFIP.

Experience and analysis from large floods since the 1990s have shown that the county's current mapping is inaccurate in many areas. The reasons for these inaccuracies include the following:

- Increasing peak flows (due to development and climate change);
- Rising sea levels (affecting tidal flooding);
- Changes in land use and management, including forest removal and active forest management;
- Changing river channels (channel migration or sediment deposition patterns);
- Inadequate topographic data; and
- Simplistic mapping technology (we now have more powerful tools to map floods).

THE COMMUNITY RATING SYSTEM

The Community Rating System (CRS) is a voluntary incentive program that offers discounted flood insurance premiums to encourage floodplain management activities beyond the minimum NFIP requirements. CRS class ratings are assigned to participating communities based on 18 activities in the following categories:

- Public information
- Mapping and regulations
- Flood damage reduction
- Flood preparedness

Snohomish County, the Cities of Monroe and Sultan, and the Town of Index are currently participating in the CRS program. The total annual savings on flood insurance premiums within the planning area is $643,681. Many of the mitigation actions identified in Volume 2 of this plan are creditable activities under the CRS program.

HAZARD PROFILE

The headwaters and middle reaches of rivers in Snohomish County are typically steep and dominated by bedrock and boulders. In these areas, floodplains are often narrow or absent. When these rivers eventually reach the Puget Sound lowlands, they flatten out, deposit sediments, and form floodplains that are often broad, ecologically complex, and biologically productive.

In the relatively brief time since Euro-American settlement began in the Puget Sound basin, the region's floodplains have been altered extensively by development. Initially these changes were caused by land clearing and installation of drainage systems that supported land uses such as farming, mining, and railroad transportation. More recently, intensive residential, commercial, and industrial land uses have come to occupy the downstream portions of some of Snohomish County's river valleys, increasing floodplain management conflicts and costs. It is in these flat, lowland floodplain areas that human development and flooding coincide, posing some of the greatest management challenges.

SNOHOMISH RIVER BASIN

The Snohomish River flows 23 miles from the confluence of the Snoqualmie and the Skykomish rivers near the City of Monroe to Port Gardner Bay in Everett. The drainage basin extends from an elevation of 8,000 feet in the Cascade Mountains to sea level at Everett. Tidal action affects river stages in the lower 13 miles. The river's average gradient is approximately 1 foot per mile. At bank-full conditions, the width of the river channel varies from 35 to 500 feet. The Snohomish River floodplain is subject to frequent inundation. Except for the French Creek Drainage District, existing levees provide protection only from normal spring floods that would damage crops. Overtopping may be expected every 2 to 5 years, depending upon the height and condition of the levees.

Runoff patterns for the Skykomish and Snoqualmie drainages indicate a high degree of uniformity in storm coverage over the entire Snohomish River Basin. Much of the recorded runoff is high mountain snowmelt. Consequently, the normal high flow period due to winter rains is followed by snowmelt peak flow in the spring. In general, the spring peak is more pronounced at higher altitudes; the winter peaks are more dominant in lowland areas. Within the Snohomish Basin, a system of dams and diversions has been developed on the Sultan River watershed and the South Fork Tolt River. Both systems are managed primarily for water supply purposes, with small hydroelectric operations being installed after the water supply systems were in place.

STILLAGUAMISH RIVER BASIN

The Stillaguamish River originates in the Cascade Mountains, flows westward, and enters Puget Sound near Stanwood. The basin is 684 square miles and has no dams. This basin includes three sub-basins: the North Fork, the South Fork, and the Main Stem. The forks are generally steep and dynamic, so bank erosion, high velocities, sediment transport, and debris loading contribute to flood hazards. The forks converge at the City of Arlington to form the main stem of the Stillaguamish River. Seventy-five percent of this basin is located in Snohomish County and is forest land, with 90 percent of the commercially harvestable land in the North and South Fork sub-basins. Forest practices such as road building and harvesting increase the potential for altering peak flows in the river and affecting downstream property. The largest tributaries to this system are Canyon, Pilchuck, and Jim Creeks. The

average annual precipitation in the basin ranges from 35 inches at the mouth of the river near Stanwood to approximately 100 inches at the headwaters.

The general flood characteristics (peak flow, crest elevation, duration of flood, etc.) of the Stillaguamish River depend on a number of factors, including rainfall, ground moisture conditions, snow pack, temperature, and tides. High tidal elevations create backwater effects in the lower reaches of the river, which when combined with high flood flows can significantly increase flood levels in the lower Main Stem. Flood flows in the Stillaguamish can last for several days, although crests are generally maintained for only a few hours.

Between 2005 and 2015, two new floodgate systems were installed by the Stillaguamish Flood Control district, with third-party funding, to drain river flood flows that overtop upriver levee systems. The large capacity flood control gates have been effective in reducing inundation periods after flood events that isolate populations who may shelter in place during flood events.

LOWER SKAGIT RIVER BASIN

A small part of this basin is located along the northwest shoreline of Snohomish County, where the southern part of the Skagit Delta is located. The threat from this river occurs if floodwaters overtop the left bank levees south of Mount Vernon, which would then flow southward toward Stanwood.

Major floods on the Skagit River are the result of winter storms moving eastward across the basin with heavy precipitation and warm snow-melting temperatures. Several storms may occur in rapid succession. Frequently, a low-elevation snowpack forms over large parts of the basin. Minor floods usually last about three days, rising to major damage proportions in a day or less and receding rapidly in 24 hours or less.

UPPER SKAGIT RIVER BASIN

The Sauk/Suiattle River sub-basin forms the Upper Skagit River Basin and drain the northeast quarter of Snohomish County. The Sauk flows north to its confluence with the Skagit River near the Town of Rockport. The Suiattle River, and to a lesser extent the White Chuck River, are the principal rivers that drain Glacier Peak. These streams do not have levee systems and have a history of channel migration and bank erosion during flood events. Because of the federal Wild and Scenic River designation, government entities and private property owners are not allowed to place any type of material along these river banks to mitigate these channel changes and bank erosion. In areas where erosion is severe or drastic channel changes occur, homes and property are often simply “lost” to the river (Skagit County Website, 2004).

LAKE WASHINGTON BASIN

The majority of this basin is in King County, but it extends north into southwestern Snohomish County. Two of its sub-basins are in Snohomish County:

- The Lake Washington Sub-basin drains the southern Everett/Mill Creek/Lynnwood/Bothell area. Three major creeks—Swamp Creek, North Creek, and Bear Creek—flow into the Sammamish River in King County, which then flow into Lake Washington.

- The Puget Sub-basin drains the southwest portion of Snohomish County from near Mukilteo to the Shoreline/King County border at Woodway. It extends inland about 2 miles to near SR-99. It is essentially a coastal drainage area, draining the bluffs facing Possession Sound through deep gulches, notably Big Gulch, Lunds Gulch, and Shell Creek.

RIVERINE FLOODING

Winter floods occur in most of the county's floodplains every 2 to 5 years. "Flood season" historically begins in mid-November and continues to mid-February. However, the timing of peak runoff is expected to change with changes in climate. In general, a weather pattern of heavy, fresh snow in the mountains followed by warm winds and heavy rain creates riverine flooding conditions. It is rare for rain to cause river flooding alone. Flash flooding, a sudden local flood, is typically caused by slow-moving thunderstorms or heavy rains associated with spring or early summer storm systems. There is a possibility for moderate flash flooding in the County, but only along smaller streams and tributaries. High tides may be responsible for holding up the normal discharge of river runoff into Puget Sound, while low tides facilitate the discharge from the Snohomish and Stillaguamish Rivers.

TIDAL FLOODING

The potential for flooding in low-lying coastal areas exists when favorable atmospheric conditions (i.e., very low pressure) occur simultaneously with periods of unusually high tides. No significant damage has been experienced in Snohomish County in the recent past due to tidal flooding. Storm surges, also known as storm tides, can affect a number of beachfront areas in the county. During a storm surge, tides may run 2 to 4 feet above the predicted tide level. Storm surges can usually be predicted up to 12 hours before occurrence. The effects of a storm surge generally range from saltwater inundation to the battering of beachhead property by water-driven debris.

The beachfront areas in Snohomish County most likely to receive storm surge damage are near Mukilteo, Marysville, the Tulalip Reservation, Hat Island, and Stanwood. Property most often damaged by storm surge includes beachfront homes and businesses, bulkheads, marinas, docks, and ferry terminals. More significantly, tidal flooding can overtop levees in the lower estuary areas of the Snohomish and Stillaguamish River valleys.

URBAN FLOODING

Like many areas in western Washington, Snohomish County has experienced rapid change due to urban development in once-rural areas. Urban flooding occurs when available conveyance systems lack the capacity to convey rainfall runoff to nearby creeks, streams, and rivers. As drainage facilities are overwhelmed, roads and transportation corridors become conveyance facilities.

Urban floods can be a great disturbance to daily life in urban areas. Roads can be blocked and people may be unable to go to work or school. Economic damage can be high but the number of casualties is usually limited. The water rises relatively slowly and usually does not reach life-endangering depths. As more of the county's natural watershed is converted to human habitation and transportation systems, the urban flooding potential will continue to grow.

FREQUENCY AND LOCATION

Snohomish County experiences episodes of river flooding almost every winter. Large, damaging floods have typically occurred every two to 10 years. Urban portions of the county annually experience nuisance flooding related to drainage issues. In flood insurance studies, floods are commonly described as having 10-, 50-, 100-, and 500-year recurrence intervals, meaning that floods of these magnitudes have a 10-, 2-, 1-, or 0.2-percent chance, respectively, of occurring in any given year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. From December of 1975 through March of 2014, there were 15 flood events in the county damaging enough to result in disaster declarations. The largest of these was in December of 1975, with over $42.4 million in damages to both public and private property. The extent of the 100-year and 500-year floods are illustrated on Map 7-1.

FLOOD WARNING

Snohomish County's flood-warning program warns of impending flooding on major rivers so that residents and agencies can prepare before serious flooding occurs. In most locations, the warning system provides at least two hours of lead time before floodwaters reach damaging levels.

SECONDARY HAZARDS

The most significant secondary hazard for flooding is bank erosion and rapid channel migration. In many cases, the threat and effects of bank erosion are worse than actual flooding. Flooding is also responsible for hazards such as landslides when high flows oversaturate soils on steep slopes, causing them to fail. Hazardous-material spills are also a secondary hazard of flooding if storage tanks rupture or sewage/manure lagoons overtop and spill into streams, rivers, or drainage sewers.

Flooding can cause increased mold growth within a home. People with asthma, allergies, or other breathing conditions may be more susceptible to mold. Those who are sensitive may experience a stuffy nose, irritated eyes, wheezing or skin irritation. Cleanup within 24 to 48 hours of flood events entails opening doors and windows and using fans to dry out the building interior (CDC 2014).

CLIMATE CHANGE IMPACTS

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

The Climate Impacts Group (CIG) at the University of Washington evaluated flood return intervals, due to climate impacts, at select sites on the Sauk, South Fork Stillaguamish, Skykomish, and Snohomish rivers. If greenhouse gas emissions continue to increase rapidly, the simulations show:

- In the 2040s, for all four rivers studied, the average projected return interval for a 10-year flood is 4–5 years.
- By the 2080s, for all four rivers studied, the 10-year flood could be expected to occur every 2–3 years
- By the 2040s, the 100-year flood has an average projected return interval of 28 years on the Sauk River, 50 years on the South Fork of the Stillaguamish River, 83 years on the Skykomish River, and 32 years on the Snohomish River.
- In the 2080s, for all four rivers studied, the average projected return interval for a 100-year flood is 10–16 years.
- Until there is clear evidence of substantial reduction in global greenhouse gas emissions, this mitigation plan recommends that these return intervals be used for planning purposes.

The CIG results indicate that high-frequency flood events (e.g. 10-year floods) will occur more often with a changing climate, and that the current 100-year flood may also strike more often, leaving many communities at greater risk.

EXPOSURE AND VULNERABILITY

PEOPLE

An estimated 75,389 people live within the 100-year floodplain within the entire county, including the following vulnerable populations:

- **Economically Disadvantaged Populations**—It is estimated that 5 percent of the people within the 100-year floodplain are economically disadvantaged, defined as having household incomes of $10,000 or less.
- **Population over 65 Years Old**—It is estimated that 10 percent of the population in the census blocks that intersect the 100-year floodplain are over 65 years old. Approximately 5 percent of the over-65 population in the floodplain also have incomes considered to be economically disadvantaged and are considered to be extremely vulnerable.
- **Population under 16 Years Old**—It is estimated that 24 percent of the population within census blocks located in or near the 100-year floodplain are under 16 years of age.

An estimated 75,389 people would need short-term shelter in a 100-year flood.

PROPERTY

There are 7,370 structures within the 100-year floodplain and 8,165 structures within the 500-year floodplain. Over 70 percent of these structures are in unincorporated areas. Sixty-two percent are residential, and 38 percent are commercial, industrial, or agricultural. It is estimated that a 100-year flood would cause up to $161.4 million in damages and a 500-year flood would cause $233.5 million in damages. It is estimated that 56 percent of the insurable buildings in the Snohomish County planning area are covered by a flood insurance policy.

FEMA identifies 210 repetitive loss properties in the Snohomish County as of February, 2014. Actions have been taken to mitigate flood risk of 46 of these properties.

A repetitive loss property as defined by FEMA is an NFIP-insured property that has experienced any of the following since 1978, regardless of any changes in ownership:

- Four or more paid losses in excess of $1,000
- Two paid losses in excess of $1,000 within any rolling 10-year period
- Three or more paid losses that equal or exceed the current value of the insured property

Map 7-2 shows the repetitive loss areas in Snohomish County.

Retrofitting: Retrofitting means making changes to an existing building to protect it from flooding. There are various ways to protect a home, including:

- Elevation: raising the home so that the lowest floor is above flood level
- Wet flood proofing: making uninhabited parts of the home resistant to flood damage when water is allowed to enter during a flood
- Relocation: moving the home to higher ground when the exposure to flooding is eliminated altogether;
- Dry flood proofing: sealing the home to prevent flood waters from entering
- Levee and floodwall protection: constructing barriers to prevent flood waters from entering the home
- Demolition: destroying the home and rebuilding properly on a safer location on the same property or buying a home elsewhere

From 2008 to 2014, seven home elevations were completed through the County's Voluntary Floodplain Home Elevation Program. Many more homes have been elevated with flood claims and private financing.

CRITICAL FACILITIES AND INFRASTRUCTURE

Flooding has impacted roads both inside and outside the 100-year floodplain in Snohomish County. Many roads, such as I-5, are built above the flood level, and many others function as levees to prevent flooding. Nonetheless, in certain events these roads may be blocked or damaged by flooding, preventing access to many areas. There are 163 bridges that are in or cross over the floodplain.

Water and sewer systems can be affected by flooding events. Floodwaters can back up drainage systems, causing localized flooding. Culverts can be blocked by debris from flood events, also causing localized urban flooding. Floodwaters can get into drinking water supplies, causing contamination. Sewer systems can also be backed up, causing wastes to spill into homes, neighborhoods, rivers, and streams.

Dikes have historically been used to control flooding in Snohomish County. Presently there are extensive dikes managed by diking districts that maintain the water overflow of the Stillaguamish, Snohomish, and Skykomish Rivers. There are also dikes on many smaller rivers, streams, and creeks that protect small areas of land. Many of the dikes are older and were built under different flood management goals. Many of these older dikes are exposed to scouring and failure due to old age and construction methods. An inventory and assessment of these facilities is included in the Stillaguamish and Snohomish River Basin Plans and will be included in any future basin plan prepared by the County.

A significant portion of the BNSF Railroad runs through flood hazard areas due to the shallow grades found in those areas. Noteworthy areas include the railroad yards on the east side of Everett, the Stillaguamish Delta near Stanwood, and most of the route through the Snohomish/Skykomish Valley. Railroad tracks tend to be well protected from flooding because they are built as levees or embankments 10 to 15 feet above the surrounding area. In some instances, railroads can worsen flooding because they can prevent drainage of flooded areas.

Tier II facilities contain hazardous materials in quantities above an established threshold. These facilities can be damaged in a flood and release the hazardous materials. Seventeen businesses in the 100-year floodplain—two of them in the floodway—report containing Tier II hazardous materials. During a flood event, containers holding these materials could rupture and leak into the surrounding area, having a disastrous effect on the environment as well as residents. These facilities are identified in the Hazardous Material/Pipelines section located in Appendix B of HMP Volume 1.

ENVIRONMENT

Flooding is a natural event, and floodplains provide many natural and beneficial functions. Nonetheless, with human development factored in, flooding can impact the environment in negative ways. Migrating fish can wash onto roads or over levees and into flooded fields, with no possibility of escape. Roadway pollutants and other hazardous materials can wash into rivers and streams. During floods, these can settle onto normally dry soils, polluting them for agricultural uses. Human development, such as bridge abutments and levees and channel obstructions, can increase stream bank erosion, causing rivers and streams to migrate into non-natural courses. Floodplains often interface with critical habitat of threatened or endangered aquatic species, such as salmon or bull trout. Impacts on the floodplains can have significant impacts on these species.

The county has taken steps to preserve the natural and beneficial functions of the floodplain, while at the same time reducing the flood risk to the built environment. As a result, it is estimated that over 40 percent of the floodplain in the unincorporated County is in an open space use.

FUTURE TRENDS IN DEVELOPMENT

Based on the analysis performed by Snohomish County for its 2009 CRS re-verification, 43 percent of the regulated floodplain in the unincorporated county is currently in an open space use. Forty-five percent of the regulated floodplain has a specified minimum lot density of one structure per five acres or larger and is zoned for land uses that support agricultural productions. The county Transfer of Development Rights (TDR) and Purchase of Development Rights programs are designed to discourage development on agricultural lands, many of which are in the floodplain.

A more detailed flood risk assessment is located in Chapter 14 of Volume 1.

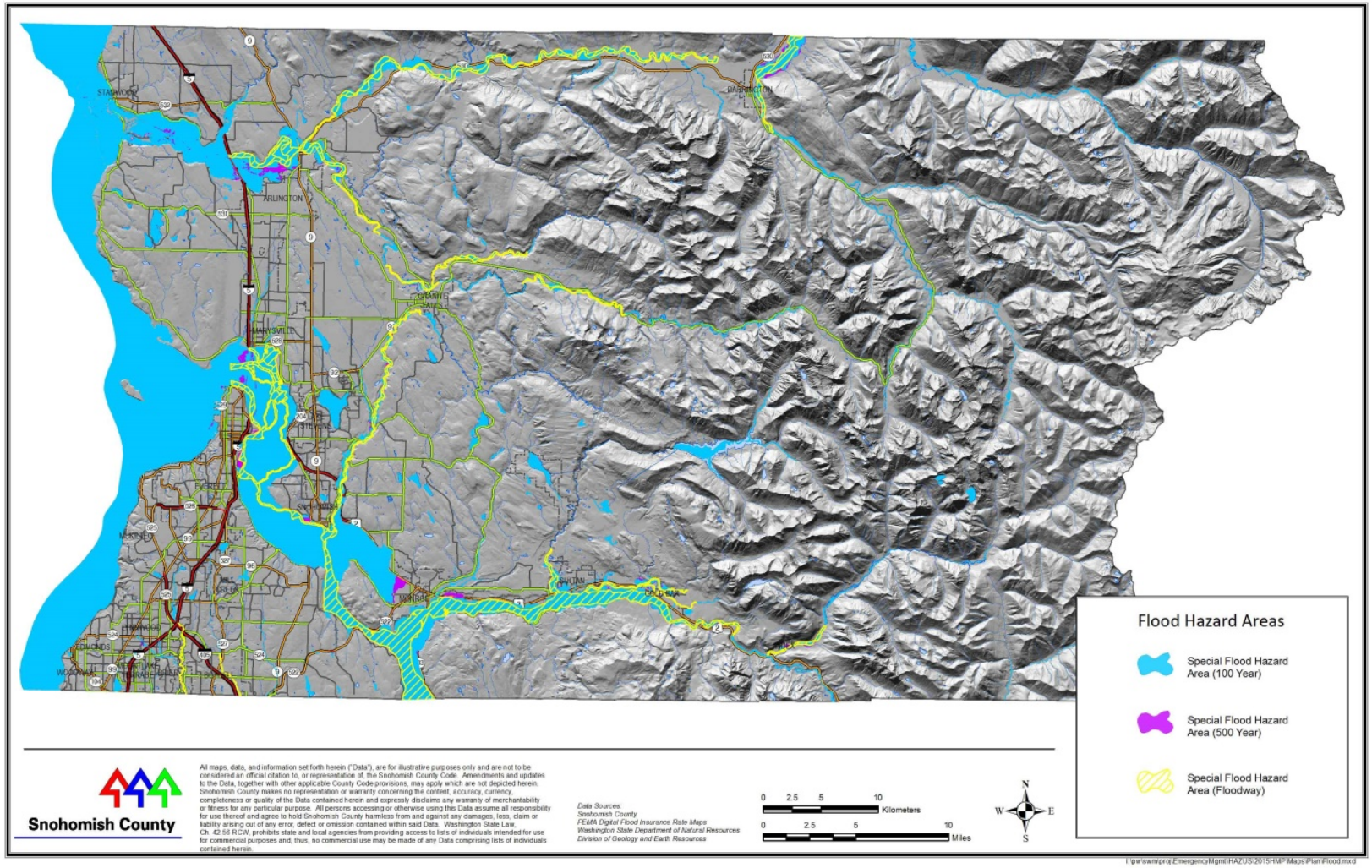
SCENARIO

The worst-case scenario is a series of storms that flood numerous drainage basins in a short time. This would overwhelm city and county public works departments. Major roads would be blocked, preventing critical access for many residents and critical functions. High river flows could cause rivers to scour, possibly washing out roads and creating more isolation problems. In the case of multi-basin flooding, the county would not be able to make repairs quickly enough to restore critical facilities and infrastructure.

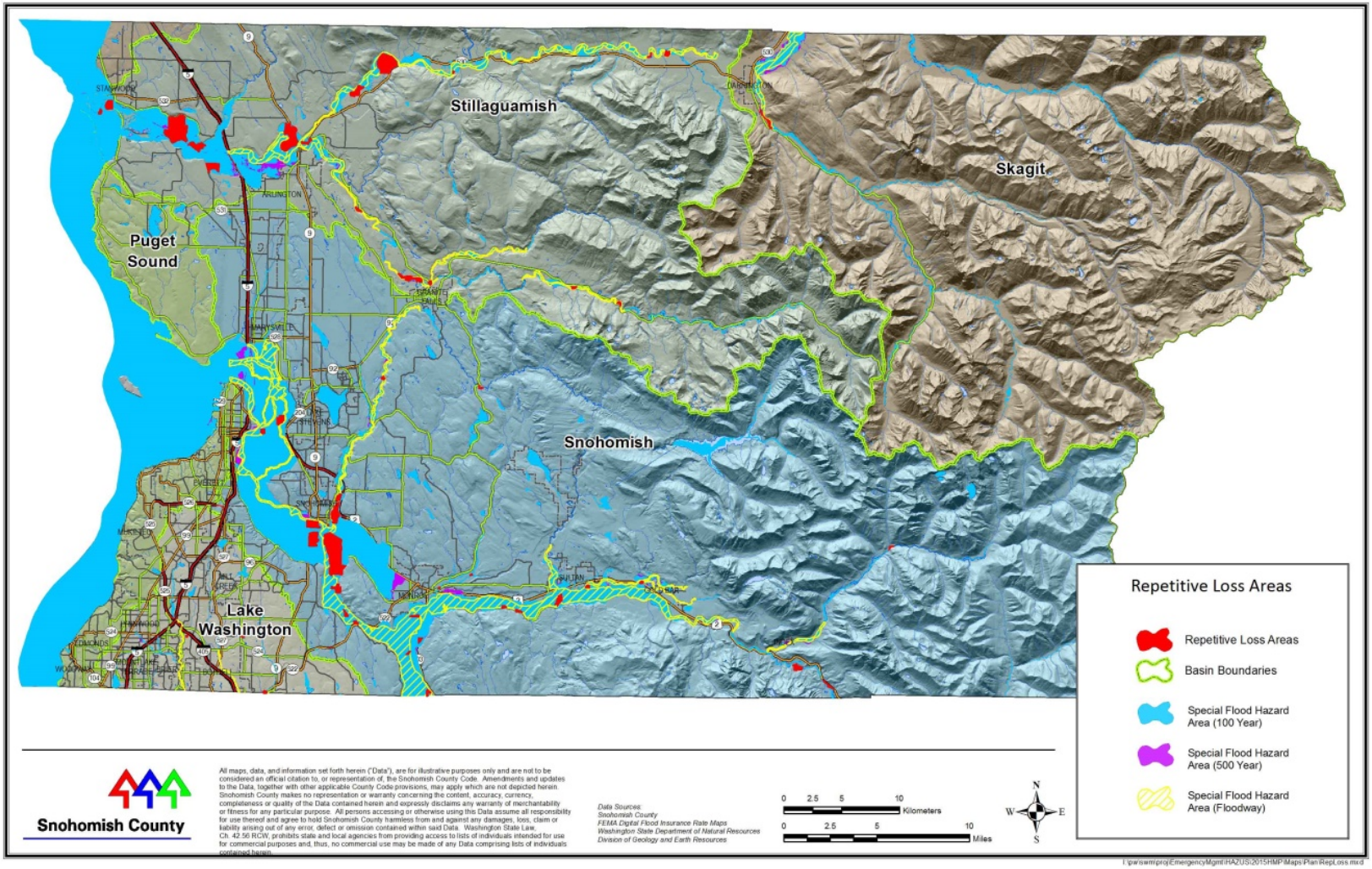
ISSUES

Important issues associated with flood hazards include but are not limited to the following:

- Older levees are subject to failure or do not meet current building practices for flood protection.
- More information is needed on flood risk to support the concept of risk-based analysis of capital projects.
- There needs to be a sustained effort to gather historical damage data, such as high-water marks on structures and damage reports, to measure the cost-effectiveness of future mitigation projects.
- Ongoing flood hazard mitigation will require funding from multiple sources to continue.
- There needs to be a coordinated hazard mitigation effort between jurisdictions affected by flood hazards in the county.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods.
- The risk associated with the flood hazard overlaps the risk associated with other hazards, such as earthquake and landslide. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.
- Stream bank erosion is still a major problem on most of the county's rivers and streams.
- The concept of residual risk should be considered in the design of future capital flood control projects and should be communicated with residents living in the floodplain.
- The promotion of flood insurance as a means of protecting private property owners from the economic impacts of frequent flood events should continue.
- Existing floodplain-compatible uses such as agricultural and open space need to be maintained. There is constant pressure to convert these existing uses to more intense uses, especially along the Stillaguamish and Snohomish Rivers.
- The economy has an impact on a jurisdiction's abilities to manage its floodplains. Budget cuts and personnel losses can tax many resources needed to support floodplain management.
- FIRMs and DFIRMs do not provide accurate estimates of future risk due to climate change.



Map 7-1 Flood Hazard Areas



Map 7-2 Repetitive Loss Area

Chapter 8: Landslides and Other Mass Movements

GENERAL BACKGROUND

A landslide is a mass of rock, earth, or debris moving down a slope. Landslides may be minor or very large, and can move at slow to very high speeds. They can be initiated by storms, earthquakes, fires, and volcanic eruptions, and by human modification of the land.

Mudslides or mudflows (or debris flows) are rivers of rock, earth, organic matter, and other soil materials saturated with water. They develop in the soil overlying bedrock on sloping surfaces when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt. A debris flow or mudflow can move rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. The slurry can travel miles from its source, growing as it descends, picking up trees, boulders, cars, and anything else in its path. Although these slides behave as fluids, they pack many times the hydraulic force of water due to the mass of material included in them. Locally, they can be some of the most destructive events in nature.

DEFINITIONS

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

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

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

Sinkhole—A collapse depression in the ground with no visible outlet. Its drainage is subterranean. It is commonly vertical-sided or funnel-shaped.

A sinkhole is a collapse depression in the ground with no visible outlet. Its drainage is subterranean, and it is commonly vertical-sided or funnel-shaped.

All these mass movements are caused by a combination of geological and climate conditions. These include steep topography as well as the encroaching influence of urbanization. The cool, rainy Pacific Northwest climate ensures that soil moisture levels remain high throughout most of the year, and in fact are often at or near saturation during wet winter months. These vulnerable natural conditions are being steadily affected by human residential, agricultural, commercial, and industrial development and the infrastructure that supports it.

HAZARD PROFILE

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

- A slope greater than 33 percent
- A history of landslide activity or movement during the last 10,000 years

- Stream or wave activity, which has caused erosion, undercut a bank, or cut into a bank to cause the surrounding land to be unstable
- The presence or potential for snow avalanches
- The presence of an alluvial fan, indicating vulnerability to the flow of debris or sediments
- The presence of impermeable soils, such as silt or clay, which are mixed with granular soils, such as sand and gravel

Figures 8-1, 8-2, 8-3, and 8-4 show common types of slides in the Puget Sound region and in Snohomish County. The most common is the shallow colluvial slide, occurring particularly in response to intense, short-duration storms. The largest and most destructive are deep-seated slides, although they are less common than other types. Puget Sound's shoreline contains many large, deep-seated dormant landslides. Occasionally, large catastrophic slides occur on Puget Sound.

Most landslides occur in January after the water table has risen during the wet months of November and December. In addition to the coastal bluffs, landslides are most prevalent around the slopes of the Puget Sound's steep, linear hills. Water is involved in nearly all cases, and human influence has been identified in more than 80 percent of reported slides.

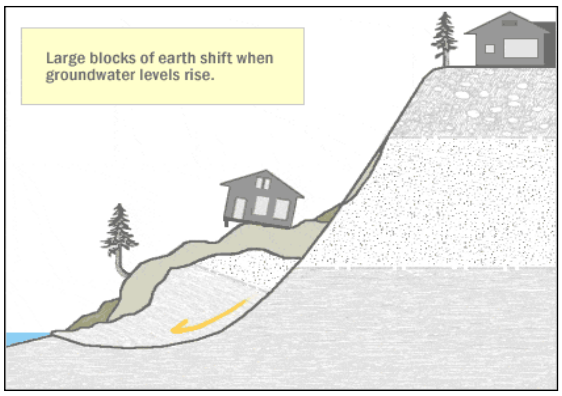


Figure 8-1 Deep Seated Slide

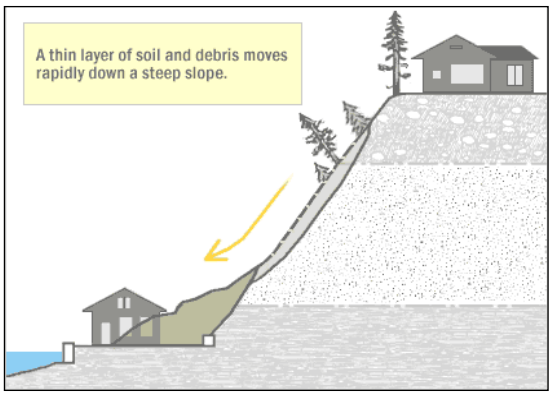


Figure 8-2 Shallow Colluvial Slide

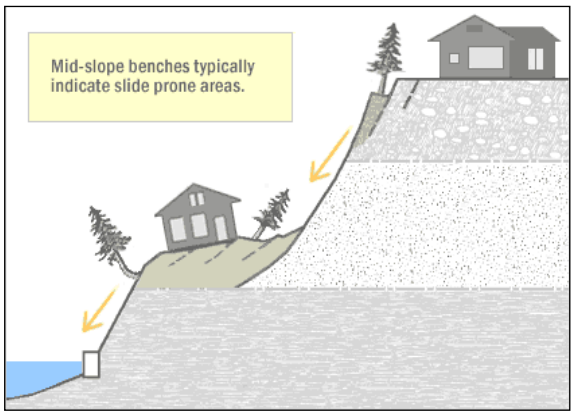


Figure 8-3 Bench Slide

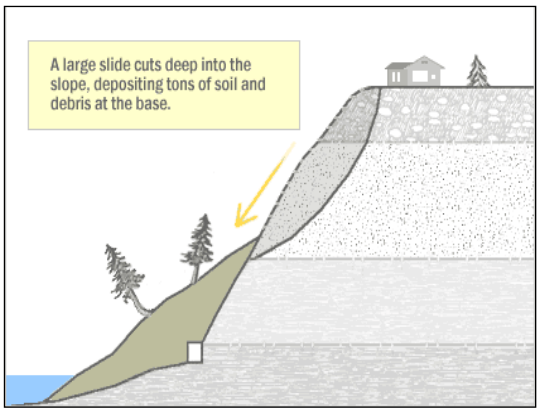


Figure 8-4 Large Slide

PAST EVENTS

There is little recorded historical information for Snohomish County regarding landslides. During the winter storm of 1996–97, more than half of the county's $60–70 million in reported damage occurred as a result of landslides, mudslides, and debris flows. Drainage systems and catchment basins could not handle the volume of runoff, focusing the water's energy against vulnerable slopes and man-made structures. In some cases, saturated soils simply became overloaded with the weight of snow and rainwater and collapsed. Private homeowners, particularly in areas where natural drainage has been paved, diverted, or otherwise modified by man, reported significant damage. Landslide and mudslide/debris flow activity during this storm caused widespread disruption of surface transportation, closing roads and in one case derailing mail cars from a freight train. The costs of repairing road damage totaled tens of millions of dollars. Given the volume of hazardous substances shipped by road and rail through Snohomish County, it was fortunate that no serious chemical spills occurred as a result of these incidents.

A large slide occurred in Woodway, just north of the Richmond Beach neighborhood, during the early morning of January 15, 1997. It cut 50 feet into the property above, passed over the railroad tracks and knocked a freight train into Puget Sound (see Figure 8-5).

Figure 8-5 1997 Woodway Slide

Snohomish County's largest and most tragic landslide, the SR-530 slide, occurred in 2014 and caused 43 fatalities. The SR-530 landslide in 2014 is estimated to cost more than $50 million in damage and recovery costs. This is the only slide known to have caused fatalities in the county. However, across the Pacific Northwest, a number of deaths have occurred as a result of slides, slope collapses, and sinkholes.

Map 8-1 shows the landslide hazard areas in Snohomish County. This map, however, does not identify areas at risk of slide run-out. The length of slide run-out is affected by many factors, such as substrate composition, saturation, and slope angle and height. Scientific research is ongoing to understand how these and other factors determine slide run-out.

The recognition of ancient dormant mass movement sites is important in the identification of areas susceptible to flows and slides because they can be reactivated by earthquakes or by exceptionally wet weather. Also, because they consist of broken materials and frequently involve disruption of groundwater flow, these dormant sites are vulnerable to construction-triggered sliding.

FREQUENCY

Landslides are often triggered by other natural hazards, such as earthquakes, heavy rain, floods or wildland fires, so landslide frequency is related to the frequency of these other hazards. In Snohomish County, landslides typically occur during and after major storms. Recent events occurred during the winter storm of 1996–97 and the October 2003 storm, which generated a few landslides, but not as many as expected, since the soil and bedrock in hilly areas were relatively dry. Recent events also occurred during the winter storms of 2006, 2007, and 2009, and the spring of 2014.

WARNING TIME

Mass movements can occur suddenly or slowly. The velocity of movement may range from a slow creep of inches per year to many feet per second, depending on slope angle, material, and water content. Some methods used to monitor mass movements can provide an idea of the type of movement and the amount of time prior to failure. Currently there is no practical warning system for individual landslides. The standard operating procedure is to monitor situations on a case-by-case basis, and respond after the event has occurred. Generally accepted warning signs for landslide activity include:

- Springs, seeps, or saturated ground in areas that have not typically been wet before
- New cracks or unusual bulges in the ground, street pavements, or sidewalks
- Soil moving away from foundations
- Ancillary structures, such as decks and patios tilting and/or moving relative to the main house
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls, or fences
- Offset fence lines
- Sunken or down-dropped road beds
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still falling or just recently stopped
- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb
- A faint rumbling sound that increases in volume as the landslide nears
- Unusual sounds, such as trees cracking or boulders knocking together

SECONDARY HAZARDS

Landslides can cause several types of secondary effects, such as blocking access to roads, which can isolate residents and businesses and delay commercial, public, and private transportation. This could result in economic losses for businesses. Vegetation or poles on slopes can be knocked over, resulting in possible losses to power and communication lines. Landslides also have the potential of destabilizing the foundation of structures, which may

result in monetary loss for residents. They also can block rivers or streams, causing upstream flooding, and potentially harm water quality, fisheries, and spawning habitat.

CLIMATE CHANGE IMPACTS

Climate change will impact storm patterns in Washington. This changing of the hydrograph means that the probability of more frequent, intense storms with varying duration will increase. Increase in global temperature will also affect the snowpack and its ability to hold and store water. Warming temperatures will increase the occurrence and duration of droughts, which will increase the probability of wildland fire, which impacts the vegetation that helps to support steep slopes. All of these factors working in unison would increase the probability for landslide occurrences within the planning area.

EXPOSURE AND VULNERABILITY

POPULATION

The estimated county population living in landslide risk areas may be as high as 60,000, roughly 8 percent of the total county population.

PROPERTY

In the county, there are 12,371 structures on parcels exposed to steep slopes, worth an estimated $3.5 billion. Ninety-five percent of the exposed structures are residential dwellings.

CRITICAL FACILITIES AND INFRASTRUCTURE

A significant amount of infrastructure (roads, bridges, railroads, and utilities) can be exposed to mass movements. Landslides can block egress and ingress on roads, causing isolation for neighborhoods. Roadway blockages caused by landslides can also create traffic problems, resulting in delays for both public and private transportation. This could result in economic losses for businesses. Other potential problems resulting from landslides are power and communication failures, creating problems for vulnerable populations as well as businesses.

Thirty-six critical facilities are exposed to the landslide hazard, including health, transportation, water and sewer, and power infrastructure. A more in-depth analysis of the mitigation measures taken by these facilities to prevent damage from mass movements is necessary to determine if they could withstand impacts of a mass movement.

The BNSF Railway corridor is exposed to landslides along much of its north-south and east-west routes and spurs. These areas include the tracks located along the Puget Sound bluffs from the King County line up to Everett. The Boeing Spur is located in a ravine and is extremely vulnerable. Other areas exposed to landslides include the bluffs north of Stanwood, the Bothell-Snohomish Branch, and tracks located in the Cascade Mountains east of Gold Bar leading to Steven's Pass.

Power lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A landslide could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines. Puget Sound Energy lines pass through steep slope areas.

ENVIRONMENT

Environmental problems as a result of mass movements can be numerous. Landslides that fall into streams may significantly impact fish and wildlife habitat as well as affect water quality.

FUTURE TRENDS IN DEVELOPMENT

Landslide hazard areas are included in the "geologically hazardous areas," one category of critical areas regulated under the state GMA for Snohomish County. Snohomish County's 2012 buildable lands report excludes critical areas from consideration as buildable lands due to the scope of regulations affecting them. The landslide hazard portions of the planning area are regulated by County Code (Title 30.62B) as well as by the International Building Code. However, County Code does not address run-out areas for landslides. Development that occurs in mapped landslide hazard areas will be regulated to reduced risks.

A more detailed landslide risk assessment is located in Chapter 15 of Volume 1.

SCENARIO

Major mass movements in Snohomish County occur as a result of soil conditions that have been affected by severe storms, groundwater, or human development. The worst-case scenario for mass movement hazards in Snohomish County would generally correspond with a severe storm that had heavy rain and caused flooding. Mass movement is most likely to occur during late winter when the water table is high. A short intense storm could cause saturated soil to move, resulting in landslides. After heavy rains from November to December, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will cause weakness and destabilization in the slope. As rains continue, the groundwater table rises, further weakening the slope. Gravity, poor drainage, a rising groundwater table, and poor soil exacerbate hazardous conditions.

In a worst-case scenario, a large slope could slide with little warning, impacting residences below and cutting off major roads. This could cause isolation to communities in sparsely populated areas. The landslide could block a river causing flooding upstream and the potential for flooding downstream if the earthen dam created by the slide breaks suddenly.

Based on historical events and steep slopes with a potential for instability, the most likely landslide areas are steep slopes along Puget Sound in the communities of Everett, Mukilteo, and Edmonds, and areas where rivers cut down through glacial till. However, mass movements can occur anywhere in the county that have been affected by historical landslides or that have steep slopes.

Mass movements are becoming more of a concern as development moves outside of city centers and into areas less developed in terms of infrastructure. Most mass movements would be isolated events affecting specific areas.

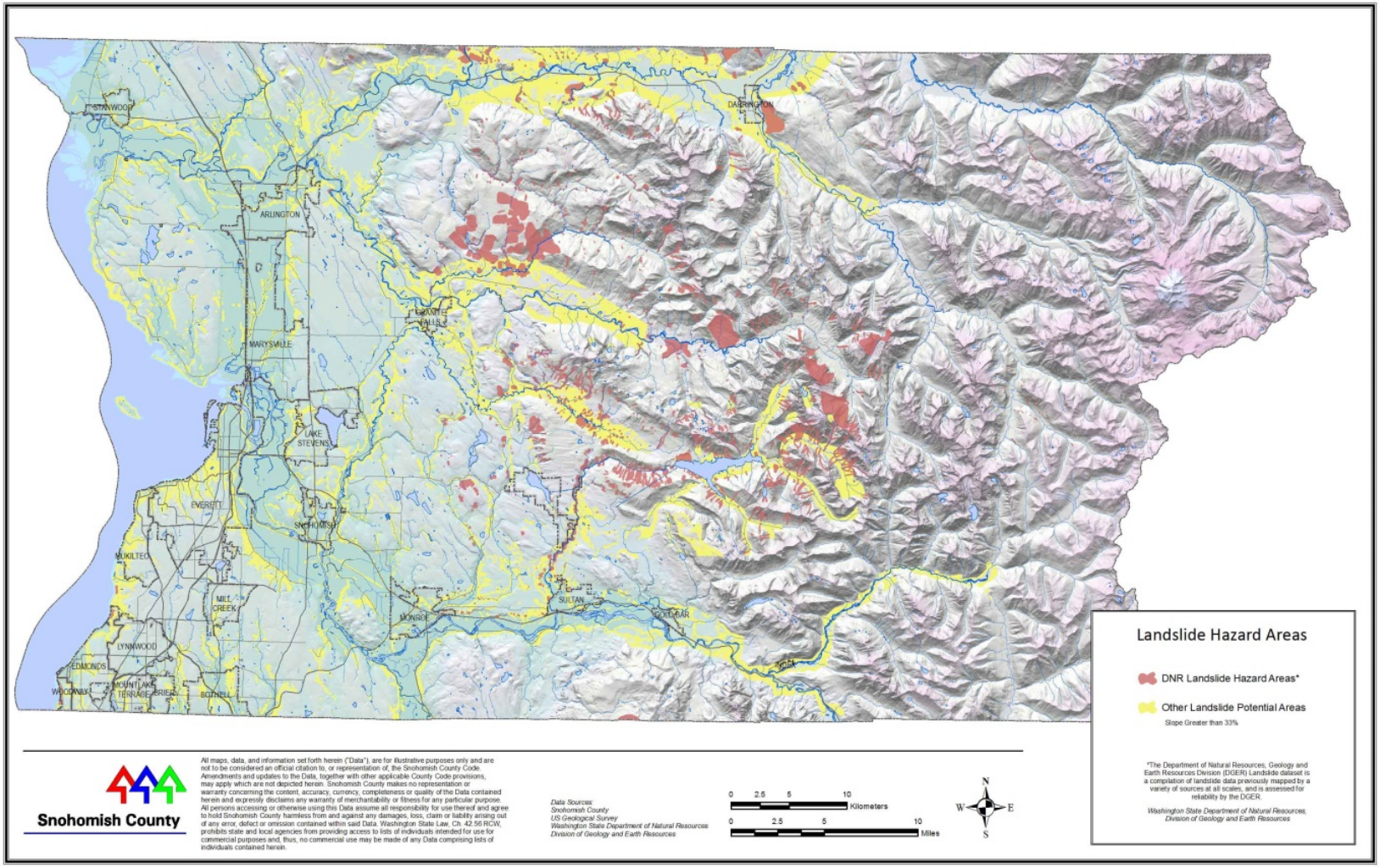
It is probable that private and public property, including infrastructure, will be affected. Mass movements could affect bridges that pass over landslide-prone ravines and knock out rail service through the county. Road obstructions caused by mass movements would create isolation problems for residents and businesses in sparsely developed areas. Property owners exposed to steep slopes may suffer casualties and damage to either property or building structures. Landslides carrying vegetation, such as shrubs and trees, may cause a break in utility lines, cutting off power and communication access to residents.

Continued heavy rains and flooding will complicate the problem further. As emergency response resources are applied to problems with flooding, it is possible they will be unavailable to assist with landslides occurring all over Snohomish County.

ISSUES

Important issues associated with landslides in Snohomish County include the following:

- There are existing homes in mass movement-prone areas, specifically on the Puget Sound shoreline, with the Cities of Everett and Mukilteo being affected significantly.
- Future development could lead to more homes in mass movement prone areas. These areas include the foothills of the Cascades and steep slope areas above the river floodplains of the North and South Forks Stillaguamish River and the Skykomish River.
- The data and science regarding the mapping and assessment of landslide hazards is constantly evolving. As new data and science become available, assessments of landslide risk should be re-evaluated.
- The impact of climate change on landslides is uncertain. If climate change impacts atmospheric conditions, then exposure to landslide risks in Snohomish County is likely to increase.
- Landslides cause environmental changes, including temporary water quality degradation and habitat loss. However, these changes may also provide habitat benefits from sediment and nutrient transport.
- The risk associated with the landslide hazard overlaps the risk associated with other hazards such as earthquake, flood, and tsunami. This provides an opportunity to seek mitigation alternatives with multiple objectives that can reduce risk for multiple hazards.
- Current landslide hazard mapping does not include areas potentially impacted from the run- out of landslides.



Map 8-1 Landslide Hazard Areas

Chapter 9: Severe Weather

GENERAL BACKGROUND

Western Washington has a predominantly marine climate. West of the Cascade Mountains, summers are cool and relatively dry and winters are mild, wet, and generally cloudy. Measurable rainfall occurs on 150 days each year in interior valleys and on 190 days in the mountains and along the coast. Thunderstorms occur up to 10 days each year over the lower elevations and up to 15 days over the mountains. Damaging hailstorms are rare in Western Washington.

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

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

HAZARD PROFILE

Notable windstorms in Snohomish County occurred in 1962, 1976, 1979, 1981, 1993, 2006, 2010, 2011, and 2014. The Columbus Day Storm of October 12, 1962 is considered to be the most powerful storm in recorded history for the Pacific Northwest.

DEFINITIONS

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

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

Thunderstorm—Typically 15 miles in diameter and lasting about 30 minutes, thunderstorms are underrated hazards. Lightning, which occurs with all thunderstorms, is a serious threat to human life. Heavy rains over a small area in a short time can lead to flash flooding. Strong winds, hail, and tornadoes are also dangers associated with thunderstorms.

Tornado—Funnel clouds that generate winds up to 500 miles per hour. They can affect an area up to three-quarters of a mile wide, with a path of varying length. Tornadoes can come from lines of cumulonimbus clouds or from a single storm cloud. They are measured using the Fujita Scale, ranging from F0 to F6.

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

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

Over 50 people died, wind gusts ranged from 50 to 150 miles mph, power outages lasted more than a week, and millions of board feet of trees were blown over. Power outages from the Inauguration Day windstorm of January 20, 1993 lasted from three to five days. The most powerful windstorm since the Inauguration Day Storm of 1993 was in December 2006, with gusts up to 70 mph in the Puget Sound basin. Severe snowstorms occurred in the planning area in 1969, 1971, 1980, and 2009.

LOCATION

Severe weather events have the potential to happen anywhere in Snohomish County. Communities in low-lying areas next to streams or lakes are more susceptible to flooding. Wind events are most damaging to areas that are heavily wooded. Maps 9-1, 9-2, 9-3, and 9-4 show the distribution of average weather conditions over the Snohomish County planning area.

FREQUENCY

According to the Washington State Enhanced Hazard Mitigation Plan, Snohomish County experiences at least one high wind event every year. The state plan indicates a 58 percent probability that Snohomish County will have a severe winter storm at least once every two years.

SEVERITY

The effects on Snohomish County of a strong thunderstorm, tornado, windstorm, or ice storm are likely to be similar: fallen trees, downed power lines, interruption of transportation lifelines, and damaged homes and public buildings. Weather-related fatalities are uncommon in western Washington, but they can occur. The most common problems associated with severe storms are immobility and loss of utilities. Roads may become impassable due to ice or snow or from a secondary hazard, such as a landslide. Power lines may be downed due to high winds, and other services, such as water or phone, may not be able to operate without power. Lightning can cause severe damage and can be deadly.

WARNING TIME

Meteorologists can often predict the likelihood of a severe storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

SECONDARY HAZARDS

The most significant secondary hazards associated with severe local storms are floods, falling and downed trees, landslides, and downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails.

CLIMATE CHANGE IMPACTS

Climate change presents a significant challenge for risk management associated with extreme weather. The frequency of extreme weather events has increased steadily over the last century. The number of weather-related disasters during the 1990s was four times that of the 1950s and cost 14 times as much in economic losses. Historical data shows that the probability for severe weather events increases in a warmer climate (see Figure 9-1). The changing hydrograph caused by climate change could have a significant impact on the intensity, duration, and frequency of storm events. All of these impacts could have significant economic consequences.

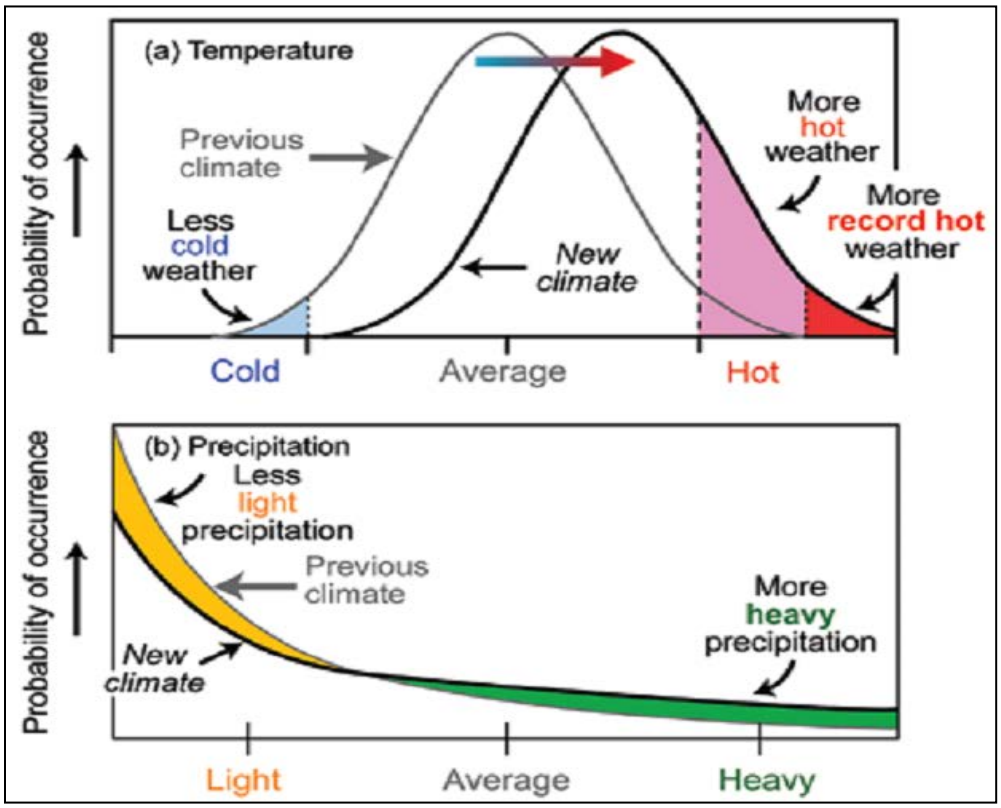


Figure 9-1 Severe Weather Probabilities in Warmer Climates

EXPOSURE AND VULNERABLITY

POPULATION

The entire County is exposed to some extent to severe weather events. Certain areas are more exposed due to geographic location and localized weather patterns. Populations living at higher elevations with large stands of trees or power lines may be more susceptible to wind damage and blackout, while populations living in low-lying areas are at risk for possible flooding.

Vulnerable populations are the elderly, low-income, or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. Power outages can be life-threatening to those dependent on electricity for life support. Isolation of these populations is a significant concern. These populations face isolation and exposure during severe weather events and could suffer more secondary effects of the hazard.

PROPERTY

According to the Snohomish County Assessor, there are 284,482 buildings within the census tracts that define the planning area. Most of these buildings are residential. It is estimated that 20 percent of the residential structures were built without the influence of a building code with provisions for wind or snow loads. All of these buildings are considered to be exposed and vulnerable to the severe weather hazard, but structures in poor condition or in particularly vulnerable locations (such as near Puget Sound) may risk the most damage. The frequency and degree of damage will depend on specific locations. Those in higher elevations and on ridges may be more prone to wind damage. Those that are located under or near overhead lines or near large trees may be vulnerable to falling ice or may be damaged in the event of a collapse.

CRITICAL FACILITIES AND INFRASTRUCTURE

All critical facilities exposed to flooding (Chapter 7) are also likely exposed to severe weather. Additional facilities on higher ground may also be exposed to wind damage or damage from falling trees. The most common problems associated with severe weather are loss of utilities. Downed power lines can cause blackouts, leaving large areas isolated. Consequently, phone, water, and sewer systems may not function. Roads may become impassable due to ice or snow or from secondary hazards, such as landslides. Of particular concern are roads providing access to isolated areas and to the elderly.

Prolonged obstruction of major routes due to landslides, snow, debris, or floodwaters can disrupt the shipment of goods and other commerce. Large and prolonged storms can have negative economic impacts for an entire region.

ENVIRONMENT

The environment is highly exposed to severe weather events in Snohomish County. Severe storm events can drastically affect the physical environment, changing natural landscapes and affecting property and people. Natural habitats such as streams and trees are exposed to the elements during a severe storm and risk major damage and destruction. Prolonged rains can saturate soils and lead to slope failure. Flooding events caused by severe weather can produce channel migration affecting property. Storm surges can erode beachfront bluffs and redistribute sediment loads. Severe local storms can have significant effects on the environment. Heavy rains will cause the ground to become saturated and rivers and streams to rise. This will result in the potential for flooding and landslides. Additionally, snowmelt after snowstorms can cause riverine flooding, which has the potential to damage riparian habitat.

FUTURE TRENDS IN DEVELOPMENT

All future development will be affected by severe storms. The ability to withstand impacts lies in sound land use practices and consistent enforcement of codes and regulations for new construction. The county and City planning partners have adopted the International Building Code (IBC) in response to Washington State mandates. This code is equipped to deal with the impacts of severe weather events. Land use policies identified in comprehensive plans within the planning area also address many of the secondary impacts (flood and landslide) of the severe weather hazard. Equipped with these tools, the planning partnership is equipped to deal with future growth and the associated impacts of severe weather.

A more detailed flood severe weather risk assessment is located in Chapter 16 of Volume 1.

SCENARIO

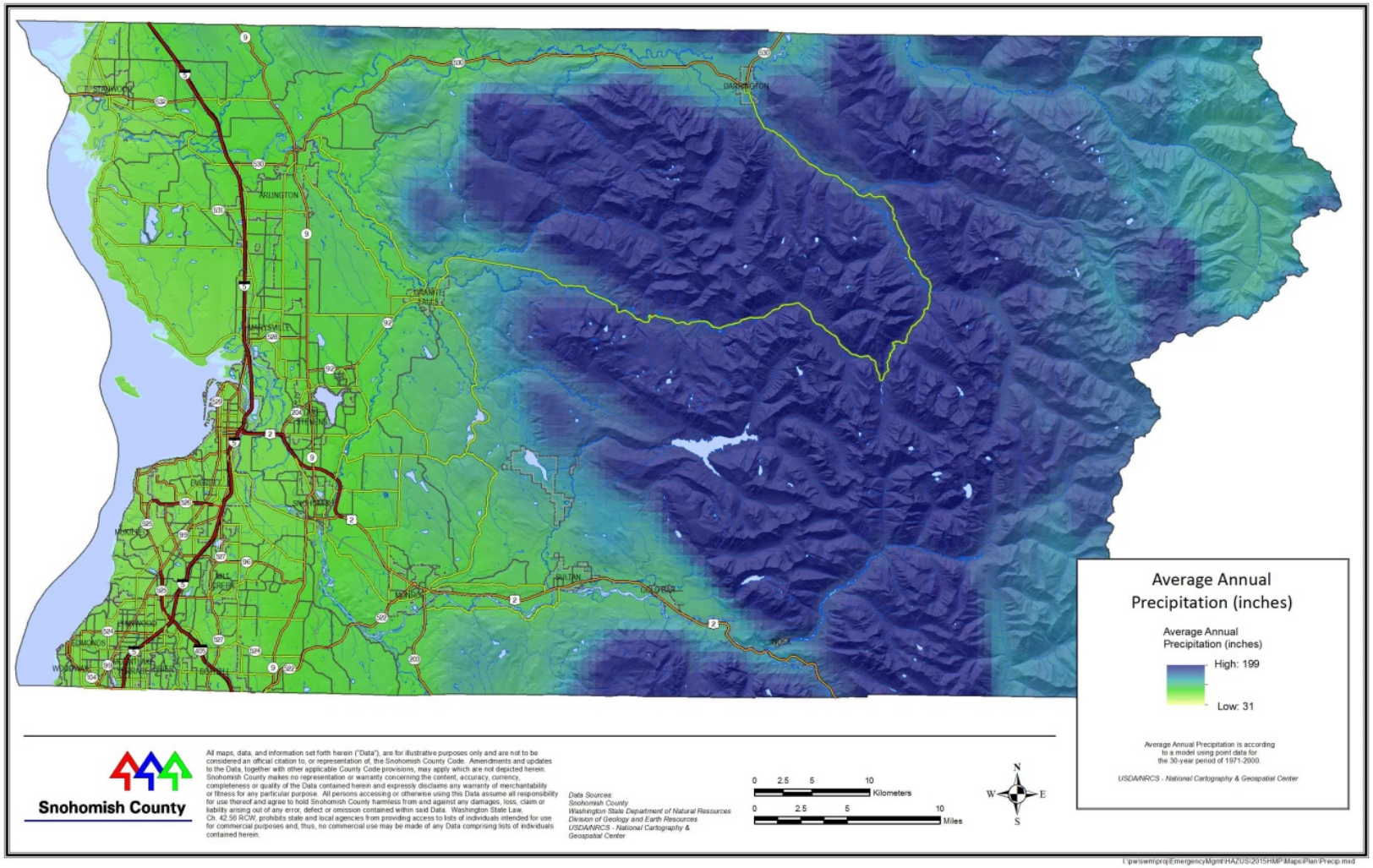
Although severe local storms are infrequent, impacts can be significant, particularly when secondary hazards of flood and landslide occur. A worst-case event would involve prolonged high winds during a snowstorm accompanied by freezing temperatures, followed by warmer weather and continued rain. Such an event would have both short-term and longer-term effects. Initially, schools and roads would be closed due to snow and downed tree obstructions. Power outages would be common throughout the county. In more rural areas, some subdivisions could experience limited ingress and egress. Later, as the weather warms and snow turns to rain, the sudden run-off could produce flooding, overtopped culverts with ponded water on roads, and landslides on steep slopes. Flooding and landslides could further obstruct roads and bridges, further isolating residents.

The most common severe storm system in Snohomish County usually occurs between early November and late February, bringing long periods of warm rainfall and mild temperatures following fairly heavy low-level snow. These storm patterns can cause widespread flooding and county-wide impacts, slowing response because services cannot be concentrated.

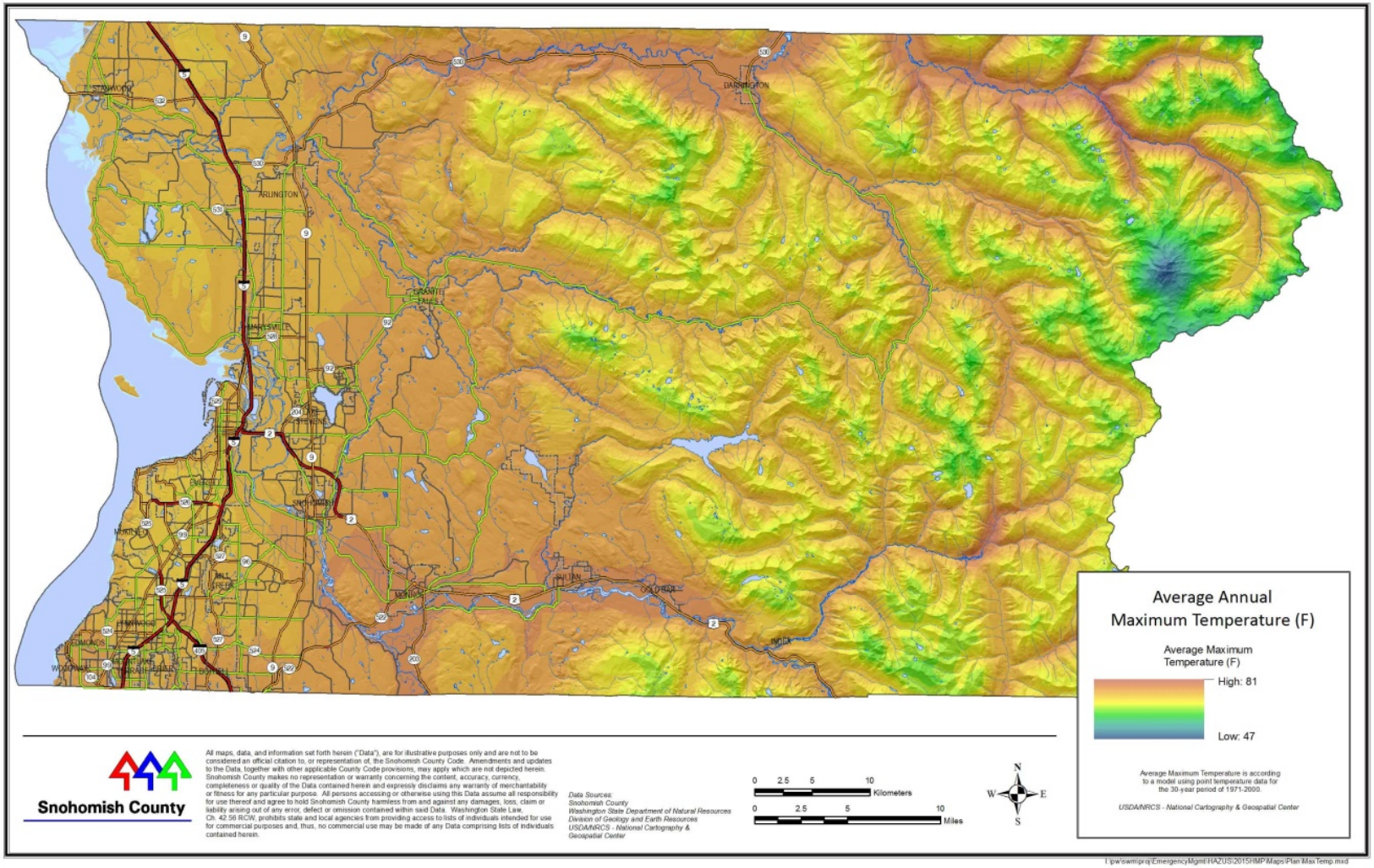
ISSUES

In general, every household and resident in the county is likely to be exposed to severe weather, but some are more likely than others to experience isolation as a result. Those residing in higher elevations with limited transportation routes may have the greatest vulnerability to isolation from storms. Another group at risk is the portion of the county population that is over the age of 65. Important issues associated with a severe weather event in the Snohomish county planning area include but are not limited to the following:

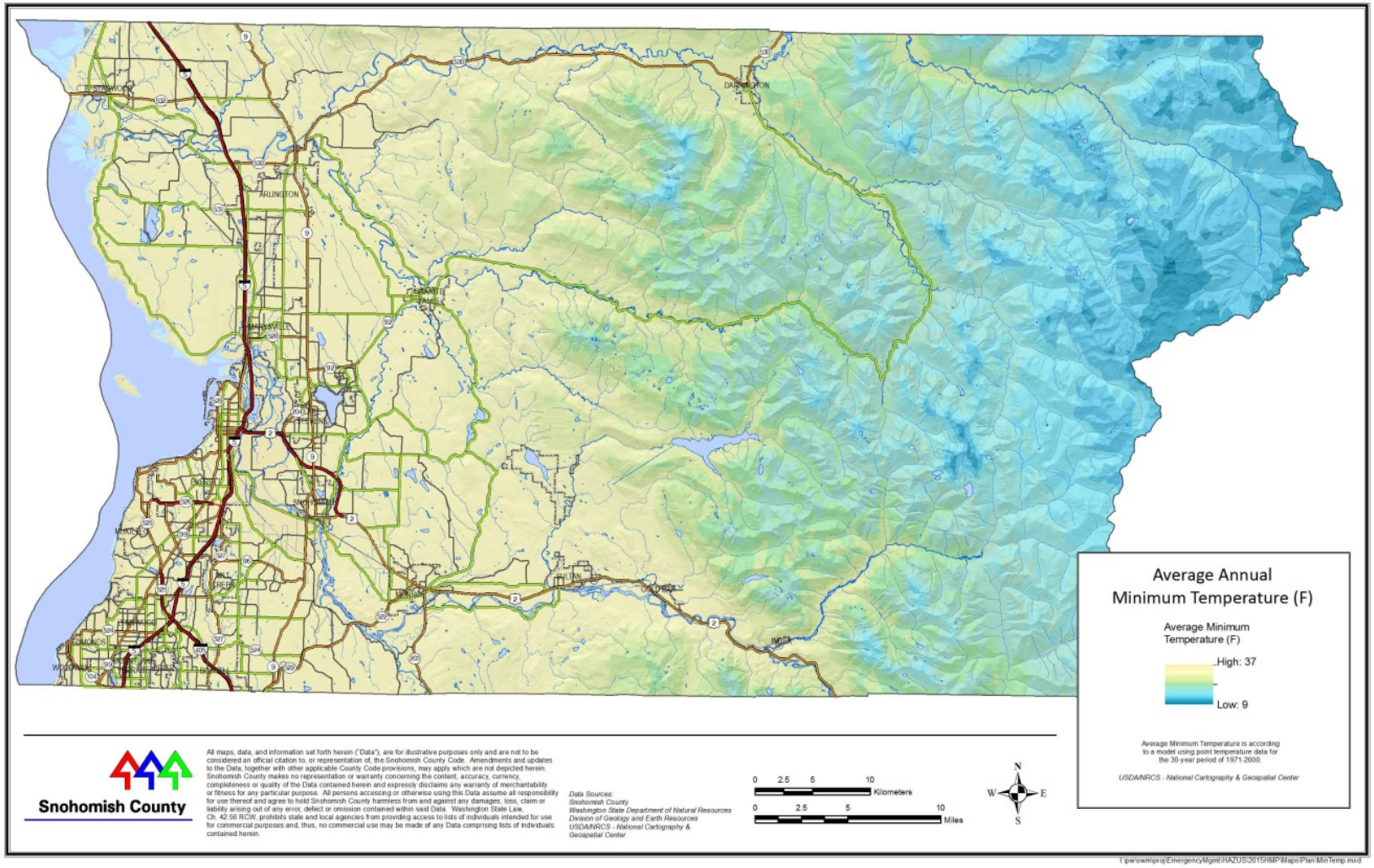
- The older building stock within the planning area is built to low code standards or none at all. These structures could be highly vulnerable to severe weather events such as windstorms.
- Redundancy of power supply must be evaluated.
- The capacity for backup power generation is limited.
- The county's capacity to deal with snow and ice removal is limited and reliant on outside sources.
- There are isolated population centers in the eastern portions of the county.



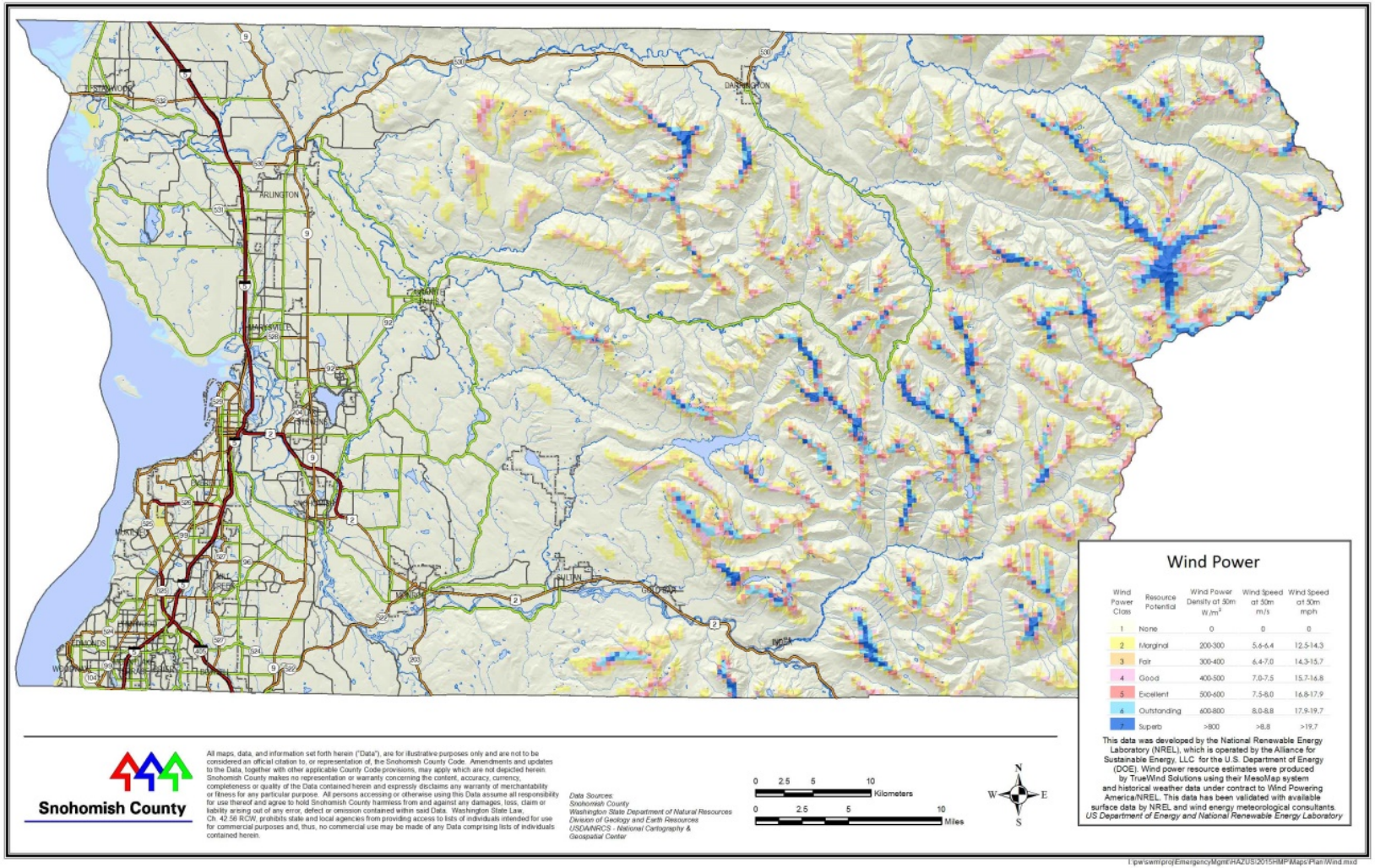
Map 9-1 Average Annual Precipitation



Map 9-2 Average Annual Maximum Temperature



Map 9-3 Average Annual Minimum Temperature



Map 9-4 Wind Power

Chapter 10: Volcano/Lahar

GENERAL BACKGROUND

The hazards related to volcanoes and volcanic eruptions are distinguished by the different ways in which volcanic materials and other debris flow from the volcano. The molten rock that erupts from a volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles.

HAZARD PROFILE

Glacier Peak in eastern Snohomish County is one of the major Cascade volcanoes. The mountain is thought to have erupted as recently as the eighteenth century. With the exception of Mount St. Helens, Glacier Peak has historically produced larger and more explosive eruptions than any other Washington volcano (Table 10-1). One event at Glacier Peak was more than three times the size of Mount St. Helens's 1980 eruption. Since the end of the last glacial episode about 14,000 years ago, Glacier Peak has erupted at least a dozen times.

Three major Cascade volcanoes other than Glacier Peak are relatively close to Snohomish County: Mount Rainier is 60 miles to the south, Mount St. Helens is 110 miles to the south, and Mount Baker is 35 miles to the north (Figure 10-1). Mount Adams, also 110 miles to the south but on the east side of the Cascade Range, poses a lower threat because of the direction of prevailing winds. Mount Hood in Oregon constitutes a low hazard because of distance, direction of prevailing winds, and evidence that its previous ash eruptions were confined to its immediate vicinity.

In the 1980 Mount St. Helens eruption, 23-square miles of volcanic material buried the North Fork of the Toutle River and there were 57 human fatalities. Prehistoric evidence of lahars of the sort experienced during the 1980 eruption of Mount St. Helens have been described by U.S. Geological Survey scientists studying Glacier Peak. Although a major volcanic debris flow is a rare occurrence, its potential volume and destructive force are such that the possibility deserves mention. The Town of Darrington and much of northeast Snohomish County could be affected by a large flow following the White Chuck and Sauk River drainage channels. An ancient lahar is responsible for diverting the flow of the Sauk from its original path to Puget Sound via the North Fork of the Stillaguamish, blocking it east of Darrington so that it was forced to capture the Skagit's headwaters.

DEFINITIONS

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

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

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

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

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

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

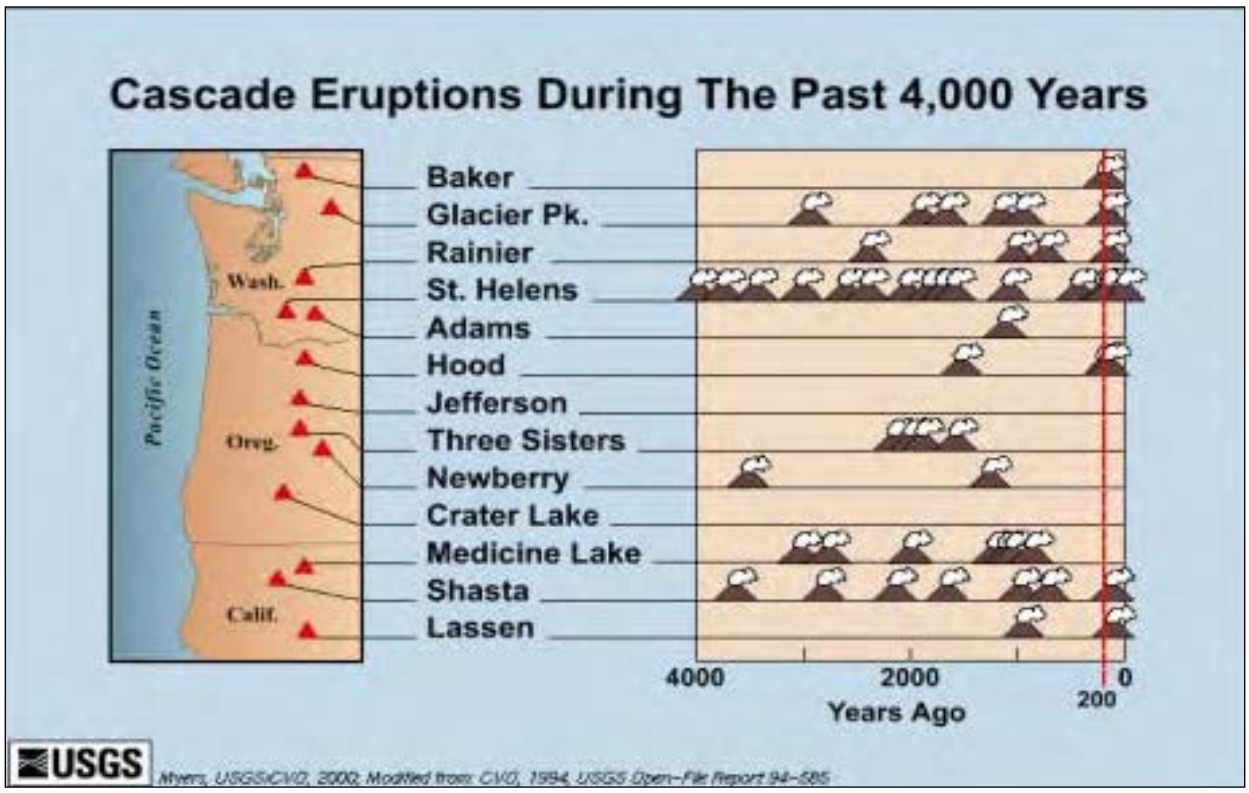


Figure 10-1 Past Eruptions in the Cascade Range

Figure 10-1 shows the location of the Cascade Range volcanoes, most of which have the potential to produce a significant eruption. The Cascade Range extends more than 1,000 miles from southern British Columbia into northern California and includes 13 potentially active volcanic peaks in the U.S. Map 10-1, at the end of the chapter, shows the Glacier Peak lahar inundation zone in Snohomish County.

Many Cascade volcanoes have erupted in the recent past and will be active again in the near future. Given an average rate of one or two eruptions per century during the past 12,000 years, these disasters are not part of our everyday experience; however, in the past hundred years, California's Lassen Peak and Washington's Mount St. Helens have erupted with terrifying results. The U.S. Geological Survey classifies Glacier Peak, Mount. Adams, Mount Baker, Mount Hood, Mount St. Helens, and Mount Rainier as potentially active volcanoes that would impact Washington State. Mount St. Helens is by far the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years.

The explosive disintegration of Mount St. Helens' north flank in 1980 vividly demonstrated the power that Cascade volcanoes can unleash. A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse. Ash is harsh, acidic, and gritty, and it has a sulfuric odor. Ash may also carry a high static charge for up to two days after being ejected from a volcano. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with the rain water to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose, and throat. Wind direction at the time of the eruption will significantly affect the amount of ash that falls in Snohomish County.

Constant monitoring of all active volcanoes means that there will be more than adequate time for evacuation before an event. Since 1980, Mount St. Helens has settled into a pattern of intermittent, moderate, and generally non-explosive activity, and the severity of tephra, explosions, and lava flows has diminished. All episodes, except for one very small event in 1984, have been successfully predicted several days to three weeks in advance. However, scientists remain uncertain as to whether the volcano's current cycle of explosivity ended with the 1980 explosion. The possibility of further large-scale events continues for the foreseeable future.

The secondary hazards associated with volcanic eruptions are mudflows and landslides.

CLIMATE CHANGE IMPACTS

Climate change is not expected to impact the hazards from volcanic eruptions. However, large-scale volcanic eruptions can reduce the amount of solar radiation reaching the Earth's surface, lowering temperatures in the lower atmosphere and changing atmospheric circulation patterns. The massive outpouring of gases and ash can influence climate patterns for years

EXPOSURE AND VULNERABILITY

Snohomish County is most exposed to a Glacier Peak eruption that generates a lahar that would travel down the Sauk, Stillaguamish, and Skagit Rivers and out to the ocean. All that is in the path of the lahar is potentially exposed to damage.

POPULATION

The entire population of Snohomish County is vulnerable to the damaging effects of volcanic ash fall in the event of a volcanic eruption. The elderly, very young, and those who experience respiratory problems are especially vulnerable to the tephra hazard. Approximately 14,609 people in the county reside in lahar zones.

PROPERTY

Most of the county would be exposed to ash fall and tephra accumulation in the event of a volcanic eruption. The most vulnerable buildings are those that are not as structurally sound and may collapse under the excessive weight of tephra and possible rainfall. 5,286 structures with an estimated value of $1.16 billion are located in the lahar zones. The majority of these properties are in unincorporated Snohomish County; the rest are in the Cities of Arlington, Darrington, and Stanwood.

CRITICAL FACILITIES AND INFRASTRUCTURE

Eighty-five critical facilities are at risk of lahar inundation. These include bridges that cross the Stillaguamish, Sauk, and Skagit Rivers in the lahar zone, as well as the section of the BNSF Railway where it crosses the Stillaguamish River and outflows from the Skagit River. All transportation routes are exposed to ash fall and tephra accumulation, which could create hazardous driving conditions on roads and highways and hinder evacuations and response. Four school facilities are exposed to lahar outflow zones. These facilities are located in Stanwood and Darrington. There are also three fire stations in the lahar outflow area.

Utilities are vulnerable to damage from lahars due to the debris that may be carried and the heat and ash of an eruption. Water treatment plants and wastewater treatment plants are vulnerable to contamination from ash fall and debris that may be carried by a lahar. Most vulnerable are those that are located on or near parcels that intersect with the lahar outflow area or those that receive input from area streams and rivers that lahars flow through.

ENVIRONMENT

Although a volcanic eruption is a natural event, it can significantly alter the local environment, including land form, air quality, and many other elements that could harm local vegetation and water quality. Snohomish County rivers and streams could be impacted by ash fall. The sulfuric acid contained in volcanic ash could be very damaging to area vegetation, waters, wildlife, and air quality. A lahar would dramatically impact surface water quality and change in water courses.

FUTURE TRENDS IN DEVELOPMENT

Lahar zones are not identified as “critical areas” as under the Washington State Growth Management Act. However, most of the lahar zones overlap the 100-year and 500-year floodplains in Snohomish County, which are identified critical areas under the GMA. Therefore, a mechanism is in place to manage development in lahar zones.

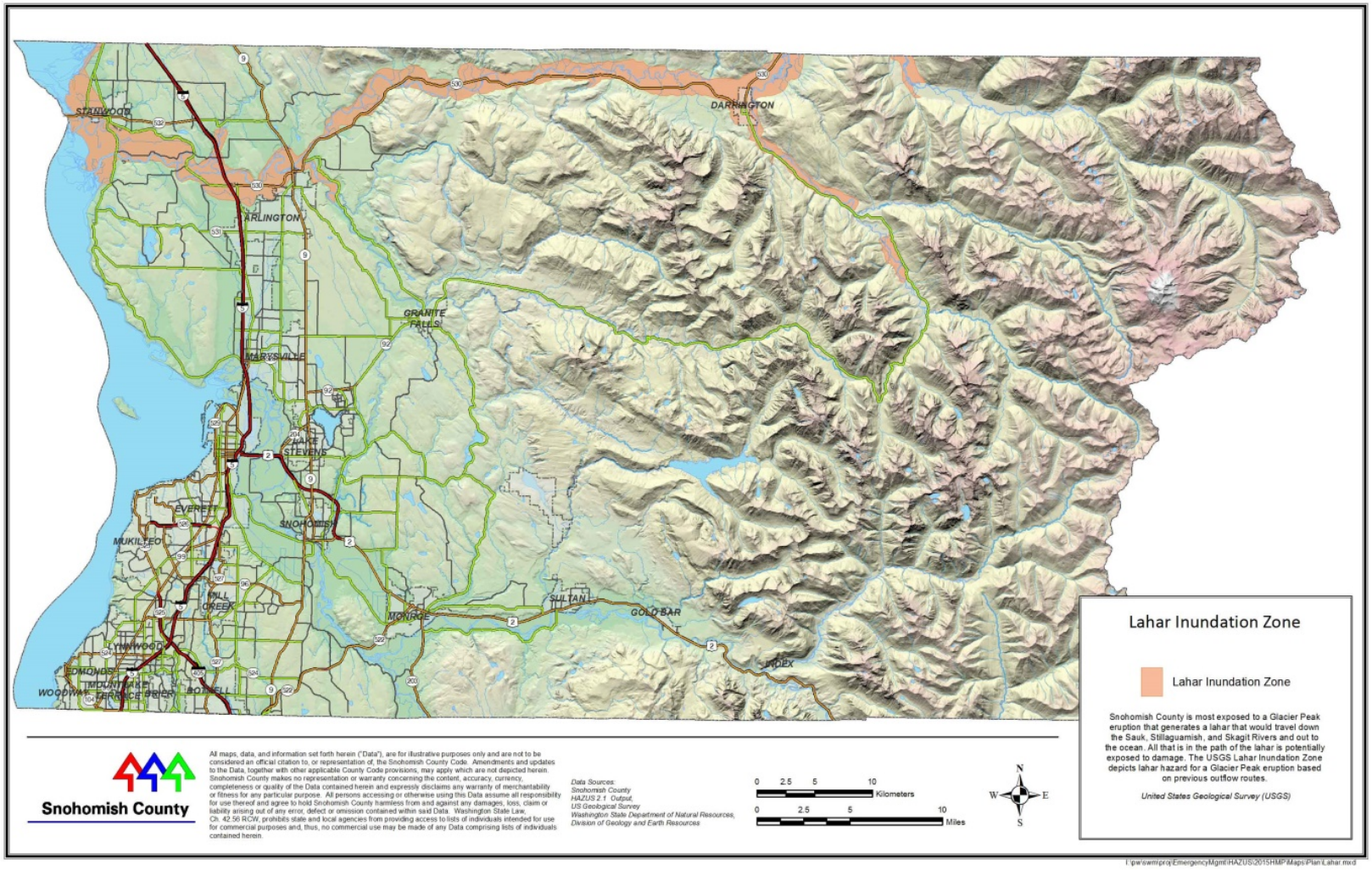
A more detailed volcano/lahar risk assessment is located in Chapter 17 of Volume 1.

SCENARIO

In the event of a volcanic eruption in Snohomish County, there would probably not be any loss of life, due to adequate warnings. However, there could be great loss of property, especially in Arlington, Darrington, Stanwood, and areas of unincorporated county. There would also be the possibility of severe environmental impacts due to lahar flows in area rivers and streams. A large area would be affected by ash fall. The most severe impacts would be on the environment.

ISSUES

Since volcanic episodes have been fairly predictable in the recent past, there is probably less concern about loss of life, but there is greater concern about loss of property, infrastructure, and severe environmental impacts.



Map 10-1 Lahar Inundation Zone

Chapter 11: Wildland Fire

GENERAL BACKGROUND

The wildland fire season in Washington usually begins in early July and ends with precipitation in late September; however, wildland fires have occurred in every month of the year. Drought, snow pack, and local weather conditions can expand the length of the fire season.

People start most wildland fires; major causes include arson, recreational fires that get out of control, smoker carelessness, debris burning, and children playing with fire. From 1992 to 2001, on average, people caused more than 500 wildland fires each year on State-owned or protected lands; this compares to 135 fires caused by lightning strikes. However, wildland fires started by lightning burn more State-protected acreage than any other cause, an average of 10,866 acres annually; human caused fires burn an average of 4,404 state-protected acres each year. Fires during early and late fire season usually are human-caused; fires during the peak period of July, August, and early September often are related to thunderstorms and lightning strikes.

How a fire behaves primarily depends on the following:

- **Fuel**—Lighter fuels such as grasses, leaves, and needles quickly expel moisture and burn rapidly, while heavier fuels such as tree branches, logs, and trunks take longer to warm and ignite. Snags and hazard trees—those that are diseased, dying, or dead—are larger but less prolific west of the Cascades than east of the Cascades. In 2002, about 1.8 million acres of the State's 21 million acres of forestland contained trees killed or defoliated by forest insects and diseases.

DEFINITIONS

Conflagration—A fire that grows beyond its original source area to engulf adjoining regions. Wind, extremely dry or hazardous weather conditions, excessive fuel buildup, and explosions are usually the elements behind a wildland fire conflagration.

Firestorm—A fire that expands to cover a large area, often more than a square mile. A firestorm usually occurs when many individual fires grow together into one. The involved area becomes so hot that all combustible materials ignite, even if they are not exposed to direct flame. Temperatures may exceed 1000°C. Superheated air and hot gases of combustion rise over the fire zone, drawing surface winds in from all sides, often at velocities approaching 50 miles per hour. Although firestorms seldom spread because of the inward direction of the winds, once started there is no known way of stopping them. Within the area of the fire, lethal concentrations of carbon monoxide are present; combined with the intense heat, this poses a serious life threat to responding fire forces. In very large events, the rising column of heated air and combustion gases carries enough soot and particulate matter into the upper atmosphere to cause cloud nucleation, creating a locally intense thunderstorm and the hazard of lightning strikes.

Interface Area—An area susceptible to wildland fires and where wildland vegetation and urban or suburban development occur together. An example would be smaller urban areas and dispersed rural housing in forested areas.

Wildland Fire—Fires that result in uncontrolled destruction of forests, brush, field crops, grasslands, and real and personal property in non-urban areas. Because of their distance from firefighting resources, they can be difficult to contain and can cause a great deal of destruction.

- **Weather**—West of the Cascades, strong, dry east winds in late summer and early fall produce extreme fire conditions. East wind events can persist up to 48 hours, with wind speed reaching 60 miles per hour; these winds generally reach peak velocities during the night and early morning hours.

- **Thunderstorm activity**—The thunderstorm season typically begins in June with wet storms and turns dry with little or no precipitation reaching the ground as the season progresses into July and August.

- **Terrain**—The topography of a region influences the amount and moisture of fuel; the impact of weather conditions, such as temperature and wind; potential barriers to fire spread, such as highways and lakes; and elevation and slope of land forms (fire spreads more easily uphill than downhill).

- **Time of Day**—A fire's peak burning period generally is between 1 PM and 6 PM.

Short-term loss caused by a wildland fire can include the destruction of timber, wildlife habitat, and scenic vistas. Vulnerability to flooding increases due to the destruction of watersheds. Long-term effects include smaller timber harvests, reduced access to affected recreational areas, and destruction of cultural and economic resources and community infrastructure.

HAZARD PROFILE

Since 1979, Snohomish County has experienced only two forest fires of 100 acres or more. A 750-acre fire in the Marblemount area during the El Niño summer of 1997 was attributed to a lengthened growing season, warmer-than-normal temperatures, and heavy windfalls from the previous year's storms. There is no record of any large wildland fires (greater than 1,500 acres) in the county since 1900.

Wildland fires historically were not considered a hazard, as fire is a normal part of most forest and range ecosystems in the temperate regions of the world, including Snohomish County. Fires historically burn on a fairly regular cycle, recycling carbon and nutrients stored in the ecosystem and strongly affecting the species within the ecosystem. The burning cycle in western Washington is every 100 to 150 years. Controlled burns have also been conducted because the fire cycle is an important aspect of management for many ecosystems. These are not considered hazards unless they get out of control. None of Washington State's most significant wildland fires have occurred in Snohomish County, although smaller wildland fires have occurred in the region.

LOCATION

Map 11-1 shows wildland urban interface areas (WUIAs) for Snohomish County as defined by the DNR (June 2009). This map is based on data from the current National Fire Protection Association risk assessment (NFPA 299).

WUIAs tend to be in the foothills and valleys east of Puget Sound stretching into the lower reaches of the Cascades, where people are present in semi-urban densities. Wildland fire analysis has been done using WUIA data created by the DNR, which analyzed areas with population densities of at least 20 people per square mile, defensible space, access and ingress, water capabilities, fuel supply, weather and topography, and speed of response.

FREQUENCY

According to data tracked by the DNR on lands that it is responsible for protecting, Snohomish County has had 905 wildland fire incidents since 1970. This is an average of a little over 20 per year, with a high of 45 incidents in 1974 and 1990 and a low of 1 incident in 1971.

SEVERITY

Potential losses from wildland fire include human life, structures and other improvements, and natural resources. There are no recorded incidents of loss of life from wildland fires in Snohomish County, and the risk from wildland fire has been deemed moderate by the State. Given the immediate response times to reported fires, the likelihood of injuries and casualties is minimal. Smoke and air pollution from wildland fires can be a health hazard, especially for sensitive populations including children, the elderly, and those with respiratory and cardiovascular diseases. Wildland fire may also threaten the health and safety of those fighting the fires. First responders are exposed to the dangers from the initial incident and after-effects from smoke inhalation and heat stroke. In addition, wildland fire can lead to ancillary impacts, such as landslides in steep ravine areas and flooding due to the impacts of silt in local watersheds.

The potential for large wildland fires in Snohomish County is normally small. Improved fire spotting techniques, better equipment, and trained personnel are major factors, as are the county's wet climate and normally low fire fuel conditions. The wet climate and the infrequent occurrence of strong, dry winds prevent potential fuel from reaching a combustible state. Snohomish County's forests retain moisture and are resistant to an abnormal dry spell.

WARNING TIME

Because wildland fires are typically caused by humans, there is no way to predict when one might break out. Since it is reported that fireworks often cause brush fires, extra diligence is warranted around the Fourth of July when the use of fireworks is highest. Dry lightning may also trigger wildland fires. Severe weather can be predicted, so special attention can be paid during weather events that may trigger wildland fires. If a fire does break out and spreads rapidly, residents may need to evacuate within days or hours. Reliable National Weather Service lightning warnings are available on average 24 to 48 hours prior to a significant electrical storm. Dry seasons and droughts are factors that greatly increase fire likelihood. Once a fire has started, fire alerting is reasonably rapid in most cases. The rapid spread of cellular and two-way radio communications in recent years has further contributed to a significant improvement in warning time.

SECONDARY HAZARDS

Wildland fires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable timber and indirect economic losses in reduced tourism. Wildland fires cause the contamination of reservoirs, destroy transmission lines, and contribute to flooding. They strip slopes of vegetation, exposing them to greater amounts of runoff. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildland fire. Most wildland fires burn hot and for long durations that can bake soils, especially those

high in clay content, thus increasing the imperviousness of the ground. This increases the runoff generated by storm events, thus increasing the chance of flooding.

CLIMATE CHANGE IMPACTS

Fire in western ecosystems is determined by climate variability, local topography, and human intervention. Climate change has the potential to affect multiple elements of the wildland fire system: fire behavior, ignitions, fire management, and vegetation fuels. Hot dry spells create the highest fire risk. Increased temperatures may intensify wildland fire danger by warming and drying out vegetation. Change in temperatures also may increase disease in forests, which would lead to increases in fuel load. When climate alters fuel loads and fuel moisture, forest susceptibility to wildland fires changes. Climate change also may increase winds that spread fires. Faster fires are harder to contain and thus are more likely to expand into residential neighborhoods.

Warming is projected under all climate scenarios in the Pacific Northwest. Under a high greenhouse gas emissions scenario, by 2050 average annual temperatures are projected to increase between 3.1°F and 8.5°F, with much greater warming possible after mid-century. This warming is expected to occur during all seasons, with greater warming during the summer. Climate models also project an increased frequency of extreme heat events and a decrease of extreme cold events (Snover et al., 2013). An average, for a low and high greenhouse gas scenario, indicates a -6 to -8 percent respective decrease in summer precipitation by 2050. However, individual model projections show as much as a 30 percent decrease during summer and an increase of winter, spring, and fall precipitation.

Such conditions would exacerbate summer drought and further promote high-elevation wildland fires, releasing stores of carbon and further contributing to the buildup of greenhouse gases. Forest response to increased atmospheric carbon dioxide—the so-called “fertilization effect”—could also contribute to more tree growth and thus more fuel for fires, but the effects of carbon dioxide on mature forests are still largely unknown. High carbon dioxide levels should enhance tree recovery after fire and young forest regrowth, as long as sufficient nutrients and soil moisture are available, although the latter is in question for many parts of the western United States because of climate change.

EXPOSURE AND VULNERABILITY

POPULATION

All residents of the county are vulnerable to wildland fire to some degree, but particular segments are more vulnerable than others. An estimated 127,784 people are living in WUIAs. This represents 17.9 percent of the total county population.

PROPERTY

Property damage from wildland fires can be severe and can significantly alter entire communities. The unincorporated county and the Cities of Arlington, Darrington, Gold Bar, Granite Falls, Index, Marysville, Monroe, Snohomish, Stanwood, and Sultan all have assets exposed to wildland fire hazards. The total value of these assets

is $9.72 billion, which represents 10.5 percent of the total assessed value of improvements in the county. Some land uses are more vulnerable to wildland fire, such as single-family rural residential, while others are less vulnerable, such as agricultural land, gravel mining, and cemeteries.

CRITICAL FACILITIES AND INFRASTRUCTURE

Critical facilities exposed to the wildland fire hazard in the county include health services, governments, protective services, schools, power, bridges, and water facilities. Critical facilities that are of wood-frame construction are especially vulnerable during wildland fire events. In the event of wildland fire, there would likely be little damage to the majority of infrastructure. Most roads and railroads would be without damage except in the worst scenarios. Fires can create conditions that block or prevent access throughout the county and can isolate residents and emergency service providers needing to get to vulnerable populations or to make repairs. Wildland fire typically does not have a major direct impact on bridges unless they are made of wood. However, wildland fires can create conditions in which bridges are obstructed. Many bridges in areas of high to moderate fire risk are important because they provide the only ingress and egress to large areas and in some cases to isolated neighborhoods.

Power lines are the most at risk from wildland fire because most poles are made of wood and susceptible to burning. GIS analysis shows 66 sections of Puget Sound Energy transmission lines in Snohomish County. A total of 11 sections cross fire risk areas and could be vulnerable during a fire event.

In the event of a wildland fire, pipelines could provide a source of fuel and lead to a catastrophic explosion. Currently, there are 27 registered Tier II hazardous material containment sites in WUIAs. During a wildland fire event, these materials could rupture due to excessive heat and act as fuel for the fire, causing rapid spreading and escalating the fire to unmanageable levels. In addition, they could leak into surrounding areas, saturating soils and seeping into rivers or into Puget Sound, and have a disastrous effect on the environment.

ENVIRONMENT

Wildland fires can cause severe environmental impacts:

- Damaged Fisheries—Critical trout, salmon, and steelhead fisheries in the Pacific Northwest can suffer from increased water temperatures, sedimentation, and changes in water quality.
- Soil Erosion—The protective covering provided by foliage and dead organic matter is removed, leaving the soil fully exposed to wind and water erosion. Accelerated soil erosion occurs, causing landslides and threatening aquatic habitats.
- Spread of Invasive Plant Species—Non-native woody plant species frequently invade burned areas. When weeds become established, they can dominate the plant cover over broad landscapes and become difficult and costly to control.
- Disease and Insect Infestations—Unless diseased or insect-infested trees are swiftly removed, infestations and disease can spread to healthy forests and private lands. Timely active-management actions are needed to remove diseased or infested trees.

- Destroyed Endangered Species Habitat—Catastrophic fires can have devastating consequences for endangered species. For instance, the Biscuit Fire in Oregon destroyed 125,000 to 150,000 acres of spotted owl habitat.

- Soil Sterilization—Topsoil exposed to extreme heat can become water repellant, and soil nutrients may be lost. It can take decades or even centuries for ecosystems to recover from a fire. Some fires burn so hot that they can sterilize the soil.

FUTURE TRENDS IN DEVELOPMENT

Per the State's Growth Management Act, the county concentrates new development in urban areas, with limited development in rural areas—minimizing development that could increase incident risk from wildland fires.

A more detailed wildland fire risk assessment is located in Chapter 18 of Volume 1.

SCENARIO

Where interface development increases, a wildland fire in Snohomish County has the potential to cause even greater damage than the Marblemount fire. A twenty-first century firestorm could burn an area approaching the size of the Marblemount burn, but because of increased development in the area, it would destroy much more property and put more lives at risk.

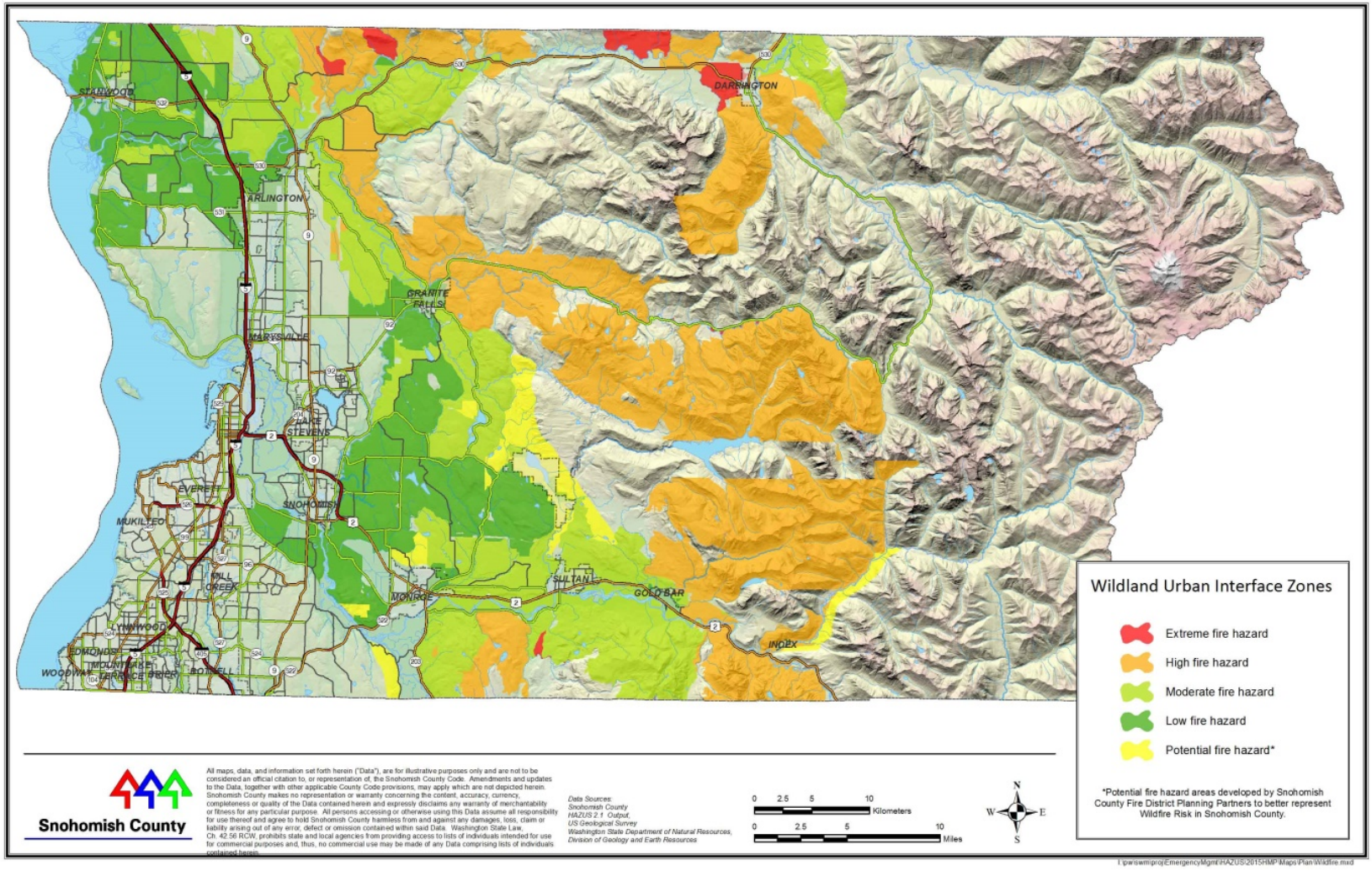
The worst-case scenario in Snohomish County would probably coincide with an active fire season in the entire American west, spreading resources thin. "Hot shot" teams could be unavailable to assist Snohomish County. Many federal assets would likely be responding to other fires that started earlier in the season. While local fire districts would be effective in the urban interface areas, they have limited wildland firefighting capabilities and experience, and they would have a difficult time responding to the ignition zones.

To further complicate the problem, heavy rains could follow, causing flooding and landslides and releasing tons of sediment into rivers, permanently changing the floodplains of the county and damaging sensitive habitat and riparian areas. Such a fire followed by rain could release millions of cubic yards of sediment into streams for years, creating new floodplains and changing existing ones. With the forests removed from the watershed, discharges could double. Floods that could be expected every 50 years may occur every couple of years. And, with streams unable to carry this increased discharge because of increased sediment, floodplains and floodplain elevations would increase. Construction along Snohomish County rivers has been increasing proportionally faster than that of the county as a whole. Due to the increase of homes built in the floodplain, flood impacts would increase substantially. Indirect and longer-term economic losses are difficult to predict, but could double the price tag for such an event.

ISSUES

The major issues of wildland fire are the following:

- Critical facilities and other structures that are wood-frame structures in wildland urban interface areas with combustible roofing materials.
- The perception of wildland fires as a low risk hazard because a major event has not occurred within the planning area.
- Climate change could impact the risk exposure to this hazard in the future.



Map 11-1 Wildland Fire Hazard Areas

Chapter 12: Area-Wide Mitigation Initiatives

SELECTED COUNTY-WIDE MITIGATION INITIATIVES

The planning partners and the Planning Committee determined that some mitigation initiatives in the catalog could be implemented county-wide to provide hazard mitigation benefits throughout the planning area. The Planning Committee determined that all county-wide initiatives identified in the initial plan were still relevant to the goals and objectives of the planning partnership and should be carried over to this updated plan. Additionally, in this update, the Snohomish county-specific initiatives were combined with the county-wide initiatives and are listed below.

For more information, HMP Volume 1 identifies hazards addressed, objectives supported and the county department that would lead implementation, funding sources, and period of implementation for each initiative. HMP Volume 1 also contains benefit-cost analysis and prioritization of the mitigation Initiatives. HMP Volume 2 contains planning partner mitigation initiative information in the jurisdictional annexes.

COUNTY-WIDE MITIGATION STRATEGY MATRIX

HAZARD MITIGATION ACTION PLAN MATRIX
CW-1—Retrofit critical facilities that cannot be moved to low risk areas.
Actions: Reduce risk to critical facilities in higher risk areas where relocation is not practicable and where life safety can be assured. 1. Support retrofitting to assure life safety and the functionality of critical facilities post disaster. 2. Elevate structures prone to increased frequency of flooding. 3. Determine the appropriate retrofitting approaches using best available science. 4. Conduct a seismic retrofit of the Snohomish County Courthouse complex (four buildings). 5. Implement structural and non-structural mitigation measures to reduce risk to vulnerable buildings and critical facilities at Paine Field Airport. 6. Retrofit, rehabilitate, or replace vulnerable road and bridge facilities and infrastructure throughout Snohomish County (includes replacement/retrofit of vulnerable bridge at May Creek (#559), provide soil stabilization at Waldheim Slide (MP 20.6) and Marten Creek (MP 21) to reduce erosion risk).

CW-2—Enhance and improve capital improvement programs, taxing, zoning, and development approaches to promote mitigation and reduce exposure/vulnerability to natural hazards.
Actions: 1. Promote development in low risk areas (General Policy Plan growth centers). a. Conduct a pre-disaster gap analysis for growth centers to identify the required provisions that need to be in place before a disaster for the growth centers to function to their full supportive capability. b. Develop approaches that reduce the pressure to develop or redevelop in high risk areas yet allow property owners to retain value to properties. (Purchase or transfer development rights from high risk areas that are not location-dependent to areas of minimal risk or where risks can be mitigated to tolerable levels.) c. Require deferral permit fees for risk-reducing development. (The local governments may even be able to secure alternative funding during the referral period and can perhaps reduce or waive the fees at the time of collection if they are not covered by private insurance.) d. Offer expedited permitting and prioritization for development within a growth center. (This would encourage use of the TDR program by homeowners within vulnerable locations to relocate to safer areas where they would be given access to rapid permitting and perhaps other incentives. Reconstruction is an ideal time to mitigate future hazard damages.) 2. Support the retrofitting of structures in land uses that are location-dependent or where locating to lower risk areas is not practicable. a. Adopt higher building standards commensurate with higher risks (such as added flood freeboard) where practicable. b. Evaluate the permitting process for opportunities to incentivize improved building practices. 3. Make greatest use of the post-disaster environment to advance the comprehensive plan and increase community safety. a. Consider more stringent building standards commensurate with higher risks (added flood freeboard) where practicable. b. Work with or create (e.g., Map-Your-Neighborhood) neighborhood organizations within risk areas to discuss risk reduction mitigation measures. c. Evaluate the permitting process for opportunities to incentivize improved building practices. 4. Seek land acquisition opportunities for open space use and preservation in areas of high vulnerability due to multiple-risk exposure.

CW-3—Create and enhance public information programs that will result in actionable preparedness and mitigation measures.

Actions:

1. Encourage emergency preparedness kits (3 to 10 days survival) and programs (CERT, SNAP, etc.).
   a. Have an earthquake plan
   b. Store food and water
   c. Supply of medicine
   d. Emergency radio (NOAA weather radio)
2. Arrange household meeting place.
3. Have hazards insurance.
4. Designate evacuation plan.
5. Know how to shut off gas/water. (earthquake)
6. Know first aid.
7. Address concerns of elderly and infirm.
8. Manage emergency communications.
9. Store heavy objects on floor. (earthquake)
10. Store critical objects above/outside of flood prone area. (flooding)
11. Secure moveable items. (earthquake)
12. Keep heavy objects off walls above and near beds. (earthquake)
13. Secure objects. (earthquake)
14. Retrofit home/office.
15. Distribute risk information and hazard mapping on websites.
16. Map and maintain critical transportation routes. (government).
17. Maintain and improve hazard monitoring and early warning systems. (government)

CW-4— Promote community's ability to self-organize by developing social capital through strengthening of community networks. Strong neighborhoods can help promote risk reduction.

Actions:

1. Promote a “Map-Your-Neighborhood” program.
2. Encourage meeting places within neighborhoods.
3. Connect neighborhoods by increasing walkability and increased connectivity of walkable and bikeable networks.
4. Inform and educate the public on hazard mitigation and preparedness via a county-operated website.

CW-5—Research the possibility of developing functional neighborhood-based micro infrastructure networks (micro grids) including the diversification, decentralization, and redundancy of utilities. Such systems have increased operational resilience, decreased carbon emissions, and decreased life-cycle costs.

Actions:

1. Establish and lead infrastructure partner/stakeholder committee to prioritize and guide research.
2. Research the following micro infrastructure networks: electrical grids, water, telecommunication, and waste systems.

CW-6—Preserve and strengthen communication systems.
Actions: 1. Solar-powered community radio system 2. VHF regional emergency radio system 3. Protection of fiber optic cables

CW-7—Support HMP and integrate HMP with other planning mechanisms such as the Growth Management Act. (The Hazard Mitigation Plan is driven by risk and is advisory. Other plans have legal standing and affect action. These legal plans should adopt sections of the HMP that strengthen their mission.)
Actions: 1. Integrate the HMP with the following plans and mechanisms: a. Comprehensive Plan b. Capital Improvements Plan c. Critical Areas Ordinances d. Shoreline Master Plan e. Other applicable mechanisms 2. Continue support, maintenance, improvement, and implementation of HMP. a. Update hazard, risk, and vulnerability information incorporating best available science and enhanced technology. b. Improve risk assessment and monitoring capabilities. c. Use scenario planning methods to identify future potential risks within county. d. Maintain a natural hazards informational website. e. Monitor implementation of the plan by Planning Committee. 3. Support and increase local governments' capacity for hazard mitigation planning. a. Increase technical capacity. b. Coordinate and provide technical assistance to jurisdictions for grant eligible projects. 4. Provide intergovernmental coordination and partnership opportunities. 5. All planning partners that committed to the update effort will formally adopt this plan once pre-adoption approval has been granted by Washington Emergency Management and FEMA Region X. Additionally, each planning partner will adhere to the plan maintenance protocol identified in chapter 7 of the plan. All actions under this initiative will be coordinated by DEM.

CW-8—Develop Departmental continuity of operations plans and neighborhood-based continuity plans (small businesses and neighborhoods).
Actions: 1. Provide incentives, such as neighborhood grants, for high-risk neighborhoods to develop plans.

CW-9—Provide incentives for eligible non-profits and private entities, including homeowners, to adapt to risks through structural and nonstructural retrofitting.
Actions: 1. Provide retrofitting information and technical expertise to organizations. 2. Develop special retrofitting loan packages with banks. 3. Work with neighborhood organizations to inform homeowners of retrofit options, through special-purpose events such as block parties. 4. Develop home-based government loan and or grant programs for communities with higher risks.

CW-10—Assure that services provided by critical facilities, including medical and emergency services, are available to at-risk communities with special emphasis on communities at risk of isolation.
Actions: Give a higher priority within capital improvement budgets, grant programs, or other funding sources to: 1. Relocate or retrofit vulnerable emergency operation centers, medical facilities, and other critical facilities serving communities at risk of isolation during an event. 2. Provide alternative access to critical facilities. 3. Establish and maintain backup or redundant power sources. 4. Strengthen community networks. 5. Relocate county-owned critical facilities out of identified high hazard risk zones.

CW-11—Map avalanche hazard areas and determine risk to residential, business, and public buildings and transportation routes.
Actions: 1. Identify and map release and run-out zones where evidence of avalanche has occurred. 2. Map areas with slopes greater than 20 degrees (emphasis on slopes from 25 to 55 degrees) and potential run-out zones.

CW-12— Increase public awareness of the avalanche hazard and promote instructional (actionable) guidance.
Actions: 1. Expand programs like “Are you beeping" winter trailhead program to winter ski and hiking trails with known avalanche risk.

CW-13— Demonstrate leadership in greenhouse gas emissions reductions through leading by example and working with stakeholders.

Actions:

Climate change is occurring and is increasingly presenting challenges to all natural hazards. It is the county's intention to build resilience into policies, programs, projects, and infrastructure. This Plan supports efforts to reduce greenhouse gas emissions while adapting to climate change impacts. Many climate change adaptation measures include mitigation alternatives presented in this Plan.

1. Continue implementation of Sustainable Operations Action Plan (SOAP).
2. Establish collaborative workgroup of county departments, municipal governments in the county, and organizations that provide public services to focus on implementation of strategies to reduce greenhouse gas emissions and adapt to changing climate. Many climate change adaptation measures include mitigation alternatives presented in this Plan.

CW-14—When updating the Comprehensive Plan and other plans, evaluate decisions through a climate change impact lens. (Many plans are based on historic information. This is particularly evident with flood projections. This practice can lead to inaccurate projections and plans that do not address future needs.)

Actions:

1. Consider best available climate science modeling in comprehensive planning efforts.

CW-15—Adopt and implement land use and transportation policies, termed "Centers" in the General Policy Plan, that reduce greenhouse gas emissions.

Actions:

Measures that reduce greenhouse gas emissions include the following:

1. Continue to support Transit Oriented Development (TOD).
2. Improve bike, pedestrian, and transit infrastructure.
3. Install electric car charging stations.
4. Encourage Leadership Energy and Environmental Design (LEED) construction and low-impact development (LID).
5. Adopt low-carbon fuels
6. In cooperation with the cities and towns, create urban developments which provide a safe and desirable environment for residents, shoppers, and workers.

CW-16— Plan and prepare for climate impacts using best available science.

Actions:

1. Conduct a study in collaboration with local jurisdictions to identify critical infrastructure that may be impacted due to climate change.
2. Use scenario planning to assess impacts from most current climate projections.
3. Upgrade/relocate county buildings and infrastructure to protect and prepare for sea-level rise, flooding, and storm events from climate change.
4. Prepare for sea-level rise throughout the county.
5. Promote water conservation to minimize impacts of drought.

CW-17—Improve hazard mitigation planning for dam and levee failure.
Actions: 1. Identify high-risk dams and levees. 2. Map the failure inundation areas for high-risk dams and levees. 3. Create dam and levee failure action plans.

CW-18—Improve dam and levee failure warning for vulnerable communities.
Actions: 1. Upgrade dam failure warning system in compliance with CRS requirements. 2. Establish levee failure warning system.

CW-19—Consider flood control structure maintenance that restores and maintains hydrologic ecosystems services of flood plains where feasible.
Actions: 1. Reestablish and maintain healthy riparian areas and, where possible, consider setbacks and the use of bioengineering techniques where it is not feasible to decommission existing flood control structures. 2. Prohibit new dikes, levees, floodgates, pump stations, culverts, dams, water diversions, and other alterations in the floodplain unless it has been demonstrated that no feasible alternative exists. 3. Consider a policy promoting the spreading of flood flows over developed land where flood risks can be accommodated. This would be a preferred alternative to the construction of ever higher and higher levees. This strategy would be appropriate where there are climate-change-predicted increases in the occurrences of more frequency, lower depth, and low-velocity events.

CW-20—Maintain levees where accommodation through elevation and other flood risk-reduction measures is not possible.
Actions: 1. Consider the benefits and life-cycle costs of removing flood-prevention structures and instituting an adaptive strategy for vulnerable land uses.

CW-21—Support improved data collection and distribution for Glacier Peak seismic activity.
Actions: Improve early warning of eruption and lahar flow. Glacier Peak is the second most active volcano in the region and has the least number of monitoring stations, one. There are plans to increase monitoring of the mountain; however, they have been delayed in recent years due to sequestration. 1. Coordinate with U.S. Geological survey staff to identify actions the county can take to accelerate new monitoring station installation and integration into public emergency notification mechanisms.

CW-22—Update and improve county flood hazard risk assessment data and methodology.
Actions: 1. Adopt improved DFIRMs. 2. Use best available science to assess changes in flood impacts due to climate change. 3. Continue to participate and improve rating in the NFIP and CRS. 4. Participate in RiskMAP program. 5. Work with the City of Bothell and the National Weather Service (NWS) Seattle Weather Field Office (WFO) to develop a flood stage for the North Creek stream gauge at 228th Street SE. Include development of flood phase's 1, 2, 3, 4 with corresponding property damages and loss of use with each flood stage identified. 6. Work with the UW Atmospheric Sciences department and Seattle Public Utilities to expand the "rain watch" products north of the City of Seattle. This would include integration of King County and Snohomish County rain gauges with the NWS Camano Island Radar to fine-tune precipitation monitoring as well as predictions for the I-5 corridor to Arlington. 7. Enhance the Flood Warning System on major rivers within Snohomish County including strengthening the computer interface and upgrading and increasing the number of weather stations.

CW-23—Improve community ability to respond to a flood event.
Actions: 1. Annually disseminate flood hazard information brochure to all floodplain-area households. 2. Upgrade/improve flood hazard warning based on CRS requirements. 3. Expand the Storm Ready program in Snohomish County to include more sites around the county.

CW-24—Promote strategies that accommodate flooding with minimal consequences within flood prone areas where risks are not life threatening.
Actions: Measures to accommodate flood waters with minimal consequence include: 1. Elevate homes above flood levels. 2. Locate critical services out of the flood area. 3. Exploit ecosystem services/benefits of open spaces, parkways, and forested lands to reduce water velocity, control debris, and hold water. 4. Protect flood waters from the discharge of household pollutants. 5. Provide emergency access. 6. Relocate or retrofit "repetitive flood-loss" properties and those at risk to channel migration.

CW-25—Enable communities to recover development value of properties as they become more frequently flooded resulting from reduced upstream storage (e.g., increased development, reduced snowpack caused by climate change).

Actions:

1. Continue acquisition of "repetitive loss" properties.
2. Expand county TDR/PDR program to include all high flood risk areas as sending areas. (See mitigation strategy **CW-2.**)

CW-26—Preserve and restore floodplain and watershed ecosystem functions and services. Functioning ecosystems provide flood risk-reducing co-benefits. Such benefits can include storing water, reducing damaging flows, containing debris, recharging aquifers, and removing pollutants.

Actions:

1. Continue compliance with the Shoreline Master Plan and Growth Management Act Programs.
2. Implement salmon recovery plans and Sustainable Lands Strategy (SLS) (e.g., watershed-based hydrologic management plan as identified in SLS). These plans include the following measures that preserve and restore hydrologic ecosystem services:
    a. Support forestry and farming resource area uses through tax and other incentives.
    b. Exempt forestry and farming activities from nuisance complaints to allow for full provisioning of ecosystem services.
    c. Preserve and protect open space and agricultural land.
    d. Restrict urban growth to non-flood prone areas unless expansion facilitates habitat restoration or open space acquisition
    e. Discourage new development and increased densities, both public and private, within riparian areas, channel migration zones, and marine shorelines wherever feasible.
    f. Decommission and treat select roads.
    g. Restore forested land cover.
    h. Restore natural hydrological and biological function to the floodplain and along shorelines.
3. Promote enhanced native vegetation along shorelines.
4. Implement storm water management to prevent land use-caused increases in flood levels and restore floodplain function. Methods may include the following:
    a. Monitor all stormwater and pumping station sites.
    b. Retrofit and repair stormwater conveyance infrastructure to restore floodplain function and maintain ecosystem services.
    c. Develop regional stormwater management plan.
    d. Continue to improve and upgrade stormwater facilities.
    e. Replace existing failed drainage system with adequately sized culvert at 22510 Cherry Valley Road.
    f. Construct bridges to replace undersized culverts at Mann Rd (MP 1.53) and Mt. Loop (MP 13.620029 to reduce flood risk.

CW-27—Utilize innovative methods to reduce increasing peak flood flows.
Actions: 1. Consider off-channel water storage. 2. Disperse retention of stormwater higher in watershed via: a. Installing snow fences b. Re-introducing beaver into watersheds, where practicable c. Constructing retention facilities

CW-28—Develop coordinated flood control district that has the ability to tax for flood control improvements.
Actions: 1. Establish and lead exploratory committee of stakeholders to identify issues that would need to be resolved and oversee coordinated flood control district development.

CW-29—Isolate wastewater infrastructure from storm and flood waters.
Actions: 1. Protect wastewater facility from ground water infiltration. 2. Seal wastewater pipes throughout system. 3. Seal pump gallery at wastewater treatment facility.

CW-30—Develop an acquisition program for homes or other uses located within high risk-hazard areas (e.g., flooding, landslide, lahar, etc.).
Actions: Use the best available science to: 1. Develop prioritization for acquisition. 2. Identify/develop financing mechanisms.

CW-31— Enable communities to recover development value of properties in prioritized hazard areas (e.g., landslide and tsunami).
Actions: 1. Incorporate best available science as required by the Growth Management Act to prioritize hazard areas. 2. Expand use of the transfer and purchase of development rights programs to include prioritized hazard areas. (See mitigation strategy **CW-2.**)

CW-32—Reduce risk to utility networks.
Actions: 1. Establish micro grids as disasters destroy original systems and as systems reach the end of their design life. (See mitigation strategy **CW-5**.) 2. Create coalition amongst municipalities and utility companies. 3. Bury above-ground systems as elements are upgraded and where practicable. 4. Install backup generators where necessary.

CW-33—Promote water conservation to minimize impacts of drought. Climate change projections warn of increasing summer drought risks.
Actions: Practicing a low-water-use lifestyle will increasingly become the norm for many communities as summer flows substantially reduce many of our rivers. Reducing water use will help meet future needs and result in cost savings and decrease energy use, helping preserve the environment. 1. Government can provide information, tools and incentives to assist residents, businesses, communities, and water providers to design and implement comprehensive and proven conservation strategies.

CW-34—Improve communities' abilities to respond to a severe weather event.
Actions: 1. Expand the Storm Ready program in Snohomish County to include more sites around the county.

CW-35—Revise existing plans to address updated assessments of tsunami risks from the Seattle and South Whidbey Island Faults.
Actions: 1. Obtain tsunami numerical modeling data from NOAA/DNR to approximate wave-height maximums along the Snohomish County coastline and map the results to better understand potential tsunami risk. South Whidbey Island Fault data should be available in 2016 and Cascadia Subduction Zone tsunami impacts will be available in 2015.

CW-36—Evaluate increased landslide potential from a tsunami and need for increased setback in high-risk areas.
Actions: 1. Coastal land uses may be vulnerable to increased landsides as tsunami wave energy destabilizes slopes.

CW-37—Create evacuation routes for communities at risk of a lahar.
Actions: Work with communities to: 1. Place volcano/lahar interpretive signage in key areas like campgrounds and trailheads. 2. Identify safe areas in the event of a lahar. 3. Identify and mark routes to the safe areas.

CW-38— Promote Firewise Program in communities and encourage Firewise risk-reduction methods for parcels adjacent to forest resource lands. Firewise encourages and empowers neighbors to work together in reducing their wildfire risk.
Actions: 1. Using a five-step process, encourage communities to develop an action plan that guides their residential risk-reduction activities, while engaging and encouraging their neighbors to become active participants in maintaining a safer place to live (www.firewise.org).

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WEBSITE RESOURCES

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Snohomish County: http://www.snohomish.org/index.php?page_id=394

Tulalip Tribes: http://www.tulaliptribes-nsn.gov/

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